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Public Debt
Management Network

Debt Management in Uncertain Times

Proceedings of the first Public Debt Management Network Conference, held in Paris on September 4-5, 2019

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Foreword

Public Debt Management (PDM) Network, an initiative fostered by the OECD, the Italian Treasury and the World Bank held a Public Debt Management Conference in Paris on September 4-5, 2019. Given the rising government debt globally and growing contingent liabilities, yet limited comprehensive and analytical discussions on the topic, the Conference addressed the dynamics of debt accumulation, the approaches to improve quantitative and analytical public debt management in the context of a shifting macroeconomic, geopolitical, regulatory, and technological environment. Nineteen papers were presented in eight sessions, focusing on the areas of sovereign asset and liability management, modeling the cost and risk tradeoff in public debt management, approaches to debt sustainability and government securities market. The main topics debated during the Conference are briefly discussed in the following to provide an in-depth background and a perspective going forward, given the COVID-19 pandemic increased vulnerabilities of government debt to external shocks.

The Conference Proceedings involve the keynote speech delivered by **Professor Pier Carlo Padoan**, Member of the Italian Parliament and former OECD DSG and Chief Economist, and ten papers by the authors who agreed to participate in the proceedings. The order of the proceedings is parallel to the sequence of the presentations held in the Conference. Here is a short description of the papers. **Jonasson and Papaioannou** provide a guideline and highlights of good practices for achieving optimal results based on lessons from countries that have adopted an SALM approach. **Fritz Bachmair et al.** emphasize a stepwise credit risk assessment approach and illustrate its application in South Africa. **Landoni et al.** suggest a deterministic framework to link the maturity distribution of new issues, with the outcomes, based on the long-run maturity distribution of outstanding issues that prevails if this policy is held indefinitely. **Bernaschi et al.** present a probabilistic model to compare cost-risk performance of proposed government bond portfolios relying on cost-risk frontier and the credit value adjustment. **Yavuz and Golbasi** suggest a stochastic cost-at-risk model to generate optimal composition of the sovereign debt and the underlying borrowing strategies. **Greco and Mormando** investigate if the ranking system effectively affect market makers in their quoting decisions and the liquidity conditions of order books. **Junior et al.** explore the transmission of the monetary policy through the wealth channel in Brazil, using a structural Bayesian model. **Fenz and Holler** present a static framework for the optimal debt portfolio hedge analyzing the potential of inflation-indexed and short-term interest-rate-linked debt to hedge government budgets against macroeconomic demand, supply and monetary policy shocks. **Bebes and Tran** propose a multi-objective optimal portfolio model, to find Pareto-optimal compositions of financing that satisfy the main objectives of public debt and construct financing compositions. **Picarelli et al.** discuss the introduction of mandatory two-limb CACs in euro area sovereign bonds issued under domestic law and evaluate the price impact of these provisions.

The Conference Organization Team included:

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Caroline Lam, OECD
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François Lefebvre, World Bank
Eric Bouyé, World Bank
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The Conference Organization Team is grateful to Professor Pier Carlo Padoan, Member of the Italian Parliament and former OECD DSG and Chief Economist, for kindly accepting to deliver his keynote speech to the Conference participants

The Conference Organization Team is grateful to the papers' selection panel members:

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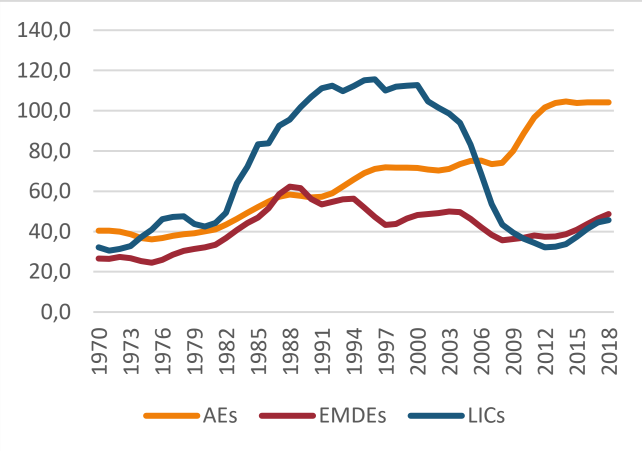
Debt Management in Uncertain Times: a background paper

M. Coşkun Cangöz[1] *and Eric Bouyé*[2]

A brief overview of public debt accumulation

According to classical public finance theory, government budgets are balanced, and deficit is temporary (Feldstein, 1985). However, over the last century, government debt accumulated mostly because of the sharp drops in government revenue, provision of stimulus and financial sector support, yet primary balance was the dominant factor in debt reduction (Abbas et al., 2011). Central government debt-to-gross domestic product (GDP) of advanced economies steadily increased since mid-1970s due to the mix of aging of the societies, expansion of social welfare state, and stationary growth of population (Reinhart and Rogoff 2013).

Figure 1. Government Debt/GDP



Source: Kose at all, 2020 and authors

Following the global financial crisis, level of central government debt in advanced economies reached to another peak (Figure 1). Until mid-1990s the trend of central government debt in emerging economies was parallel to advanced countries, then it was deleveraged for around a decade and started to increase after the 2008 crisis. The reasons for debt accumulation in emerging countries differ across different regions and income groups.

Kose et al. (2020) identify four waves of debt: 1970-1989, 1990-2001, 2002-2009, and since 2010. The first three waves occurred mainly in one or several regions. However, the fourth wave (2010 onwards) has covered all regions. The first three waves began during prolonged periods of low real interest rates and ended with financial crises with global recessions or downturns. These crises typically feature sudden stops of capital flows.

In the fourth wave, capital inflows to emerging markets and developing economies increased significantly and yield-seeking investors contributed to falling of the spreads. Very low level of interest rates in the advanced economies and high liquidity in the financial markets were the major factors that enabled increasing interest in emerging markets (Figure 2). The share of foreign investors in emerging markets and developing economies' (EMDEs) government debt had increased to 43 percent by 2018. In parallel, low-income countries' (LICs) access to international markets has become stronger

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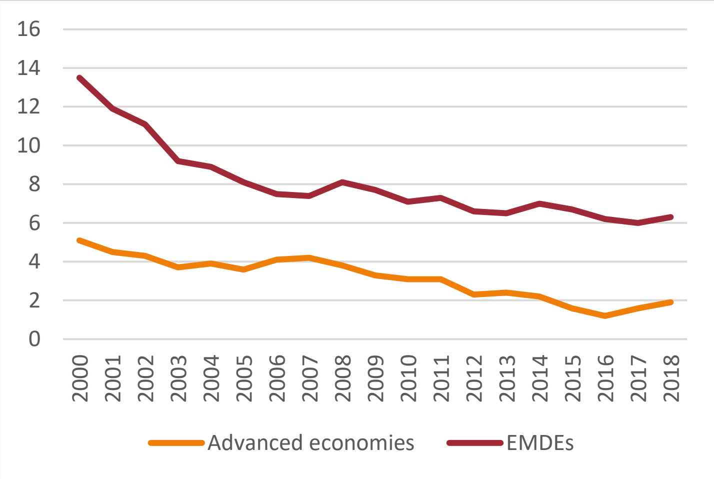
The analysis and conclusions set forth in this paper are the authors' and do not necessarily reflect those of The World Bank. The authors are grateful to Antonio Velandia and Rodrigo Cabral (World Bank), Fatos Koc (OECD), and Fabio Vittorini (Ministry of Economy and Finance, Italy) for their contributions and comments to the earlier versions.

and the share of non-concessional government debt had risen to 55 percent by 2016. Accordingly, EMDEs have now higher external debt but lower financial reserves. Considering their fiscal and current account deficits, record level debt buildup accumulated vulnerabilities against external shocks. (Kose et. al. 2020).

Figure 2. Long-term Interest Rates (%)



Source: Kose et al. 2020

During the last episode of debt accumulation, the COVID-19 pandemic locked-down the economies and resulted in shortfalls in government budgets which has not seen since WWII. Government debt has doubled since 2008 and will further increase in response to the pandemic. As stated by the International Monetary Fund (IMF, 2020), stain in market functioning and declining external demand and capital flow reversals in EMDEs increased debt stress in many countries. International Institute of Finance (IIF) reported that only in March 2020 debt outflows reached to $31bn, the second largest monthly outflow on record, since 2008 (IIF, 2020a). As a result, due to declined economic activities and uncertainties for recovery, and existence of severe market conditions EMDEs exposure to external shocks further piled in the extension of current debt accumulation phase.

Management of public debt and the use of financial modelling

Historical episodes of debt accumulation indicate five ways to reduce large debt-to-GDP ratios: economic growth; fiscal adjustment-austerity; explicit (de jure) default or restructuring; inflation surprise; and a steady dose of financial repression accompanied by a steady dose of inflation (Reinhard and Rogoff 2013). On the other side, current wave of substantial increase in government debt demonstrated the critical role of strong institutional and governance framework established starting from 1990s. Sound debt management leads to structuring less riskier debt portfolios in terms of currency and interest rate composition and maturity, to alleviate risks and reduce cost of funding. Furthermore, government borrowing is functioning to support the efficient asset pricing mechanism and development of financial markets through the amount and features of the government securities (Cangoz and Balibek, 2014).

The objective of debt management offices (DMOs) is to reduce the cost of debt while keeping the risk at a prudent level over the medium and long-term. A DMO usually faces four types of risk due to its funding operations: market risk, rollover risk, liquidity risk and credit risk (IMF and World Bank, 2014)[3]. The risk level can be measured through different indicators such as the variability of the interest rate change, the volatility, or the dispersion from a baseline value (Renne and Sagnes, 2006). Several approaches ranging from deterministic to stochastic models have been employed by debt managers in order to identify the best borrowing strategy reflecting the cost and risk preferences of decision makers. A sound policy framework, which includes medium term cost-risk optimization models, allow

[3] Two additional risks are settlement and operational risks.

governments to determine the best possible funding strategies consistent with monetary and fiscal policies.

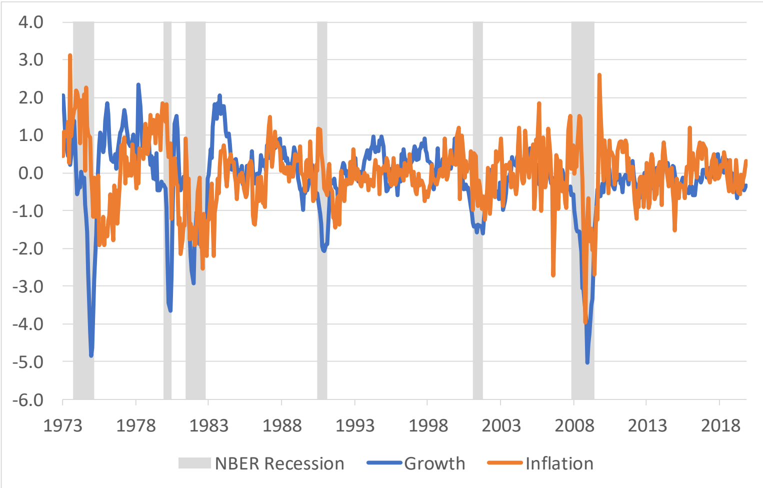
The financial modeling of the debt portfolio can be decomposed in five steps: the definition of objectives and constraints, the design of capital market assumptions, the optimization process, the study of robustness across scenarios, and the ex-post assessment of the funding strategy. First, the management horizon and the risk tolerance should be defined together with governance principles (e.g. definitions of roles and responsibilities, committees, decision process). Second, the risk factors need to be identified for the universe of instruments available such as nominal, inflation-linked, contingent debt. Some assumptions can also be formulated for foreign exchange rates, in the case of a multi-currency issuance programs. The medium and long-term assumptions on these factors allow to define the expected cost and risk either by using simulation models, scenarios or both. Third, a cost-risk efficient frontier can be constructed to define the possible optimal debt portfolios, exhibiting the different optimal combination of debt instruments (Velandia, 2002). Fourth, different economic scenarios can be defined to explore their implications on the relevant financial factors and test the robustness of different debt portfolios across these scenarios. This is particularly relevant in a low interest rate environment with a significant probability of rising interest rates, increasing the cost of debt through rollover risk. It also illustrates that debt management and monetary policy may have competing objectives. Fifth step is the monitoring of the performance of debt management, for example through cost attribution methods.

Deterministic and stochastic models rely on similar approaches and both can provide useful information to support decision-making. On the other hand, there are different approaches to identify and measure the risk indicator: for example, Turkey first used the upper 95th percentile of cost distribution and then moved to the conditional Cost-at-Risk metric, which focuses on the average of the expected cost values that occur in the tail of the probability distribution rather than a single value in the determined confidence level. The model uses debt stock, non-borrowing financing sources and historical macroeconomic data as an input (Balibek and Memis, 2012).

Macroeconomic oriented models are chosen by some of the practitioners for their capacity to fit the factors of the term structure of interest rates in a dynamic way. They also allow to include macroeconomic variables, for example in a structural vector autoregressive (SVAR) representation like the Dynamic Nelson-Siegel model (Diebold and Li, 2006). Denmark has been using 3-factor arbitrage free Nelson-Siegel model for the projection of interest rates, but low or negative interest rates environment constitutes certain modelling challenges (Danmarks Nationalbank, 2015). In this context, gaussian models would be preferred to log-normal ones to obtain stochastic simulations more aligned with observed values.

Gross domestic product (GDP), inflation and credit spreads are the other macroeconomic variables of interest for the debt manager. The output gap allows to compute the primary deficit, while inflation forecasts provide different breakeven scenarios. The term structure of real interest rates is necessary to evaluate the tradeoff between nominal and inflation-linked instruments. Additionally, the set of constraints for macroeconomic variables is a key element of the debt portfolio optimization. For example, the volatility of the debt-service charges and their correlation with the primary balance contribute to the budget outcome (Bolder and Deeley, 2011). Some authors find that the introduction of inflation-linked instruments decrease the cost while slightly increasing the variability of interest charges with mixed effects on the volatility of the budget balance (Renne and Sagnes, 2006).

Figure 3. NBER recessions, Growth and Inflation indicators (US)



Source: Bloomberg

An alternative to SVAR is regime-switching models that allow to simulate different economic regimes with conditional probabilities of moving from one regime to another (Hamilton, 1989). Markov-switching models can be calibrated with National Bureau of Economic Research (NBER) recessions to model and forecast recessions and expansions in a two-regime models. Figure 3 provides an illustration for the United States. Alternatively, a more granular approach of business cycles can be achieved using two indicators (up and down) for inflation and growth, leading to a four-regime model (growth up/inflation up, growth down/inflation up, growth up/inflation down, growth down/inflation down). This can be of interest to compare the dynamic of debt instruments under scenarios for inflation, growth, and by extension nominal and real interest rates. This class of model has been explored by DMOs over the last two decades, a recent example being Hungary. They design a two-state Markov-switching model to produce 5-year forecasts to design their optimal portfolio (Bebes et al., 2018). The authors use the local and Eurozone interest rates and Consumer Price Index (CPI), the local CDS spread and the EUR/HUF exchange rate as variables of interest.

Approaches to balance sheet risk management

After the global crisis, liquidity buffers have become an important instrument to mitigate liquidity risk, central banks in advanced countries introduced unconventional monetary policy and purchased government securities as a part of the quantitative easing, contingent liabilities have grown significantly. Accordingly, the size and complexity of sovereign balance sheets have increased in most countries. Therefore, coordination between sovereign's assets and liabilities is now more crucial to evaluate the risk position as a whole and develop a strategic approach to mitigate these risks.

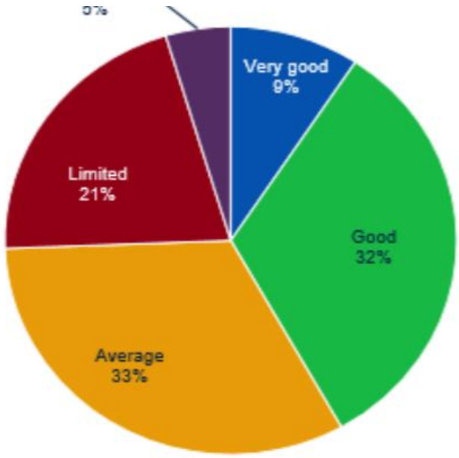
On the other hand, in most countries there is no or very little coordination, as they are managed by separate institutions with different objectives. In a survey of 28 countries, it has been found that countries regularly produce an accounting balance sheet with the objective of monitoring sovereign assets and liabilities, rather than determining mismatches between them (Cangoz et.al, 2018). Although there are challenges to its implementation, multiple resources address the benefits of sovereign asset and liability management (SALM) such as reduction of risk exposure through matching their main financial features (Cassard and Folkerts-Landau 1997, Velandia 2002, Wheeler 2004, Das et al. 2012).

Koc (2014) argues a stepwise approach in implementation of policy based SALM approach, which involves prioritizing sub portfolios of balance sheet as the first step and apply simplified risk analysis. Cangoz et al. (2019) suggests optimizing a country's net currency position based on an analysis of its central bank's currency reserve positions and central government debt portfolios. Focusing on the case of Uruguay, Amante et al. (2019) presents a practical implementation of ALM framework for stylized sovereign balance sheet by identifying the exposures and mismatches, and execution of transactions (e.g. liability management operations in managing foreign exchange risk, and hedging foreign currency risk of SOEs) to reduce financial vulnerabilities.

SALM is diverse across countries, from a fully integrated framework to different levels of coordination (Koc 2014, Cangoz et al. 2018). Among others, existence of developed local government bond markets is a common element in such countries applying elements of ALM approach such as Canada, Australia, Denmark, New Zealand and Turkey. Based on the Uruguay's case, Amante et al. (2019) underscored the structure of domestic capital markets, which may limit implementation of ALM because some countries cannot issue domestic debt due to illiquid debt market and lack of reliable local investor base.

Similar to the assets and liabilities, explicit and implicit liabilities are managed separately in most countries. However, there are sound practices that DMOs deal with credit risk stemming from contingent liabilities such as guaranteed and non-guaranteed debt of State-owned enterprises (SOEs), liabilities from public-private-partnership contracts and on-lending loans. However, a survey of 43 countries demonstrated that more than half of them have limited capacity to manage risks from contingent liabilities as shown in Figure 4 (Lee and Bachmair, 2019).

Figure 4. Capacity to manage risks from CLs



Source: Lee and Bachmair (2019)

Credit risk from SOEs and other public entities can be mitigated with clear definition of risk event and quantification of exposure through models and application of credit risk management tools. The most common approaches used by the governments are credit scoring, statistical models, scenario analysis and structural models such as Black-Scholes option pricing model (Bachmair, 2016). Additionally, countries may employ different risk management tools which are not necessarily based on analytical risk assessment. Many countries including Brazil, Finland, Mexico, Sweden and Turkey set limit on government guarantees. Also, contingency reserve funds are established by some countries, Sweden and Turkey, to be used for the called state guarantees. Partial guarantee is another tool employed by the countries (e.g. Canada, Iceland and Turkey) to establish a risk sharing mechanism between the government and the lender (Ulgenturk, 2017).

Development of local currency debt markets

Parallel to the balance sheet structure, the composition of liability portfolio has shown some changes. Lower inflation rates and stronger macroeconomic and fiscal performance increased financial credibility and improved debt position in emerging and developing economies. Governments have started issuing more debt in domestic markets. Accordingly, local currency bond markets have developed significantly and become more liquid (Didier and Schmukler 2014). The amount of debt issued in bond markets by EMDEs almost tripled between 1997 and 2007, to $190 billion. However, commercial banks remained the most important source of finance for EMDE corporates, accounting for more than 80 percent of total external debt in 2007 (Kose et al. 2020).

Table 1. Emerging Markets Government Debt (USD Trillion)

	2011	2012	2013	2014	2015	2016	2017	2018
Local Currency Debt	5.9	6.5	6.6	6.7	7.2	8.4	10.1	11.0
Total Debt	6.5	7.2	7.3	7.5	8.0	9.4	11.2	12.2

Source: G20 IFAWG (2020)

As reported by the G20 International Financial Architecture Working Group (IFAWG), over the last two decades, with the help of the capacity building provided by international organizations, countries have significantly improved their debt management, adapted medium-term strategies by increasing local currency debt (Table 1). Accordingly, debt managers established benchmark building programs, to improve secondary market liquidity. For example, Albania, Georgia, Peru, and Ukraine recently established their benchmark building programs (G20 IFAWG, 2020).

Starting from 1960s, countries including the USA designated a group of specialized banks and/or securities dealers/brokers as primary dealers, with obligations to make bids and offers, and privileges such as noncompetitive bidding, to assist developing of government bond market and mitigate refinancing risk. In most cases, primary dealers are also required to operate as market makers that includes providing two-way pricing for some (benchmark) bonds. In 2000s emerging countries established primary dealership system, and recently there are initiatives in many developing countries. As indicated in the recent G20 IFAWG report, as of June 2019, 83 countries use primary dealership systems.

In order to strengthen market discipline and ensure primary dealership system provides liquidity, countries monitor and publicly rank the performances of primary dealers. Monitoring includes obligations of primary dealers, beyond auction participation, and explicit and implicit incentives to secure market-making functions. In some cases, market makers quote in different segments of the market, based on their specialization. To this end, primary dealers may be assigned to quote a mix of benchmark securities and off-the-run bonds within a defined bid-ask spread. Competitive bidding is crucial in price discovery where the market making functions are in place and an effective secondary market provides valuable input to bidding in the primary market. D’Agostino and Ehrmann (2013) argue that macro fundamentals, risk aversion and liquidity risk are influential determinants of spreads, and the design of secondary market implies a reduction of risk premium and cost of borrowing.

Countries with strong macroeconomic fundamentals, flexible exchange rate regimes and well-functioning, liquid bond markets attracted foreign portfolio investors. Furthermore, low yield in the advanced economies has created an environment for foreign investors to increase their demand for local currency bonds issued by emerging and developing countries. The share of nonresident investors in local currency sovereign bond holdings has risen close to 40 percent in some countries, such as Indonesia, South Africa, and Czech Rep., and even more than 50 percent in Peru as of September 2019 (IIF, 2020b).

Improved microstructure and liquidity in government bond markets have played an important role in growing demand for local currency government securities in emerging markets and average time-to-maturity of local currency government debt increased from 6.5 years in 2007 to 7.3 years in 2018 (G20 IFAWG 2020). Extension of the maturity of local currency bonds in most countries has happened along with the increased demand of foreign investors due to low interest rates in developed countries and inclusion of emerging country bonds in the global bond market indices.

Parallel developments have been observed in the international capital markets as sovereign borrowers have increasingly accessed international bond market. Countries such as Mexico and Argentina first time issued 100-year bonds, thanks to the favorable market conditions. Similarly, as reported by G20 IFAWG more than 20 EMDEs have accessed international capital markets for the first time over the last decade. New market bond indices specific to frontier markets have facilitated these countries' access to international debt market and borrow with a relatively low cost, compared to local currency bonds.

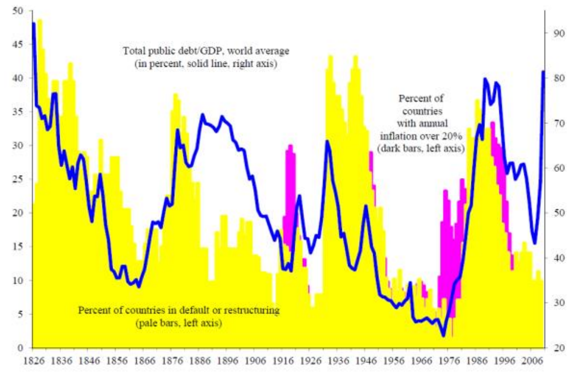
Debt sustainability and restructuring

Even there are improvements, achieved over the last two decades, and the overall debt levels have significantly declined in low-income countries (LICs) since mid-1990s (Figure 1), a sizable number of countries not only have high but short-term external debt compared to pre-crisis periods.

Government debt in LICs has started rising since 2013 and the median public debt-GDP ratio reached 47 percent, by an increase of more than 13 percentage points. The debt-GDP ratio increased by at least 10 percentage points in 29 low-income countries. In parallel, fiscal balances have deteriorated in 70 percent of low-income countries in recent years and interest expenditures increased due to higher reliance on more expensive commercially-placed debt and dropped amount of grants (IMF 2018). On the other hand, as of end-2018, 25 LICs had reserves below the conventional benchmark of three months of import coverage, while the bottom quartile of countries had reserve levels of less than two months coverage. Reserves levels at such low levels leave countries particularly vulnerable to external shocks (IMF 2019). Countries with high external debt, especially if it is short-term, and low international reserves are more exposed to external shocks. Furthermore, unanticipated increase in sovereign financing needs due to COVID-19, increased debt sustainability concerns in low-income countries which have pressure on current account balance and high external debt service.

As a response to COVID-19 related vulnerabilities, G20 announced Debt Service Suspension Initiative (DSSI) which calls official bilateral creditors for a suspension of public sector debt repayments for the poorest countries upon the request of the borrower. On the other hand, DSSI-eligible countries' debt payments to private creditors is recorded as $13 and outstanding Eurobond issuance is $70bn, which are not in the scope of DSSI (IIF, 2020c). Therefore, high debt position accompanied by weak macroeconomic conditions and riskier debt portfolio increase the default probability in many countries. Reinhart and Rogoff (2013) demonstrate that countries experiencing higher than 20 percent of inflation and high central government debt recorded an increase in debt restructuring (Figure 5). A common finding of empirical literature is that a default leads to drainage in capital flows and further increases in the perceived probability of a future default (Hatchondo et al. 2007).

Figure 5. Sovereign Default (Total public debt/GDP)



Source: Reinhart and Rogoff, 2013

In case of a default, bond holders' incentives to restructure the debt may not be aligned all the time. Collective action clauses (CACs), allowing supermajority bondholders to agree on legally binding restructuring for all bondholders, have become common in international capital markets. In 2013, in reaction to the euro area crisis, mandatory two-limb CACs were introduced in the euro area sovereign bonds with more than one-year maturity and issued under domestic law. CACs are means to tackle sovereign debt crisis. However, the probability of a country falling into default is affected by the composition of debt, as occurred for Russia, Ukraine, Ecuador, Pakistan and Argentina, and not by the fact that it has issued bonds with CACs (Weinschelbaum and Wynne 2003).

Conclusions

Government debt has been in the core of macroeconomic and political agenda over the last century and given the debt levels have increased significantly since the global crisis and a COVID-19 related new wave of fiscal stimulus is in place; it will continue to stay as an important topic. Due to the recent global pandemic crises, countries have locked-down, international trade and mobility declined significantly, and economies are signaling a sharp distraction. As a response, central banks reduced policy rates and governments are now issuing more debt as revenues lacked, yet expenditures are growing because of the fiscal stimulus packages. As a result, debt managers will need to rollover substantial amount of debt redemption in the coming years. Therefore, debt markets will stay exposed to the volatilities in global economic conditions, and the countries with fiscal space, strong institutional and legal framework of public debt management, less riskier debt composition and developed government bond market will be more resilient to external shocks. To this end, the conference agenda and topics covered in the proceedings are relevant to the current discussions and provide an insightful perspective which can be useful in strengthening soundness of debt management framework and overall management of sovereign balance sheet risks.

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Public Debt Reduction in Uncertain Times – With a View to Europe

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Public Debt Management Conference

Keynote Address

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We live in uncertain times both economically - growth remains weak, especially in the fundamentals - and in the policy response and from the point of view of governance, both nationally and globally.

Public debt remains a source of fragility for many countries. Private debt also, in some countries. Putting debt/GDP over a declining path remains imperative to reduce fragility.

While this topic has been subject to scrutiny for quite a long time I will consider some additional longer term determinants of debt dynamics that have gained relevance recently and relate them to broad uncertainty.

What drives debt dynamics? Let me start from two recent contributions, among the many that look at the determinants of debt dynamics and provide policy implications.

Bernardini, Cottarelli *et al.*(2019), investigate thirty episodes of public debt reduction in advanced economies since the Second World War. The paper demonstrates that four main approaches succeeded in lowering the debt ratio. First, after the end of WWII, high and unexpected inflation eroded a large share of public debt. Second, during the Bretton Woods era, a mix of financial repression, high economic growth and moderate inflation helped reducing public debt.

Third, since the 1980s, several advanced economies followed “orthodox” fiscal adjustments, namely improving their primary balance by reducing expenditure and/or raising taxes. The fourth approach (debt restructuring) was implemented only in one case: Greece in 2011-12. However debt restructuring remains an option on the table, including in the Eurozone.

One key findings by Bernardini, Cottarelli *et al.* (2019) is that debt reduction has never been achieved by relaxing fiscal policy (cutting taxes or increasing expenditure), hoping that this would set in motion a growth process sufficiently strong to lower the debt ratio (the so-called “denominator approach” which has recently become fashionable in some countries, including Italy). All in all, the empirical evidence of the last 70 years suggests that running a sufficiently large primary surplus is the only viable option to reduce public debt ratio, particularly in countries that are part of the euro area.

While interesting the contribution by Bernardini, Cottarelli et al does not take into account the impact of the “r-g” factor (the difference between the interest rate and the nominal rate of growth) in a changing global environment. My point is that both the primary surplus and the r-g factor contribute to debt dynamics and should be taken into account.

Blanchard (2019) in a much discussed paper takes a different view. He looks at conditions under which high debt can be sustainable given appropriate values of “r-g”, while neglecting the role of primary surplus. He finds that rising debt can be sustainable if the rate of interest is lower than the rate of growth. Otherwise, as we know, the size of the primary surplus must be such as to offset the negative consequence of an interest rate higher than the growth rate.

Blanchard draws some implications that point to space for debt to grow so as to improve welfare. However this possibly additional fiscal space requires the condition for negative “r-g” to hold. (Blanchard also excludes that he is in favour of unconstrained debt growth).

Critics of Blanchard (e.g Wyplosz) note that: “r-g” is not always negative; it can be highly volatile; the primary surplus cannot be ignored; the evolution of “r-g” can impact on fiscal discipline and hence on the primary surplus itself.

Currently “r-g” is negative for most countries (with the notable exception of Italy), however this should not be considered the norm. Especially if long term determinants of “r” and “g” (in addition to the factors that prevail in the short medium term) come into play. What impacts on “r-g” on the longer term beyond cyclical conditions (which lead to “r-g” to be larger in downturns)? The list includes demographics, the global saving glut, the debt level itself (which, if high impacts directly on “r-g” by raising it).

Let’s concentrate on more long term, and structural factors. They represent additional determinants of “r-g”. I would argue that these factors may be such as to offset (partially) the positive contribution of “r-g” to debt reduction and eventually turn it into a debt increasing factor.

It follows that in uncertain times such as the one we are currently in, other things equal, conditions for debt sustainability are harder to achieve because of adverse pressure on the variables that bear on debt dynamics, the growth rate and the interest rate.

These forces originate from structural factors generated by the state of global policy uncertainty itself related to weak global economic governance and the forces underlying weak potential growth including secular stagnation.

Governance

Over the last few years global governance has been under increasing pressure. Pressure has impacted on several policy domains, notably trade and security. In addition, policy uncertainty has increased. The Economic Policy Uncertainty (EPU) index has gone up in tandem with events such as the Eurozone crisis in 2009, it has gone down with the initial solution of the Eurozone crisis during 2011-15, increased with the Brexit vote in 2015, increased with the migration crisis during 2015-17 and increased with the US-China trade war.

Policy uncertainty reflects, among other factors, changing conditions in global governance. Over the past few years, increasing fragmentation and conflicts have replaced a more coordinated approach to global governance that had prevailed in the recent past. Taking into account evidence of the relationship between policy uncertainty and risk (Johannidis C. and Kook K., 2018) as well as policy uncertainty and growth, other things equal, higher uncertainty about global governance translates in an increase in the interest rate and lower growth. A more conflictual approach to governance implies, other things equal, that adjustment of imbalances is more costly and disorderly with negative consequences on growth and risk perception. The current state of global relations suggest that conflicts and weak governance are on the rise and will persist. Other things equal the degree of risk should increase, leading to (possible) higher interest rate.

Weak growth

The global financial crisis has significantly impacted on the potential growth rate. Beyond the crisis growth also suffers from symptoms of secular stagnation. There is a broad debate on the symptoms and the causes of secular stagnation. The divide has put supply and demand factors on two different sides. As is often the case when looking at long term factors both supply and demand factors play a role. Let me elaborate briefly a major symptom of secular stagnation is low or declining investment. Weak investment reacts to the weak tone of expected demand, low expected profits, and reflects debt accumulation, which has implications for higher perceived fragility. Low profitability in turn points to lack of reforms that (should) enhance profitability. So, structural reforms impact on investment through improved profitability (hence structural reforms impact on expectations).

The opposite causation also holds. Investment is the vehicle through which reforms change behaviour and change the economy. For instance reforms which encourage innovation and environment production of friendly goods and services. So lack of structural reforms is both a cause and a consequence of secular stagnation.

Finally, expectations that “r-g” will remain negative over the long term could impact in the propensity to reduce the primary surplus, leading to a lower surplus and more debt other things equal.

Putting together all these factors the implication is that debt sustainability has become more, not less, difficult to achieve because, other things equal, of a higher value of “r-g” reflecting both weaker governance and weaker long term growth.

Policy Implications and Governance

The implications are straightforward. There is a need to improve global governance, lower systemic risk, and raise long term growth. Revert the trends to higher confrontation and declining growth. How can this be achieved? Policy should at the same time decrease global risk and raise global growth: two targets that mutually reinforce each other (in both directions).

What are the challenges for global economic governance? As mentioned global governance is under severe stress. Global governance has changed dramatically after the outbreak of the global financial crisis, shifting the focus from the G7 to the G20. Recognizing the raising role of large emerging economies. The G20 agenda has extended over a very broad range of issues, including “strong, sustainable, balanced and inclusive growth”. However it is hard to say that global governance has succeeded in achieving risk reduction. The opposite holds as we look at the state of international relations today.

Over the recent past attempts to strengthen global cooperation and multilateralism seem to be replaced by increasing bilateralism and ‘sovereignism’ (i.e. the view that nation states should prevail over multilateral agreements).

The global hegemon, the US, has been increasingly inward oriented, looking at national interests and contributing less to global public goods such as stability and open markets. In other words, there is a lack of hegemonic stability as the largest power prefers bilateral relations (both positive and negative) to multilateral cooperation. And other key countries have similar attitudes. Therefore governance needs to deal with increasing fragmentation.

Because of the absence of a global hegemon, the provision of public goods by global governance would require fundamental changes, which are unlikely in the short to medium term. Conditions for systemic risk to be minimized are not at hand. Without hegemony international cooperation (in an international oligopoly), it is much more difficult, requiring key players' willingness to reciprocate, adjust preferences and adopt a long term perspective. Europe could play a much more effective role from this point of view. The new EU Commission could be instrumental in this respect.

What about global growth?

Long-term growth is the result of the interaction of different drivers and policies: macroeconomic, monetary and fiscal, microeconomic, structural, and financial. The way such policies interact is matter of continuous research and analysis (OECD analysis has always been at the frontier of such analysis). What we can safely say is that one dimension policies are less effective, if at all, in sustaining long term growth. One needs an integrated approach by which policies mutually support each other. In what follows I concentrate on the role played by structural reforms. However this should not be seen as saying that only supply side measures matter.

Indeed (as mentioned), conditions for structural reforms to succeed in terms of raising growth require demand and supply interaction as well as a long term horizon.

Well known features of the structural reforms process include: 1) Understanding that the initial impact of structural reforms could bear short term costs in terms of income and/or employment. Such costs could be mitigated by more favourable cyclical conditions. 2) Structural reforms can also improve confidence and expectations about the long term, with benefits both on growth and on risk perception (so they improve r-g). 3) Structural reforms require significant political capital to be implemented and such a political capital seems to be in short supply. Both reform fatigue and discontent with the prevailing economic system are on the rise in Europe and elsewhere (OECD, Going for Growth 2018). "New" options (populism and "sovereign nationalism") are on the rise. Dismantling reforms rather than strengthening the reform agenda, favouring state led rather than market based policy recipes, and focusing on national rather than European solutions seems to be the rising political bet. (This in part has been mitigated by European Parliament elections but the challenge is still alive and kicking).

So, the issue arises of what are the incentives for structural reform. Political incentives are weak.

Reasons for this include the fact that the traditional "structural reform cycle" is long and difficult to complete, thus generating reform fatigue. Another one is that increasing reform fatigue is associated with decreasing support for Europe and the European project.

Structural reforms require a complex and long cycle to be completed and this implies that they carry a very high cost in terms of political capital. Reforms have to be introduced by the government and approved by parliament; they have to be translated into administrative procedures, which have to be implemented, often by several government institutions, both national and local; they have to deliver visible outcomes, and such outcomes have to be perceived by citizens (and voters) as generated by the reform process. This may require quite a substantial communication effort by the government. In addition, while outcomes of reforms are typically widespread and delayed, costs of reforms are usually upfront and concentrated in smaller (and more vocal) groups. Finally, evidence suggests that benefits of reforms are stronger and more visible when the macroeconomic cycle is on the upswing.

Two implications, among the many, follow. First, governments introducing reforms should, in general, be prepared to wait several years to see some returns for the investment of their political capital. And this may run against political "short termism" in governments. Second, governments may want to activate compensation mechanism for the losers to broaden their consensus base. In such a case, the reforms may bear (additional) budget costs for the government.

Considerations about the Eurozone

In Europe structural reforms can and should be implemented at the national and the EU level. Political support is needed both for national reform policies and for EU level policies. One example: the interaction between product market liberalization at the national level and at the EU level (single market) would bring additional benefits with respect to case of policies implemented in isolation. There are political economy implications in this case too. In some cases EU policies can be more attractive for citizens insofar as they are perceived as dealing with inequality (examples include competition policy as a way of confronting monopoly power of big internet giants, tax policy as an instrument for redistribution). In other cases in the current more Eurosceptic environment EU level policies are seen as mechanism that weaken national sovereignty, and hence they tend to be resisted. A possible misalignment between economic and political reforms priorities may emerge as economically crucial reforms might be much harder to introduce.

How do the above considerations bear on debt sustainability? In the Eurozone all countries except Italy display negative "r-g", debt over GDP is declining and growth is relatively sustained. However optimism is out of place. A new recession could be looming given significant weakness in Germany and the UK, while Italy remains in stagnation. Monetary policy has stretched to the limits although the European Central Bank (ECB) suggests that limits could be stretched further. If symptoms of secular stagnation have to be taken seriously, the single monetary policy should be integrated by fiscal and structural policy. Structural reforms can improve the effectiveness of monetary policy, for example by increasing the response of labour and product markets to the monetary stance (Masuch, K *et al.,* 2018)

In short, in a monetary union the interaction between fiscal policy and structural policy is even more relevant. However, it is also important to look at country specificities so that individual countries adopt the appropriate policies taking into account the Europe wide framework. This has implications for fiscal policies. A proactive fiscal policy in the Eurozone has several dimensions. At the national level, prominence should be given to debt reduction. Hence, as long as the interest rate is larger than the nominal growth rate a primary surplus is needed. But also growth enhancing measures would strengthen debt reduction.

At the same time a reconsideration of the stability and growth pact should be initiated so as to strengthen incentives for public and private investment. A growth oriented flexibility should be introduced. An appropriate division of labour between countries is needed. Coordination among national policies should be improved by softening asymmetry in adjustment and improving the policy allocation. To clarify, countries with no fiscal space should concentrate on structural reforms, while striving to recreate fiscal space, but countries with fiscal space should use it while maintaining an appropriate primary surplus.

Steps towards a common fiscal capacity should be accelerated, including by the introduction of a European safe asset. The proposals to reform the EU budget carry some progress in dealing with convergence and adjustment, and hence growth. As one driver of stagnation in Europe is the dynamics of geography and cumulative effects, periphery suffers most. Secular stagnation is more evident in peripheral countries. So more long term convergence carries more growth. However, there is no progress in the stabilization function and the cyclical impact of downturn on reforms is not being dealt with at the EU level. The unemployment insurance mechanism is one example of an EU wide stabilization function which could have positive structural implications.

Irrespective of the “r-g” value structural policy should be implemented by all countries. Structural reforms at the national level should be integrated by EU level policies including by completing the Single market.

Conclusions

Deep and sometimes neglected causes are behind debt accumulation in addition to the ones we are used to take into consideration. Debt to GDP dynamics must be under the control of policy authorities, not vice versa. Control is not (only) a short term issue. It is also a long term issue.

Challenges in the long term include increasing potential growth and reducing systemic risk contributing to a smaller, if not negative “r-g”. This requires strategy and vision, and stronger international cooperation. Any single year budget must be plugged into a multiyear perspective to enhance credibility and allow the benefits of reforms to work through the economy. Fundamentals must be such that debt goes in the right direction. Growth must go up interest must go down. However action at the country level is only one condition for long term sustainability. The other is a stable and well managed international system. What is needed is a new framework for international cooperation and governance. A stronger and more resilient G20. At the EU level much progress can be made by integrating better monetary fiscal and structural policies at the level of single member state and at the EU level.

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Implementing a Sovereign Asset and Liability Management Framework in Emerging Market Countries

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Abstract

We provide an overview of the main strategic and operational issues, as well as some institutional challenges, in the implementation of a Sovereign Asset and Liability Management (SALM) approach. Application of an SALM framework allows the authorities to monitor sovereign balance sheet exposures in an integrated manner, identify and measure maturity, foreign currency and interest rate risk mismatches on a systematic basis, and manage identified risks more efficiently. In turn, this helps increase the economy's resilience to encountered risks, strengthen financial stability, and implement a more cost-effective management of the public-sector debt.

JEL Classification: H63, G11, G15, G18, G23

Keywords: Public Debt Management, Financial Risk, Foreign Exchange Hedging, Government Securities Markets

1. Introduction

The SALM approach focuses on the identification[3] and management of the financial risk exposures of the public sector as a whole, so that a sound balance sheet is preserved in support of a sustainable policy path and economic growth (International Monetary Fund and World Bank, 2014). In general, the sovereign balance sheet includes the assets and liabilities of the general government (central government, municipalities, and public pension entities) or the public sector (general government, state owned enterprises, and the central bank). The SALM approach can also encompass off-balance sheet instruments and policy commitments. This approach entails monitoring and quantifying the impact of movements in economic and financial variables, including exchange rates, maturity structures, interest rates, inflation, and commodity prices, on sovereign assets and liabilities, and containing other asset- and debt-related vulnerabilities in an integrated way.

A comprehensive SALM framework can have significant advantages over separate management of assets and liabilities (see Lu et al., 2007; Das et al., 2012; Koc, 2014). It allows an analysis of the financial characteristics of the balance sheet, identification of sources of costs and risks and quantification of the correlations among these sources. A financial risk management strategy can then be developed to manage exposures in a cost-efficient manner. Thus, when an SALM approach is applied to the consolidated public sector portfolio, overall sovereign risk exposures can effectively be analyzed and managed and financial crises can be averted (Allen et al., 2002).

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[3] For the purposes of this paper, "sovereign" equates with the public sector defined as those areas over which the government has financial control.

The SALM approach can also be adapted to facilitate the attainment of a country's long-term macroeconomic and developmental objectives, such as economic diversification, broadening the export market, or reducing dependence on key imports. Further, the SALM approach can help to identify long-term fiscal challenges, such as unfunded social security liabilities, which imply a future claim on resources. Thus, an SALM framework can serve as a central element of an overall macroeconomic management strategy. Especially for commodity-exporting countries, an SALM approach can highlight the potential asset management challenges that stem from and in turn influence a medium-term debt management strategy (see Al-Hassan et. al., 2018; Maziad et. al., 2014).

However, a comprehensive SALM approach is conceptually and operationally challenging for governments because (i) many governments do not compile a full statement of financial positions, thus making it difficult to directly observe all assets and liabilities; (ii) many government assets are tangible in nature (for example, land, buildings, or plant), or are in the form of off-balance sheet positions, that do not lend themselves to an analysis of financial risk; (iii) a government's main asset is its ability to tax, which is directly related to its discretionary fiscal policy and not to on-balance sheet financial assets; and (iv) responsibility for various parts of the public sector balance sheet is typically divided across institutions, thus creating limitations on the implementation of an SALM framework. Despite these challenges, some governments have produced full statements of their financial stock position for many years,[4] and only a few have moved beyond the consolidated reporting of the entities that make up the sovereign to the integration of risk management across those entities (see Amante et. al., 2019).

Based on the practice of countries that apply an SALM approach, we propose it as an effective policy innovation in monitoring and managing sovereign portfolio risks. We suggest guidelines and good practices for achieving optimal results based on lessons from countries that have adopted an SALM approach. However, it is recognized that certain preconditions should be fulfilled, including availability of relevant sovereign asset and liability data, and political will to undertake such a coordination-intensive project.[5]

The paper is organized as follows: Section II provides an outline of the SALM framework and its objectives in the context of a stylized sovereign balance sheet. Section III discusses key aspects of the implementation of specific policies. Section IV distills some key lessons and sound practices in applying an SALM model. Section V offers some concluding remarks and considerations on the way forward.

3. The SALM Framework

3.1 SALM and Economic Policy

The objective of SALM is to improve the efficiency of policy implementation in terms of reducing risk and/or cost, consistent with the objectives and policy frameworks of monetary and fiscal policies, conventional public debt management, state-owned enterprises (SOEs), and publicly managed financial-asset portfolios.[6] Effective SALM therefore requires coordination at the policy level, e.g., levels and composition of foreign-currency reserves and foreign-currency debt. Each policy area will

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[4] The IMF Public Sector Balance Sheet Database contains comprehensive estimates of public sector assets and liabilities. It is compiled on a best-effort basis, currently covering 38 countries, and was used in the October 2018 Fiscal Monitor analysis (see International Monetary Fund, 2016 and 2018).

[5] SALM differs from private ALM, as the strategic goal of SALM is maximization of the overall social welfare, while that of private ALM is maximization of net worth or profitability (Claessens and Kreuser, 2017; ECB, 2004).

[6] Typically, an SALM framework concentrates on financial assets and financial values of other assets, while it does not take into consideration "fiscal" assets (e.g., tax-collection ability).

shape the nature of a sovereign's financial assets and liabilities, while, at times, policy conflicts may arise:[7]

- *Monetary policy objectives* have an impact on SALM strategies, by affecting either market—interest rate and exchange rate—risk management or directly the size of the sovereign balance sheet. On the liability side, debt management strategy aims at minimizing debt service cost subject to a prudent level of risk (see also bullet on debt management objectives).[8] On the asset side, strategic asset management aims primarily at accumulating an adequate level of net foreign assets, including foreign exchange reserves, to be used for conducting effective monetary and foreign exchange policies, as well as a buffer against external shocks.[9] Also, it may involve the management of "excess" foreign currency assets (e.g., reserves above an adequate level), including through the design and management of investment portfolios, e.g., sovereign wealth funds (SWFs), so that returns on international assets can be enhanced and passed on to future generations, or help offset the impact of domestic and external shocks on the fiscal position.
- *Fiscal policy objectives* that aim at limiting the size, or volatility, of annual debt service costs may put forward policies that affect SALM objectives, including constraints on the duration and currency composition of public debt, e.g., high shares of short-term debt are perceived to lead to greater volatility of service costs.
- *Debt management objectives* that aim at minimizing debt service cost subject to risk provide the basis for the integration of public debt management (PDM) and SALM strategies. Maintaining robust formal institutional arrangements in developing PDM strategy provides investors and the public with a greater degree of assurance about the management of the sizable risks in the government's balance sheet. A well-articulated PDM strategy, which has as much specificity as possible and clearly explains the analysis and rationale for the chosen approach is essential for such purpose.
- *International and domestic capital market structure* also affects SALM implementation. Some developing countries cannot issue domestic debt because of illiquid and/or shallow domestic debt capital markets and a lack of a reliable local investor base. Their attempts to issue domestic-currency debt externally have also not been well-received in international markets owing, in part, to their vulnerability to shocks, restrictions on foreign investors to buy local-currency debt (e.g., on type of instruments, minimum holding period), poor transparency, and/or a lack of interest rate and exchange rate hedging instruments.
- *The governance of publicly managed financial asset portfolios (such as SWFs, pension funds, and insurance companies)* tends to emphasize granting boards and fund managers independence to pursue agreed objectives.[10] This is designed to address historic underperformance in the sector caused by, among other factors, a lack of contestability, imposition of non-commercial objectives, and political interference in asset allocation. Prima facie, this independence could constrain the scope of SALM from including such entities, as their objectives typically are framed to maximize returns subject to agreed risk constraints, which generally would reflect the nature of their own liabilities. Yet the central government may have a legitimate interest in their activities: the public sector as a whole may be over-

[7] See, for example, Togo (2007).

[8] Sometimes, the debt servicing cost excludes exchange rate valuations.

[9] The determination of an appropriate level of international reserves depends on domestic economic conditions. For example, in a dollarized economy, in which an important share of commercial bank liabilities is dollar-denominated, the level of reserves will be higher, because of the role of the central bank as a lender of last resort.

[10] See, for example, principles 6 and 9 in "Santiago Principles: Sovereign Wealth Funds Generally Accepted Principles and Practices", International Working Group of Sovereign Wealth Funds (2008).

exposed to particular assets (concentration risk), or, conversely, individual entities may have asset allocation strategies that negate each other.

- *Sound practice in the governance of SOEs* also places an emphasis on an arm's-length relationship with the central government in order to strengthen accountability and improve commercial performance. For example, the OECD's guidelines on governance of SOEs state that the "government should allow SOEs full operational autonomy to achieve their objectives and refrain from intervening in SOE management."[11] Nevertheless, as is the case with publicly-managed funds, the central government may have an interest in their financing activities, e.g., if the borrowing strategies of SOEs, when viewed collectively, are in conflict with and undermine the debt management strategy of the central government. This has heightened relevance when the government is a direct lender to, or guarantees the debt of, SOEs, and in the event of default may need to assume all or some of their debt.

3.2 Country Experiences in Applying SALM

SALM can be a powerful tool to obtain a timely, systematic and comprehensive overview of the consolidated public sector balance sheet (sovereign balance sheet). Depending on its coverage the SALM Framework can provide a view of the extent and size of the assets and the liabilities, including off-balance sheet that gives authorities a view of their net exposures. For countries with a centralized budgetary system, e.g., with SOEs implementing investment plans, the SALM gives a view of commitments across the public sector and their financing. This is turn can enable the identification of financing pressures and helps coordinate actions of the public entities in managing associated risks.

A number of governments apply some form of SALM, in which they try to identify risks and vulnerabilities of sovereign assets and liabilities, without necessarily identifying an economic form of the sovereign balance sheet or establishing formal SALM objectives. In these cases, governments often determine specific debt management or reserve management strategies that reduce certain exposures and reduce balance sheet vulnerabilities, without always quantifying the risks. Further, they may use a balance sheet in conceptual terms to visualize the interrelationships between different assets and liabilities to determine the direction in which these assets and liabilities need to be changed. In particular, an overlay strategy could entail a legal or institutional framework that requires investment objectives, strategic asset allocations etc. of different entities to take account of aggregate SALM objectives.

Common challenges identified are inadequate institutional arrangements, uncertain or absent mandates, coordination between institutions, data availability and asset valuation. Therefore, some countries have embarked on some form of coordinated ALM, which typically involves integrated management of the net position on central government debt and other financial liabilities, and international reserves from a currency composition perspective. If the scope of SALM covers all public entities that make up the sovereign, assembling the data can become even more challenging. As noted earlier, more governments are producing balance sheets that consolidate the assets and liabilities of the various parts of the sovereign on a consistent reporting basis. It is only in recent years that governments have started compiling a full statement of financial position (balance sheet) and, while the number of countries that do so is growing, the practice has still to gain full momentum.[12] Thus, most countries would need to gather the information from individual entities manually, which may

[11] OECD (2015).
[12] See International Monetary Fund, 2016.

also provide it in different forms. A case can be made for a gradual expansion as data coverage improves over time.

While some governments have produced full statements of financial position (balance sheets) for many years, moving from consolidated reporting of the entities that make up the sovereign to integrated risk management across those entities is a major step. For example, the government of New Zealand has been producing a consolidated statement of financial position since the early 1990s, which provides detailed information on the overall position of assets and liabilities. While there has been some coordination between the government and the central bank in managing financial risk across their individual balance sheets, the remainder of the consolidated position is a result of decisions taken by separate entities in accordance with their objectives.

Where a full overview of assets and liabilities is not available, SALM principles can be adapted to "sub-portfolios" of the balance sheet. The process may be described as pragmatic and incremental, focusing on significant positions where the analysis is tractable and implementation is feasible, rather than being fully comprehensive in scope. These operations generally fall into four categories: (i) coordinated management of foreign currency reserves with foreign currency debt; (ii) managing asset levels to provide a buffer against adverse market conditions; (iii) transactions between the central bank and government that strengthen policy outcomes, reduce cost, and reduce risk; (iv) analyzing the variables that drive government revenues and then developing alternative debt portfolios; and (v) developing market access and debt instruments that reduced the identified exposures. The currency composition of public debt and net international reserves may be matched, to the extent that a portion of the reserves level is regarded as stable, so as to create natural hedges.

The challenge of coordinating independent entities can be eased either by limiting interventions by the central government strictly to support the SALM framework, without compromising independent governance arrangements, or by an overlay strategy. One possible option is that at the sovereign level, mechanisms are developed to lessen the risk of undue political interference when investment mandates (for example, for particular asset classes) are provided by the center. These could include legislative and institutional structures that set limits on such actions and require transparency.

Studies show that there are various approaches to the SALM framework with regard to balance sheet production and objectives (Amante et al., 2019; Jonasson and Papaioannou, 2018; Cangoz et al., 2018; Koc, 2014). In particular, an overlay strategy could entail a legal or institutional framework that requires investment objectives, strategic asset allocations, etc. of different entities to take account of aggregate SALM objectives, priority areas and challenges associated with integrated management. Surveys by Cangoz et al. (2018) and Koc (2014) confirm that the number of countries that have developed a comprehensive SALM framework is limited. However, most of the respondents indicate that they regularly produce an accounting balance sheet with the objective of monitoring sovereign assets and liabilities, rather than determining mismatches between them. Also, there are observed significant differences in practices across countries, e.g., while most countries include SOEs in the sovereign balance sheet, only a minority include central banks (in some cases only international reserves and sovereign wealth funds). Among the challenges cited are inadequate institutional arrangements, uncertain or absent mandates, coordination between institutions, data availability and difficulties in consistent valuation of assets.

Countries that have undertaken some degree of coordination in this area include Canada, Denmark, Hungary, New Zealand, Norway, Turkey, Sweden, and the United Kingdom (and some of these take it a step further by matching duration).[13] Within the domestic debt portfolio, some countries offset domestic on-lending against domestic debt, in order to manage the net position (for example, Denmark and New Zealand). Several other countries apply SALM concepts, at least partially, by adopting strategies to reduce vulnerabilities of the sovereign assets and liabilities without necessarily having explicit SALM identified objectives (Table 1).

Table 1. Selected SALM Country Cases

Country	Management of Sovereign Assets and Liabilities.
Australia	Allocation of assets between alternative portfolios and funds may take account of the government's broader priorities and objectives, but not specifically of balance sheet risks, coordination is by the responsible ministry
Canada between the entities involved in SALM	Decision-making authority for both assets and liabilities is assigned to the Ministry of Finance, which delegates the day-to-day management is delegated to the Central Bank. The coordination mechanism is instituting regular meetings
Denmark	Manages the consolidated position of the government debt by considering assets of government funds (e.g., pension funds, holding primarily government bonds and on-lending), guidelines for government guaranteed entities on exchange rate risks and loan types
Finland, Turkey	Management of central government debt and cash reserves is on a net basis
Hungary, Uruguay	The coordination mechanism is instituting regular meetings between the entities involved in SALM
Mexico	Reduced its external debt in 2006 through issuing domestic securities and using the proceeds to acquire FX from the central bank, which in turn redeemed its securities to reduce negative carry-costs improving the composition of the sovereign balance sheet
New Zealand	Manages local currency and foreign currency assets and provides derivative transactions for government entities
Norway	The coordination is through net transfers from oil plus return on assets to the fiscal budget; issuance of public debt as a market benchmark
Turkey	Manages the currency composition of the international reserves based on the maturity structure and currency composition of the government foreign exchange liabilities

Source: Jonasson and Papaioannou (2018) and country websites.

4. Implementation of an SALM Framework

4.1 Practical Challenges of Applying an SALM Framework

4.1.1 Data Requirements and Contours of the Sovereign Balance Sheet

The term "asset and liability management" (ALM) is well understood in the context of financial institutions, where it is a core element in risk management across their balance sheets. The application of an ALM framework is typical of financial intermediaries. The main objective of an ALM framework is to contain risks by matching the financial features (e.g., interest rate or currency) of assets and liabilities, so that one side of the balance sheet will be hedged—or immunized—by the other side. To oversee and manage the financial risks resulting from their activities, financial intermediaries have asset liability committees that periodically review the features of their assets and liabilities, analyze

[13] See Anderson, 1999; Bolder, 2002; Davis, 1998; Irwin and Parkyn, 2009; United Kingdom Cabinet Office, 2017.

currency and interest rate mismatches, and decide on possible adjustments to the balance sheet structure based on associated risk exposures and their level of risk tolerance.

While drawing on insights from private sector practice can support more effective risk-management for governments, there are conceptual differences and practical difficulties in doing so. As outlined above, first, most governments do not compile a full statement of their financial position in assets and liabilities, as a standardized information base is typically lacking and accounting treatment can differ among various entities, e.g., central banks and ministries of finance; second, many governments' assets are tangible in nature (for example, land, buildings, or plant), which do not readily lend themselves to analysis of financial risk; and third, the government's main asset is its capacity to tax and the financial features of this 'asset' are not easy to determine.

Even if consistent financial reporting is available across sectors, it may not be of sufficient granularity for SALM. For example, if the authorities wish to manage currency risk it would require information on assets and liabilities in each foreign currency, including their maturity profile and interest rate/revenue profile. The main financial statements may report only aggregated information, e.g., the amount of foreign-currency debt in total. The same limitation would apply when managing interest-rate and credit risks across the sovereign as a whole. In these circumstances, entities would be required to provide supplementary reporting to the center based on associated risk exposures and their level of risk tolerance.

Given that applying these insights to the risk analysis of a sovereign balance sheet is challenging, a common approach is to consider the major financial assets on the government's balance sheet such as international reserves, cash balances and other sovereign funds such as sovereign wealth or pension funds, in tandem with major financial liabilities.

4.1.2 Institutional Coordination

The nature of the policy objectives and the institutional arrangements in a country will shape the implementation of an SALM framework. The level of coordination and how it is implemented will vary from case to case and will depend on the main policy goals that are expected to be achieved through SALM. The fact that the participating institutions are managing parts of the consolidated balance sheet may enjoy statutory independence, such as a central bank, or operate under independent boards, such as SOEs or SWFs, can make the process of coordination challenging. For example, to take a relatively simple case where foreign reserves are managed by the central bank while the Ministry of Finance (MoF) is responsible for the government foreign-currency debt portfolio, each institution may set different objectives and evaluate risks over different time horizons. Developing an SALM approach to better manage currency risk would require the two institutions to negotiate in order to establish common ground within their respective frameworks and mandates, i.e., respecting accountability and governance structures.

The challenge of coordinating independent entities could be facilitated either by limiting interventions by the central government strictly to support the SALM framework, without compromising independent governance arrangements, or by an overlay strategy. Grimes (2001) presents the view that in the interest of efficient ALM at the sovereign level, mechanisms could be developed to lessen the risk of undue political interference when investment mandates (for example, for particular asset classes) are provided by the center. These could include legislative and institutional structures that set limits on such actions and require transparency.[14]

However, a potential downside risk remains that full accountability of the managers of the participating sovereign funds could be undermined. An alternative approach would be for the center to aggregate the positions of all participating entities that form the sovereign and offset risks that are not consistent with the SALM strategy. While this has the advantage of not interfering in the management of funds, it would incur additional transaction costs and be limited to more liquid asset classes and risk instruments. Also, monitoring the performance of SALM may be difficult if the accounting principles used in the sovereign funds differ from that in the center.

4.2 Role of Institutional Entities in Supporting SALM

The SALM approach requires a comprehensive framework for coordination among the various sovereign entities involved, including those dealing with monetary, fiscal, debt and asset management policies. In adopting an integrated SALM Framework, a joint analysis of the characteristics of financial assets and liabilities on the sovereign balance sheet would allow decision makers to take into account more fully the interrelationships and correlations among sources of risks when formulating strategies and policies.

Given the operational issues and institutional challenges underlying the SALM approach, strategies based on coordination of participating entities' policies is key to aligning implementation of SALM policy objectives. For example, operating as an autonomous entity, the central bank is primarily responsible for stabilizing the currency's internal and external value. Thus, in an SALM framework, the central bank's objective to maintain an ample level of international reserves to act as an important buffer (e.g., to intervene) in case of severely illiquid conditions in the foreign exchange market will be supported by other public entities' actions.

Several actions are typically needed to implement the SALM Framework:

- The establishment of a SALM Oversight Committee to provide a formal structure to monitor the implementation of the asset and debt management strategies of relevant public entities, based on their mandates and risk constraints. The SALM Oversight Committee should serve as the core of the governance of a SALM structure, headed by the Minister of Finance, and consisting of the governor of the central bank and the key heads of relevant public entities.
- The appointment of a dedicated project manager and technical team from the MoF, tasked with the collection of data and information, compilation of the SALM Framework and the analysis of the information contained in the SALM structure, including size of assets and liabilities and risks in the sovereign portfolio. As the SALM Framework progresses, the technical team could serve as the secretariat to the SALM Oversight Committee.
- Sufficient technical training should be provided to MoF and relevant public entities involved in the SALM Framework. The training should consist of, e.g., workshops, specialized courses on balance sheet risk management and study visits.

4.2.1 Considerations for SALM Application

High-level support, adequate resources and clear objectives will be required to establish the SALM Framework. Progress on establishing and implementing the SALM Framework could be gradual and be cast as a medium-term project (2–3 years). It is suggested to start with an initial compact SALM

[14] In particular, an overlay strategy could entail a legal or institutional framework that requires investment objectives, strategic asset allocations etc. of different entities to take account of aggregate SALM objectives.

Framework and gradually develop into a comprehensive depiction of the assets and the liabilities of relevant public entities. Based on other countries' experience, the authorities should aim for a gradual process allowing for a recalibration of the SALM Framework as more experience and information becomes available.

Box 1. Sequenced Development of an SALM Framework

Phase 1. Address Preconditions for the SALM Framework

- Obtain official approval within MoF to collect data from relevant public entities based on a clearly defined mandate
- Form a technical team with a dedicated project manager within a technical team from MoF
- Collect reliable data for assets and liabilities from each relevant public entity
- Glean and analyze asset and liability data

Phase 2. Develop the SALM Framework

- Develop an initial fully-fledged SALM framework consisting of the assets and liabilities from each of the relevant public entities
- Form a SALM Oversight Committee, which could be chaired by the Minister of Finance and include the heads of other relevant public entities
- Form a SALM Secretariat to support the SALM Oversight Committee
- Disseminate the analysis relating to the SALM Framework to the SALM Oversight Committee

Phase 3. Implement the SALM Framework

- Use the SALM Framework for communication with internal and external stakeholders
- Continued refinement of the SALM Framework and its integration within the policy framework

Source: Authors.

5. Lessons Learned and Steps Forward

A comprehensive understanding of the sovereign's assets and liabilities (wider public sector) will require the authorities to produce complete statements of relevant financial positions (i.e., balance sheets) of public entities. This will provide the basic data required for applying an integrated SALM set up. The data requirements for a meaningful SALM structure call for granularity and detailed recording of the financial accounts of the individual government entities involved. Accordingly, the need for producing financial reporting for the entire sovereign should be a priority in developing an SALM framework.

In this context, the management of sovereign liquidity risk, defined as the minimum level of cash balances that ensures the government can meet its day to day cash requirements, is especially important. In particular, it should ensure that the government has sufficient funds available to cover current expenditure and debt amortization during periods when market access is impaired or prohibitively expensive, or experiences volatility effects, forecast errors, and so on. It is managed by maintaining liquid assets at levels that are sufficiently robust to meet shock scenarios. Countries that have explicit policies in this regard include Denmark, New Zealand, South Africa, Turkey, and Uruguay.

Further, as many sovereigns take into consideration the risk characteristics of their revenue base when developing a medium-term debt management strategy, this should be similarly extended to SALM. Specifically, the observation that most sovereigns are dependent on revenues denominated in local currency, and that the level of the exchange rate does not have a strong relationship with revenues, has highlighted the risk of public debt portfolios with a high share of foreign currency debt.

5.1 Considerations for Developing an SALM Strategy

A financial risk management strategy can be developed to manage exposures in a cost-efficient manner. Thus, when an SALM approach is applied to the consolidated public sector portfolio, overall sovereign risk exposures can effectively be analyzed and managed by establishing an overall SALM strategy that is aligned with risk management strategies of individual public sector entities included in the SALM Framework.

The SALM approach can also be adapted to facilitate the attainment of long-term macroeconomic and developmental objectives, such as economic diversification, broadening of the export market, or reducing dependence on key imports. Further, the SALM approach can help identify long-term fiscal challenges, such as unfunded social security liabilities, implying a future claim on resources. Thus, an SALM framework can serve as a central element of an overall macroeconomic management strategy. Especially for commodity exporting countries, the SALM approach can highlight the potential asset management challenges that stem from and in turn influence a medium-term debt management strategy (Al-Hassan et al., 2018).

5.2 Implementation Challenges

5.2.1 Data Requirements

The data requirement for the application of an SALM framework is analogous to that of financial intermediaries applying ALM. To oversee and manage the financial risks resulting from their activities, financial intermediaries have asset-liability committees that periodically review the features of their assets and liabilities, analyze currency and interest rate mismatches, and decide on possible adjustments to the balance sheet structure based on associated risk exposures and their level of risk tolerance.

In cases where financial reporting is available across entities, sufficient granularity should be ensured for the purpose of developing an SALM framework. For example, if the authorities wish to manage currency risk, it will require information on assets and liabilities of entities in each foreign currency, including their maturity profile and interest rate/revenue profile. However, the main financial statements may report only aggregated information, e.g., the amount of foreign-currency debt in total, which would necessitate appropriate enhancements. The same limitation would apply when managing interest-rate and credit risks across the sovereign as a whole.

Generally, the entities included in a SALM framework will be required to provide supplementary reporting to the MoF, based on associated risk exposures and their level of risk tolerance. Given that applying these insights to the risk analysis of a sovereign balance sheet is challenging, a common approach is to consider the major financial assets on the government's balance sheet, such as international reserves, cash balances and other sovereign funds, like sovereign wealth and pension funds, in tandem with major financial liabilities.

5.2.2 Institutional Coordination

The nature of the policy objectives and the institutional arrangements will typically shape the implementation of an SALM framework. The level of coordination and how it is implemented will need to take into account the main policy goals that are expected to be achieved through SALM and the country's objectives. The fact that the participating institutions are managing parts of the consolidated balance sheet may enjoy statutory independence, such as a central bank, or operate under independent boards, such as SOEs, and pension funds operating under specific mandates. This will make the process of coordination challenging.

Developing an SALM approach to, e.g., better manage currency risk would require the institutions to negotiate in order to establish common ground within their respective frameworks and mandates, i.e., respecting accountability and governance structures. In principle, the challenge of coordinating independent entities can be eased either by limiting interventions by the central government strictly to support the SALM framework, without compromising independent governance arrangements, or by an overlay strategy. Special mechanisms could be developed to lessen the risk of undue political interference when investment mandates, e.g., for particular asset classes, are provided by the center. These could include legislative and institutional structures that set limits on such actions and require transparency. However, it is essential that the risk remains the full accountability of the participating entities.

An alternative approach to the implementation of the SALM strategy would be for the center to aggregate the positions of all participating entities that form the sovereign and offset risks that are not consistent with the SALM strategy. While this has the advantage of not interfering in the management of funds, it would incur additional transaction costs and be limited to more liquid asset classes and risk instruments. Also, monitoring the performance of SALM may be difficult if the accounting principles used in the sovereign funds differ from that in the center. As a result, this would not likely be the preferred modus operandi for many countries.

A number of factors can contribute to the adoption of a SALM framework. First, the approach to "gross public sector debt" is important and the central government should have a direct interest in the balance sheets of the entities included in the SALM. Thus, the central government can address risk from a portfolio perspective, taking into account correlations between different types of risks. Further, the use of hedging transactions can be mitigated, e.g., by using the comparative advantage of the central government to issue local currency bonds.

Also, country authorities can expect that SALM operations evolve over time, from a less formal framework, to a more formal institutional setting. A track record of cooperation to address balance sheet and risk management issues between the entities included in the SALM is advisable, prior to establishing a more formal institutional setting. Nonetheless, the establishment of an overseeing committee, with broad terms of reference, can improve the integrated approach to a more systematic analysis of the public-sector balance sheet. Decisions about transferring risk to the private sector, via insurance or through capital markets, can be taken on the basis of such systematic analysis in order to ensure that resources were allocated in the most efficient manner.

It should be noted that the accounting standards used by public entities may be a crucial factor in their decision to enter an SALM framework, as they affect the value of their assets and liabilities. The selection of accounting standards for an SALM framework would then affect the value of the assets and liabilities of the included public entities, as they will depend on whether mark-to-market valuation or historical price is used. Typically, a central bank, the MoF and other SALM entities apply different accounting practices. For example, foreign exchange valuations are understood to be similar for central banks and MoFs (mark-to-market), while interest rate valuations tend to be different (mark-to-market for a central bank and nominal or face value for a MoF).

A comprehensive SALM framework would be a valuable tool to an SALM Oversight Committee for monitoring sovereign portfolio risks. Experience indicates that risk management decisions regarding foreign currency, maturity and interest rate risks are typically made between the MoF and the central bank balance sheets. The currency, maturity and interest rate structures of the MoF and the central bank could be aligned in order to determine foreign currency, maturity and interest rate mismatches that could be managed on a consolidated basis. However, the foreign currency, maturity and interest rate mismatches of the other entities could be left with the individual companies involved, respecting the roles and the responsibilities of their risk management operations, while the aggregation of those entities would be monitored by the SALM framework. Furthermore, an SALM Oversight Committee can determine whether further aggregation in hedging operations can selectively include certain relevant public entities or whether aggregation of other risks should be grouped as they may be suitable for intragroup risk management operations.

In particular, the application of the SALM framework should prove to be useful for understanding asset dynamics. For the budgetary central government, future dividends from assets of public companies, such as SWFs and SOEs, are an integral part of revenue projections and issuance strategies. Large scale investments across public entities may also impact the issuance programs of the budgetary central government, as adjustments in asset composition on other parts of the balance sheet could require more time. Understanding future investment commitments and identifying resources would be the responsibility of the relevant public entities, but due to the potential lumpiness of such flows it would be feasible to ensure that asset sales and investments are implemented in an orderly manner.

The SALM framework can also be applied to further improve and expand existing coordination mechanisms, e.g., between MoF and the central bank on liquidity management. The intersection of government financing and central bank liquidity management provides an important junction, since it directly affects the central bank's ability to forecast banking sector liquidity that underpins its sterilization policies. Efforts to improve information-sharing on cash management for MoF and the central bank should be encouraged, with additional information about the actions and coordination of relevant public entities being derived through the SALM Framework.

Improving the information sharing among public entities would not only improve the predictability of financing flows, but could also help the efficacy of policies, e.g., exchange rate policy during periods of currency stresses, where monetary authorities may need to intervene in the foreign exchange market to support the currency. In such case, an SALM framework could help coordinate liability management operations of the budgetary central government and other relevant public entities so as the central bank's efforts to support the currency is not undermined. For example, the budgetary central government and other relevant public entities should not proceed with prepayments of their foreign currency liabilities during periods of currency distress in order to reduce potential conflict between monetary policy objectives and liability management operations of relevant public entities.

6. Conclusions

The application of an SALM framework will enable the authorities to assess future public sector liability and financial investment decisions in a comprehensive manner. The framework will thus allow the authorities to identify and monitor any sovereign exposure mismatches, increase resilience by mitigating foreign currency, maturity and interest rate risks, strengthen financial stability and implement a more cost-effective management of the public-sector debt and assets.

The development of an SALM framework should be consistent with the country's macroeconomic setting and policy priorities. A multi-step approach towards developing an analytical framework for SALM requires: (i) delimiting the scope of the analysis and the public entities to be included; (ii) collection of balance sheet data and financial information from all the entities covered by the SALM framework; (iii) assessment of financial risks across the relevant entities to identify natural hedges and mismatches; (iv) development of a SALM strategy, based on risk analysis; (v) examination of institutional considerations, including the participating entities' coordination; and (vi) implementation of the SALM strategy and evaluation of its outcomes.

In developing an SALM framework, the public entities to be included, along with key sovereign risks and mechanisms to monitor them, should first be identified. Furthermore, other considerations for developing a SALM framework should be taken into account, including the establishment of an appropriate institutional structure and coordination mechanisms based on a technical plan consisting of three phases: (i) addressing preconditions for developing an SALM framework, (ii) development of a SALM framework, and (iii) implementation of a SALM framework. In this endeavor, the importance of high-level ministerial support, appointing a dedicated technical team from within the MoF, and forming an SALM Oversight Committee, to be chaired by the MoF, is considered critical.

The development of an SALM framework may be viewed as a collaborative effort among the various country authorities, including the MoF, the central bank, possible SWFs, public pension funds, SOEs, and other public entities, to dealing with sovereign balance sheet risks. Further, it will also be critical to manage the SALM project in coordination with possible other related country initiatives, e.g., projects relating to accrual accounting, the identification of fiscal risks, the management of government guarantees and the development of a treasury single account. In this regard, a greater coordination and elaboration would be needed among the SALM Oversight Committee and specialized entities overseeing such projects, in particular with regards to exchanging of data and information in the areas of their operations.

It is widely recognized that an SALM framework is suitable for countries that fulfill certain preconditions. If authorities decide to adopt an SALM framework, first, they need to devise an integrated sovereign balance sheet, following good practices, along with appropriate data for participating public entities. Second, they should aim to create an appropriate institutional/coordination platform for those government entities whose financial accounts will be included in the sovereign balance sheet and whose corresponding portfolio risks will need to be monitored. Third, they will need to have policy instruments that are effective in modifying the overall portfolio cost and risk characteristics. Under these conditions, adoption of an SALM framework would allow the country to efficiently and adequately identity and measure prevailing and/or emerging portfolio risks, as well as to manage them in the most cost-effective manner.

However, it is recognized that a fully developed sovereign balance sheet may not be always feasible and may have to be a long-term goal. To take advantage of the benefits that SALM can offer, the authorities should at least be able to identify the main assets and liabilities that would have a material impact on the management of financial risk, analyzing them accordingly. For most countries, they would include the balance sheets of the central government and central bank in the first instance.[15] Beyond that, the focus should gradually turn to other entities with significant debt and financial assets, such as financial institutions, investment and pension funds, and SOEs.

Also, it may take time to establish a formal body that is able to coordinate SALM. In some countries, earlier ALM actions used existing channels and networking by officials, e.g., Uruguay. In particular, the establishment of a specialized team, with broad terms of reference, could provide an impetus for systematic analysis of financial risk, costs and returns across the main entities.

As the assets and liabilities that make up the sovereign balance sheet are usually managed by a range of entities, some with constitutional or statutory independence, adoption of a fully-fledged SALM framework may require extensive negotiations among these entities. However, any operational independence of an SALM entity can only come about through a common understanding of relevant country authorities that share the same overarching SALM objective. In principle, constitutional or statutory independence of participating entities should not be a reason to resist the formation of an SALM framework. As its implementation aims to improve the efficiency of policy outcomes, it should be in the interest of the sovereign as a whole. Also, if application of an SALM framework calls for changes in the investment, borrowing or risk management actions that could be accommodated within the policy framework of constituent entities, then such changes should not be resisted.

In this context, a separate entity, like an SALM Oversight Committee, to implement strategic SALM analysis may be desirable. Such Committee would need to be supported by a dedicated team of asset and debt management professionals. A team with financial expertise from the MoF or from an expanded public debt management unit would be a prime candidate. Its core role of developing an SALM strategy, which will integrate the country's public debt management strategy, requires an analysis of the nature of the government's assets, revenues and liabilities. In addition, it could undertake institutional arrangements to manage operational risks associated with the execution of high-value transactions in financial markets.

Along the same lines, as an SALM framework can serve as a monitoring device for the SALM Oversight Committee of the dynamic evolution of sovereign balance-sheet risks, it can also help assess instruments and markets to offset identified exposures. When such means are not readily available, such Committee can suggest to governments to support the development of relevant instruments and markets. To this end, countries have facilitated the development of local currency bond markets, promoted the issuance in the international capital markets, or supported the capacity to enter into derivative transactions.

Further, the dynamic aspects of implementing an SALM framework should be stressed. Implementation of an SALM model will typically impact the respective country's macroeconomic setting, including its fiscal accounts (effects on issuances and liability management operations), asset management policies, monetary and exchange rate policies (effects on interest and exchange rates), and institutional structure (effects on sovereign asset and liability hedging strategies). These effects will likely trigger policy reactions to any unintended or undesired consequences, especially if they are sizeable, in addition to policy changes stemming from changes in the underlying macroeconomic setting and assumptions. Then, a round-two application of the SALM approach will generate new asset and liquidity proposals, which, if implemented, will have new macroeconomic consequences and

[15] Regarding the central government balance sheet, efforts should be made to include the government's main "fiscal" asset, i.e., its ability to tax, for a more comprehensive representation of the government's total assets. In this study, we have mainly taken into account the central government's financial assets.

create another feedback loop (a dynamic mechanism of monitoring, assessing, and addressing resulting sovereign portfolio risks), and so on. A dynamic process of this kind, that helps improve sovereign risk management outcomes and secure optimal hedges, can be facilitated by ad hoc stress testing and/or ex-ante scenario analysis of the adopted SALM model.

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Managing South Africa's Exposure to Eskom: How to Evaluate the Credit Risk from the Sovereign Guarantees?

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Abstract

The South African government offers various mechanisms to support Eskom, the state-owned electric utility, and the independent power producers in providing low-cost electricity, including credit and payment guarantees. Guarantees constitute contingent liabilities to the government and pose risks to government finances. This note illustrates the methodologies explored by South Africa to assess the credit risk from guarantees extended to Eskom. To manage and closely monitor this risk, a dedicated Credit Risk directorate in the Asset and Liability Management division at the National Treasury of South Africa has implemented a risk assessment and management framework, supported by the World Bank Treasury. The team developed a sector-specific internal credit rating methodology to assess Eskom's creditworthiness. The credit rating methodology is based on a scorecard using qualitative and quantitative risk factors. Scores for each risk factor are assigned based on scoring guidance provided in the methodology and aggregated to a weighted overall rating for Eskom on a scale from 1 (extremely low risk) to 9 (imminent default/in default). Additionally, the team developed a scenario analysis methodology to assess Eskom's ability to service debt from cash flows generated through operations and cash reserves. Scenarios are defined using macroeconomic and industry-specific variables (e.g. economic growth, inflation, interest rates, and commodity prices). The scenario analysis tool is currently used on an ad hoc basis to feed into the various scenarios that are considered for the budget process. Risk assessments are reported to the Fiscal Liabilities Committee on a quarterly basis for risk monitoring and to support recommendations for taking on new contingent liabilities, such as government guarantees. The National Treasury is considering further risk mitigation and monitoring tools, such as risk-based guarantee fees, budget allocations, and a contingency reserve account, is under discussion.

JEL classification: E62, G32, H63, H81, L94, N77, O55

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1. Introduction[3]

Contingent liabilities are obligations that emerge only upon the materialization of an uncertain event. The uncertainty surrounding the timing and the magnitude of the event are both factors outside the control of the government and have the potential to create unexpected pressures on government finances.[4] To avoid unnecessary adjustments in an unplanned and/or untimely manner during the fiscal year, governments need to identify, measure, and manage risks from contingent liabilities. In many countries, the energy sector is one of the key sources of risk exposure of the government. The energy sector generates significant investment needs and is expensive to finance. Therefore, governments sometimes choose to provide guarantees to entities responsible for undertaking investments for the generation, transmission, and distribution of energy to help them become profitable or sustainable. Also, energy utilities are often owned by the government. All of this is true in South Africa where the energy sector is dominated by Eskom, a state-owned and vertically-integrated electric utility. Additionally, there are independent power producers (IPPs) that are increasingly becoming important actors in generating electricity from renewable sources. Eskom has entered into power purchase agreements (PPAs) with these IPPs.

The objective of this note is to illustrate credit risk assessment practices explored in South Africa and provide guidance to risk managers in other countries. The work presented in this note draws on the activities of a project carried out by the World Bank Treasury[5] in collaboration with the National Treasury of South Africa (NTSA) for assessing and managing the contingent liabilities of the Government of South Africa stemming from Eskom's guaranteed debt portfolio.

This note draws on a framework for risk assessment and management presented in a World Bank policy research working paper on contingent liabilities risk management (Bachmair, 2016). The four steps outlined in the paper are highlighted and extended, with an emphasis on sections related to credit risk analysis and quantification. This note may be considered an extension of the working paper and provides a more focused country case for South Africa.

While the focus of the paper is on explicit guarantees, i.e. contractual obligations signed by the sovereign, the methodology could easily be extended to implicit guarantees, since the underlying credit risk drivers are similar. Efforts at NTSA to improve contingent liability risk management are an ongoing process, hence some of the issues presented are work in progress.

2. Framework for risk assessment and management

To design a framework for assessing and managing risk from contingent liabilities such as guarantees, government risk managers can follow a four-step process (figure 1, and Bachmair, 2016):

- Context and defining characteristics: Risk managers need to identify the volume of exposure to risk, the types of risks they are exposed to (e.g. credit risk, demand risk, exchange rate risk, etc.), and require a clear understanding of the context they are operating in (e.g. data availability, resources, and capacity).
- Risk analysis: Key risk drivers relevant to the beneficiary and its industry are identified, and the degree of risk is assessed.

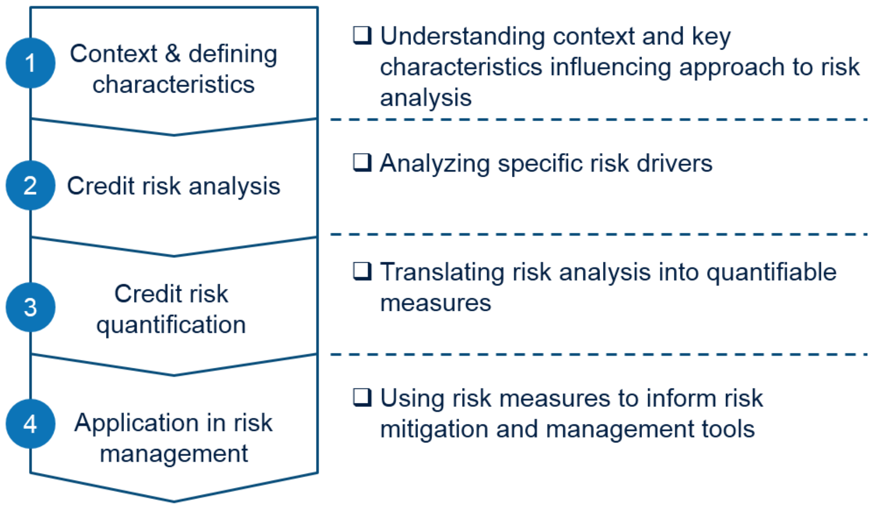
[3] Please see the Abbreviation list at the end of the paper.

[4] For South Africa, Bachmair and Bogoev (2018) assessed contingent liabilities and their impact on debt dynamics. The realization of contingent liabilities may increase government debt by 0.6 to 0.8 percent annually over the next years.

[5] The project was supported under the Government Debt and Risk Management (GDRM) program: http://treasury.worldbank.org/bdm/htm/GDRMProgram.html

- Risk quantification: Outputs from risk assessment (e.g. ratings) are translated into quantified measures that allow for comparability with policy alternatives (e.g. risks expressed in nominal terms which may feed into the budgeting process).
- Application of risk management tools: Insights from risk analysis and quantification are used to design and implement risk mitigation and monitoring tools, e.g. decision-making process for issuing new guarantees, structuring guarantee agreements (including, for example, guarantee fees), budgeting for potential losses, etc.

Figure 1: A framework for credit risk assessment and management



Source: Bachmair, 2016

Subsequent sections describe how this framework applies to NTSA's credit risk management for Eskom.

a) Defining context and key characteristics

The South African context of credit risk management can be described along four critical factors, including the characteristics of the guarantee portfolio, the definition of risk exposure, data availability, and internal resources and capacity.

i) Characteristics of the guarantee portfolio

The South African government has outstanding guarantees to state-owned companies (SOCs) operating in various sectors, public-private partnerships (PPPs) and IPPs. The total limit of guarantees currently authorized by the government amounts to R 675.8 billion (14.7 percent of GDP) against which SOCs have so far borrowed R 300.4 billion (6.5 percent of GDP).[6]

The portfolio is highly concentrated in Eskom, which accounts for 73 percent of the authorized guarantee limit to SOCs and 74 percent of current exposure (i.e. disbursed and guaranteed borrowing, Table 1). Eskom is fully owned by the government and is a virtual monopolist for electricity generation in South Africa, accounting for 95 percent of electricity generated (the remaining electricity is generated by IPPs which sell their output to Eskom). Eskom is vertically integrated; it generates,

[6] Numbers are compiled based on the latest available information at the time of publishing NTSA's Budget Review 2018 (February 21, 2018).

transmits, and distributes electricity to commercial and residential customers.[7] Eskom's generation is heavily dependent on coal, accounting for about 85 percent of generation capacity, followed by nuclear and hydro power sources. Eskom is regulated by the National Energy Regulator of South Africa (NERSA) which sets tariffs for electricity sold by Eskom. The government explicitly guarantees various long-term debt instruments of Eskom, including foreign currency loans and bonds, as well as domestic bonds.

Table 1: Government guarantees in South Africa

	2015/16		2016/17		2017/18	
R billion	**Guarantee**	**Exposure[2]**	**Guarantee**	**Exposure[2]**	**Guarantee**	**Exposure[2]**
Public institutions	**469.9**	**255.8**	**475.7**	**290.4**	**466.0**	**300.4**
of which:						
Eskom	*350.0*	*174.6*	*350.0*	*202.8*	*350.0*	*220.8*
SANRAL	*38.9*	*27.2*	*38.9*	*29.4*	*38.9*	*30.1*
Trans-Caledon Tunnel Authority	*25.8*	*21.2*	*25.6*	*20.9*	*25.7*	*18.7*
South African Airways	*14.4*	*14.4*	*19.1*	*17.8*	*19.1*	*11.8*
Land and Agricultural Bank of South Africa	*6.6*	*5.3*	*11.1*	*3.8*	*9.6*	*6.6*
Development Bank of Southern Africa	*13.9*	*4.4*	*12.5*	*4.1*	*12.3*	*4.2*
South African Post Office	*4.4*	*1.3*	*4.4*	*4.0*	*0.4*	*0.4*
Transnet	*3.5*	*3.8*	*3.5*	*3.8*	*3.5*	*3.8*
Denel	*1.9*	*1.9*	*1.9*	*1.9*	*2.4*	*2.3*
South African Express	*1.1*	*0.5*	*1.1*	*0.8*	*0.8*	*0.8*
Industrial Development Corporation	*2.0*	*0.2*	*0.4*	*0.2*	*0.5*	*0.1*
South African Reserve Bank	*3.0*	*–*	*3.0*	*–*	*–*	*–*
Independent power producers	**200.2**	**114.0**	**200.2**	**125.8**	**200.2**	**122.2**
Public-private partnerships[3]	**10.3**	**10.3**	**10.0**	**10.0**	**9.6**	**9.6**

1. A full list of guarantees is given in Table 11 of the statistical annexure in the Budget Review
2. Total amount of borrowing and accrued interest for the period made against the guarantee
3. These amount only include the national and provincial PPP agreements
Source: NTSA, 2018 Budget Review

In addition to credit guarantees to Eskom, the government provides payment guarantees to IPPs as they contract with Eskom through PPAs for up to 20 years.[8] Under these payment guarantees, NTSA is obliged to purchase power from IPPs if Eskom is unable to honor its obligations from PPAs. If a project were terminated early, the government may be required to pay project sponsors. The maximum payment from the government due to early termination is currently estimated at about R 122.2 billion (2.7 percent of GDP) (see Box 1 for a discussion of guarantees related to IPPs).

[7] Distribution to residential customers is mostly channeled through municipalities. These residential customers, hence, have payment obligations to municipalities which in turn have to pay Eskom. Eskom does however, have direct sales to residential customers although this constitutes a very small percentage.
[8] In terms of legislation, guarantees are issued directly to Eskom by the Minister of Public Enterprises, while the guarantees to the IPPs are issued by the Minister of Energy, with the concurrence of the Minister of Finance, who is the Head of NTSA.

Box 1: Assessing risks from government guarantees related to independent power producers (IPPs)

The Government of South Africa supports increased use of renewable energy sources for the generation of electricity. The government has instituted an IPP scheme for renewable energy. Currently, 112 IPPs have been awarded. IPPs sell all energy generated to Eskom. The government is sharing in the risk IPP shareholders are taking by providing guarantees. The government is guaranteeing two types of risks:

- Eskom's inability or unwillingness to pay for energy sold by IPPs, and
- termination of IPPs by government.

NTSA perceives the risk of materialization of these guarantees to be limited (NTSA, 2018).

First, the National Energy Regulator of South Africa the regulator, assured Eskom that charges for electricity sold by IPPs will be treated as a pass-through cost, i.e. the regulator will approve a tariff to compensate Eskom for the cost of electricity purchased from IPPs.

Second, termination by government is a choice rather than a risk. Furthermore, if IPPs were terminated and termination payments made, the government would acquire an asset which may amortize termination payments made over time.

Source: NTSA, authors

ii) Definition of risk exposure

The relationship between the government and Eskom is multidimensional. Through various ministries, divisions, and agencies, the government acts as shareholder, creditor, guarantor, regulator, and customer to Eskom. As a virtual monopolist for electricity generation, and transmission,[9] Eskom provides an essential service impacting economic activity in South Africa. As such, the government has a strong interest in Eskom's performance related to multiple aspects, including the provision of electricity to support economic activity, the achievement of social and development objectives such as the provision of electricity to poor households, dividends, environmental hazards, and contingent liabilities.

It is important to differentiate and properly assess and manage the risks the government is exposed to from Eskom's performance. If Eskom was unable to meet its obligations to service guaranteed debt or honor payments for electricity to IPPs, the government is obliged to step in and make a payment to creditors or IPPs.

Given the complex relationship between the guarantor (the government), and Eskom, the clear definition of a credit event is essential. Eskom has not defaulted in the past for any of the guaranteed debt or amounts owed to the IPPs and it may be unlikely to do so in the future. The government has a strong incentive to avoid outright default which may lead to an acceleration of loans and bonds by creditors, a disruption in the electricity supply, contagion to other SOCs, and broader negative macroeconomic repercussions. Hence, the government is likely to step in before an outright default occurs, as long as the government's own fiscal strength enables it to do so. A narrow definition of a credit event would not capture these events as an actual default would not occur vis-à-vis creditors and the guarantee agreement would not be formally triggered.

[9] Half of electricity distribution is provided by Eskom.

Hence, the Credit Risk Directorate at NTSA has defined a credit event more broadly as any type of unplanned government support aimed at avoiding default.[10] These include:

- an unplanned capital injection, beyond any planned injection to support Eskom's capital expenditure program;
- the temporary (or permanent) servicing of debt payments to the creditor (e.g. an annual principal and interest installment); and
- an immediate payment of all guaranteed debt outstanding.

iii) Data availability

NTSA uses a variety of information sources to inform risk analysis. Annual reports and financial statements (income statement, cash flow statement, and statement of financial position) are an essential resource. Statements are prepared according to International Financial Reporting Standards, audited, and are usually available within six months following the end of a fiscal year (ending March 31). In addition to backward-looking financial statements, NTSA receives corporate plans. Corporate plans describe planned performance, and initiatives and capital expenditure programs for a five-year period. Corporate plans also contain projected financial statements.

As no SOC benefitting from guarantees has defaulted in the past, no historic default data are available. However, the Credit Risk Directorate is in the process of compiling a database of credit events consistent with its definition. Such a database will contain unexpected payments from government to Eskom in order to avoid triggering guarantees.

Additionally, NTSA uses market and third-party information for credit risk assessment. Market information includes secondary market prices and credit spreads for domestic and foreign currency bonds of Eskom. As Eskom is fully government owned, no traded equity prices can be observed. From rating agencies, NTSA uses both rating reports on Eskom as well as rating reports of peer companies outside South Africa (i.e. monopolistic state-owned electric utilities) and rating methodology papers (i.e. Moody's methodology paper for regulated electric and gas utilities) (Moody's Investor Service, 2013). NTSA uses RiskCalc and Credit Edge as additional tools to assess credit risk. RiskCalc is software aiming to estimate default probabilities of privately held companies using the financial ratios of the respective entities. Credit Edge is similar software for publicly traded companies. NTSA employs this information complementarily. Ratings of peer companies and rating methodology papers have been used to develop an internal credit rating methodology (section 2.b.). Market prices are monitored to detect changes in market participants' perception of credit risk which may trigger a review by the Credit Risk Directorate. These are ultimately used to support the determination of the internal risk rating that is assigned to Eskom.

Compared to other SOCs within South Africa and SOCs in other countries, the degree of information available on Eskom is rich. A major challenge in credit risk assessment for SOCs in developing countries is depth and reliability of available information. The choice and design of risk assessment methodologies (discussed below) needs to factor in these constraints.

iv) Internal resources and capacity

The Credit Risk Directorate at NTSA is mandated with assessing the government's credit risk exposure from government guarantees to SOCs, IPPs, and cash balances at commercial banks. Additionally, the team is undertaking analyses of fiscal risks from Public Private Partnerships (PPPs) and various

[10] This is particularly relevant when estimating probabilities of distress and when defining rules for accessing future contingency funds for payouts related to guarantees.

government funds.[11] The Credit Risk Directorate is part of the Chief Directorate for Strategy & Risk Management, one of five Chief Directorates of the ALM division.[12]

The Credit Risk Directorate is headed by a director and includes four permanent staff, supported by one to two interns on a rotating basis. Staff have predominantly backgrounds in accounting, finance, and economics. The Credit Risk Directorate works closely with staff in the Governance and Financial Analysis and Sectoral Oversight Chief Directorates at the ALM division. These chief directorates are responsible for financial oversight of some SOCs and NTSA's shareholder role. They regularly interact with SOCs under their remit and possess information about SOC performance valuable for credit risk assessment.[13]

Most credit risk analyses are conducted using Microsoft Excel.

b) Risk analysis

Government risk managers employ various methodologies to assess credit risk, including credit rating, statistical models, scenario analysis, and structural models.[14]

NTSA has historically relied on credit rating for credit risk assessment. To complement this methodology, NTSA has developed a scenario analysis tool. NTSA has also considered, but rejected, a modified Merton approach. All three methodologies are discussed below. NTSA's use of credit risk assessment methodologies and risk quantification is codified in a methodology paper (NTSA, 2017).

i) Credit rating

In 2009, NTSA started performing credit risk assessment of SOCs that benefit from guarantees. Initially, NTSA developed a standardized score card for all relevant SOCs. To reflect differences in risk drivers by industry, NTSA later differentiated score cards by industry. Due to significant differences in business models, risk drivers, and balance sheet items of financial institutions, NTSA developed a separate score card for development financial institutions. As part of a project supported by the World Bank Treasury, NTSA further tailored its corporate score card. NTSA has finalized a score card for the energy sector to analyze Eskom's credit risk and developed additional sector specific score cards for aviation, infrastructure, transport, defense, and telecommunications.

NTSA's rationale for choosing credit rating reflected various factors. A credit score card is intuitive and its outputs (credit ratings) are easy to communicate, not least because of policy makers' familiarity with credit ratings of the sovereign by rating agencies. A credit score card is relatively easy to develop and maintain. No advanced quantitative analysis is required. Accounting skills are more important than statistics. Also, NTSA has limited access to historical information, partly because no default of relevant SOCs has occurred in the past.

Eskom is also rated by the three most prominent international rating agencies, S&P, Moody's, and Fitch. The credit rating undertaken by these rating agencies is considered by NTSA. However, NTSA believes the risks it is exposed to are not fully reflected in rating agencies' assessment. Rating agencies consider the implicit and explicit government support provided as a potential reason for an upgrade.

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[11] Including the Compensation Fund, Export Credit Insurance Corporation South Africa, Road Accident Fund, South African Special Risk Insurance Association, and Unemployment Insurance Fund.

[12] See the National Treasury website (http://www.treasury.gov.za/nt/Top%20Structure%20Organisation.pdf) for details of the organizational structure.

[13] The government's role as shareholder is managed by the different government departments that are Executive Authorities for the various SOC with the Department of Public Enterprises being the shareholder for the largest SOCs including Eskom. NTSA is shareholder for some SOCs but also plays an oversight role for all SOCs.

[14] See (Bachmair, 2016) for a discussion of alternative methodologies.

From the government's perspective this explicit and implicit support constitutes a risk.[15] Furthermore, NTSA believes it has access to information about entities that rating agencies do not (e.g. due to its role as shareholder).

The credit score card for the energy sector assesses business risks and financial risks (Table 2). As Eskom operates in a highly regulated environment, the regulatory environment and adherence to regulation are key risk factors. Financial risks are grouped into categories, with debt capacity ratios and liquidity ratios as the most significant risk drivers. NTSA's methodology paper guides credit analysts in their assessment. The methodology paper standardizes risk assessment across the directorate, various analysts, and beneficiary entities by providing scoring guidance and weights for each risk factor. For qualitative factors, scoring guidance describes the sub-factors analysts should take into consideration. For example, when assessing the operating environment, scoring guidance refers to "[…]inflation, interest rates, fuel prices and gross domestic product as well as microeconomic factors such as competition within the sector, demand for the entity's product offering and supply of raw material utilized by the entity" (NTSA, 2017). For financial risk indicators, ranges are provided to guide scoring for each financial ratio.

Table 2: Scoring factors in energy score card in South Africa

Business risk indicators	Financial risk indicators
• **Industry Prospects** ○ Operating Environment ○ Regulatory Framework • **Corporate Governance** ○ Adherence to applicable legislation ○ Management Quality • **Market Position** ○ Diversification ○ Size (capacity)	• **Profitability** ○ Operating margin ○ Net profit margin ○ Revenue growth • **Debt capacity** ○ Debt to assets ratio ○ Debt to equity ratio ○ Interest cover ratio • **Efficiency** ○ Cost to income ratio • **Cash flow adequacy** ○ Funds from operations to total debt ratio • **Liquidity** ○ Cash ratio ○ Quick ratio ○ Current ratio

Source: NTSA

Credit analysts then present their recommendation to a rating committee, consisting of other credit analysts and chaired by the director of the Credit Risk Directorate. Final ratings are assigned on a scale from one to nine (Table 3). While the rating methodology paper has undergone external audits, the ratings themselves do not. However, rating reports are subject to an annual performance audit conducted on the ALM division. It is very important for the Credit Risk Directorate that assesses risks to be independent from the Fiscal Liabilities Committee which makes recommendations to the

[15] Despite this potential notching of entities due to (government) support mechanisms, most rating agencies also disclose a stand-alone rating, i.e. a rating of creditworthiness of an entity based on its stand-alone strength, excluding government support.

minister of finance on responding to new guarantee requests. The output of the Credit Risk Directorate also forms part of the annual performance audit conducted on ALM.

Table 3: Credit rating scale in South Africa

Risk ratings	Extent of risk exposure	Likelihood of materialization
1	Extremely low risk	Remote
2	Low risk	
3	Moderate risk	
4	Marginal risk	
5	Special attention	Possible
6	Substandard	
7	High risk	Probable
8	Very high risk	
9	Imminent default/in default	

Source: NTSA

ii) Scenario analysis

Over time, the Credit Risk Directorate's familiarity with credit rating increased. At the same time demands from management increased. Management was particularly interested in the quantification of credit risk and the use of risk assessment tools based on quantitative analysis. In an ongoing project supported by the World Bank Treasury, the Credit Risk Directorate developed a scenario analysis tool. The Credit Risk Directorate employs scenario analysis complementary to credit rating, and in response to specific requests by management or other units within NTSA. The scenario analysis tool aims to offer insights into Eskom's financial health and its ability to service debt obligations if certain scenarios materialize.

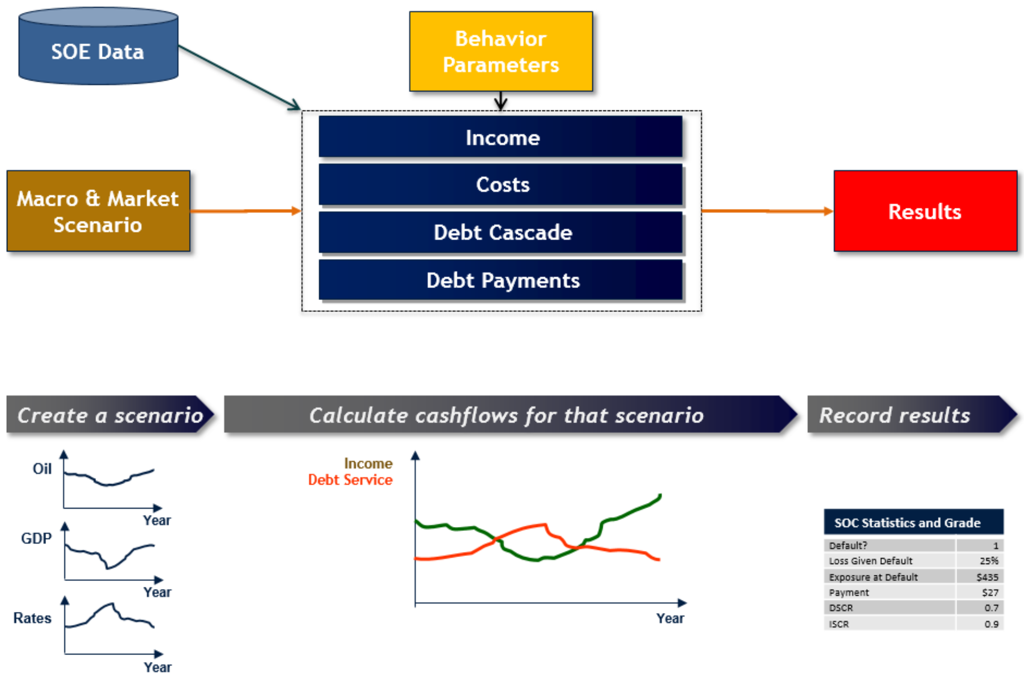
As any scenario analysis tool, this model consists of inputs, a cash flow engine, and outputs/results (Figure 2).[16]

Inputs include:

- Macroeconomic and industry specific variables. These include economic growth (as measured by Gross Domestic Product), inflation (Consumer Price Index and Producer Price Index), interest rates (Repo rate), and commodity prices (oil prices and coal prices).
- Eskom's corporate plan. Corporate plans include projections of financials (income statement, cash flow statement, and statement of financial position).

[16] Readers who may be familiar with the World Bank/IMF Medium Term Debt Management Strategy analytical tool will note that the structure of the model is identical. However, instead of simulating debt service cash flows, this model simulates cash flows of a corporation.

Figure 2: Scenario analysis model for Eskom



Source: Risk Integrated, authors

NTSA constructs four to five scenarios: one consistent with Eskom's corporate plan; one based on NTSA's baseline, consistent with the macroeconomic model used for budgeting; and two to three downside scenarios where specific macroeconomic risks materialize.

The cash flow engine then estimates Eskom's cash flows for each scenario. For example, a slowdown in economic growth would impact demand for energy and hence the quantity of electricity sold by Eskom. Another example would be an increase in generation costs if commodity prices increased.

In addition to the macroeconomic and industry specific variables considered, NTSA may consider adding idiosyncratic variables that are specific to Eskom. Such factors could include decisions on tariff increases by the NERSA or the payment behavior of customers, such as municipalities.

One output of the tool is illustrated in Table 4.[17] Based on an opening cash balance, and cash flows from operations and investment activities, the tool shows whether Eskom would have sufficient cash to service its debt payment obligations under different scenarios. A cash shortfall may require government action.

[17] Note that numbers have been changed to preserve confidentiality.

Table 4: Illustration of aggregated cash flows in scenario analysis model in South Africa[18]

R'billions	FY18	FY19	FY20	FY21	FY22
Opening balance	**100,00**	**33,00**	**3,00**	**11,00**	**50,00**
Cash from operations	90,00	120,00	170,00	200,00	210,00
Cash from financing activities	-127,00	-100,00	-127,00	-101,00	-198,50
Total debt payments needed	*-130,00*	*-105,00*	*-130,00*	*-100,00*	*-210,00*
Required Repayment loans	-30,00	-25,00	-40,00	-60,00	-120,00
Required Interest to be paid	-100,00	-80,00	-90,00	-70,00	-110,00
Interest received	3,00	3,00	2,00	2,00	1,50
Other financing activities	-	2,00	1,00	-3,00	10,00
Cash available for investment	**-37,00**	**20,00**	**43,00**	**99,00**	**11,50**
Investment activities	-80,00	-100,00	-90,00	-110,00	-60,00
Net borrowings	50,00	50,00	55,00	50,00	60,00
Cash available to pay debt	**163,00**	**108,00**	**141,00**	**150,00**	**271,50**
Required debt payments	-130,00	-105,00	-130,00	-100,00	-210,00
Shortfall/Cash remaining	**33,00**	**3,00**	**11,00**	**50,00**	**61,50**

Source: NTSA, authors

iii) Modified Merton model

Robert Merton pioneered structural models for credit risk assessment (Merton, 1977). Structural models assume default of an entity occurs when an entity’s asset value falls below the value of its debt.

A guarantee may be viewed as a put option.[19] A guarantee is a put option on the assets of the firm with an exercise price equal to the face value of the debt. If an entity’s asset values are larger than debt, full repayment of debt can be expected and the put option is not exercised. If, however, an entity’s asset values fall below the value of debt, the creditors exercise the put option. The guarantor has to buy the entities’ assets at the exercise price.

The Black-Scholes’ theory to price options (Black, Scholes, 1973) can be applied to price the guarantee as a put option. To price the put option, the volatility of assets and growth rate of assets are important inputs. Given that Eskom is fully government owned, no market prices for its equity[20] can be observed, and there is no forward-looking measure of its volatility. Hence NTSA considered a modification. Historical book values were used to estimate the firm’s volatility and the exercise price for a put option.[21]

NTSA considered employing such a modified Merton model to complement credit rating and scenario analysis. NTSA, however, decided against using this model. NTSA assessed the marginal insights gained not to justify the cost of maintaining an additional model. Also, NTSA perceived weaknesses in the methodology, including the reliance on historical volatility of book values. Such reliance would not consider business cycles and structural changes. NTSA’s analytical process is described here for the benefit of a reader considering such an approach for credit risk assessment in their country.

[18] Numbers have been changed and do not reflect the actual situation.

[19] A put option gives the owner the right, but not the obligation, to sell an asset for a pre-specified price (the exercise price) on or before a certain maturity date.

[20] Equity prices may be used as proxies for asset values in the Merton model.

[21] For example, an assumption was made for the value of the debt service coverage ratio at which Eskom would be unable to service debt and hence experience credit distress.

iv) Summary of credit risk assessment methodologies and their use by the NTSA

All three credit risk assessment methodologies discussed in this paper exhibit strengths and weaknesses. NTSA primarily relies on credit rating, uses scenario analysis as a complementary tool, and discontinued using a modified Merton approach.

Credit rating is flexible and intuitive. Scores can be translated into probabilities of distress (PDs)[22] using PD tables (Chapter 2.c.) and credit scores incorporate qualitative information. However, they are mostly based on information from financial statements. Also, using credit ratings and PDs offers limited information on the short-term impact of credit events on the fiscus.[23] The use of corporate plans as part of the analysis enables a forward-looking approach to be incorporated into the assessment. In South Africa, credit rating is used to assess Eskom's ability to service guaranteed debt (see risk management tools chapter below). When rating Eskom, NTSA undertakes a stand-alone rating, not factoring in potential implicit government support. Rating agencies, however, sometimes notch entities' ratings upward if they perceive strong government support.

Scenario analysis allows to estimate the potential impact on the fiscus for a relatively short time period,[24] and is used forward looking, incorporating corporate plans. On the other hand, results from scenario analysis cannot be easily translated into PDs[25] and the models require more time and capacity to develop and maintain.

A modified Merton model can capture an intuitive and well-known theoretical concept and it is easy to apply. However, the results may be questioned in the absence of trading in Eskom's stock and the reliance on infrequent book values.

c) Risk quantification

Historically, NTSA performed limited risk quantification. Credit ratings allow for a ranking of SOCs assessed (i.e. an SOC rated 8 is less creditworthy than an SOC rated 7). However, the Credit Risk Directorate at NTSA is in a process to improve risk quantification using insights from risk assessment as described above. Improved risk quantification will improve reporting and help in the design of risk management tools currently under discussion (such as risk-based guarantee fees, the provisioning for financial losses in the budget, and proactively dealing with elevated risks).

Initially, NTSA started converting internal risk ratings into probabilities of distress. As NTSA does not have an internal data base of historic credit events for SOCs it is exposed to, it relies on third-party information. First, NTSA assigns an internal credit rating on a scale from one to nine (described in Chapter 2.b.). Second, the internal credit score is translated into a credit rating on rating scales used by rating agencies. An internal conversion table is used (Table 5). The proper conversion of risk ratings from an internal to an external scale is a key factor in this process and it is dependent on the experience of credit analysts and a robust rating methodology.

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[22] This paper uses probability of distress instead of probability of default. In the case of SOCs, outright default events rarely occur due to government intervention. From the perspective of the South African government managing its exposure to SOCs, financial distress which may lead to government intervention is the relevant credit event, not default.

[23] Credit rating is used to derive probabilities of distress. They focus on the likelihood rather than the severity of a credit event. Also, probabilities of distress may only be expected to converge towards observed distress frequencies in sufficiently large and well diversified portfolios, or over the long term. In the short term (e.g. the budget period), observed default frequencies may be significantly different from estimated PDs due to the small number of beneficiaries in the guarantee portfolio of NTSA and the potential correlation among them.

[24] In South Africa, budget projections are conducted for a three-year period.

[25] Unless stochastic modeling was used and probability distributions and correlations among scenario parameters were estimated.

For example, an internal credit score of five translates to a credit rating of Ba2 on Moody's rating scale. Third, PDs are inferred from Moody's published default frequencies by rating and time horizon (Moody's Investor Service, 2018).[26] Moody's default frequencies are adjusted as the definition of credit event at NTSA differs from Moody's.[27] Table 6 illustrates probabilities of initial distress by rating and time horizon adapted to the South African context (i.e. probabilities of Eskom being in distress in a given year for the first time, and not having experienced distress in any previous year). In addition to PDs based on the historic and expected performance of Eskom, NTSA will also use results from stressed scenarios (discussed in Chapter 2.b.) to infer stressed PDs.

Table 5: Table matching internal credit ratings and Moody's ratings

Internal risk ratings	Moody's ratings	Rating definitions
1	Aaa	Highest credit quality with the smallest degree of risk
2	Aa2	High credit quality and are subject to low credit risk
3	A2	Upper-medium grade and are subject to moderate credit risk
4	Baa2	Medium grade and are subject to moderate credit risk
5	Ba2	Obligations have questionable credit quality
6	B2	Obligations are speculative and subject to high credit risk
7	Caa2	Obligations are of poor standing and subject to very high credit risk
8	Ca	Obligations are highly speculative and are usually in default on their obligations
9	C	Obligations are lowest rated class and are in default

Source: National Treasury of South Africa

NTSA is currently working on estimating the economic value of guarantees; at the moment, the annual expected losses are calculated for a three-year period.

Annual expected losses are the product of exposures, PDs, and loss given default (LGD). NTSA is using annual debt service payments to represent exposure,[28] and annual PDs derived from PD tables (such as Table 6). LGDs depend on the ability of the government to recover payments made under a guarantee from the guarantee beneficiary, and an entity's ability to cover at least part of its debt service payments when they occur. At the moment, LGD is assumed at 100 percent.

[26] The time horizon chosen will depend on the objective. It may be the entire maturity of the loan or bond guaranteed or a shorter period for fiscal planning.

[27] In Moody's default frequency tables, an entity defaulting in year one is no longer represented in the sample of entities in year two (i.e. it can only default once). However, in the context of South Africa, entities may experience a credit event in year one (and the government steps in to make a periodic debt service payment) and may or may not experience a credit event in year two (see Chapter 2.a. for a discussion of the definition of a credit event).

[28] Consistent with its definition of a credit event.

Table 6: Probabilities of initial distress by rating and time horizon in South Africa

	Moody's rating	Internal rating	Year 1 (%)	Year 2 (%)	Year 3 (%)	Year 4 (%)	Year 5 (%)	Year 6 (%)	Year 7 (%)	Year 8 (%)	Year 9 (%)	Year 1 (%)
Investment Grade	Aaa	1	0.003	0.006	0.012	0.023	0.039	0.057	0.076	0.093	0.103	0.1
	Aa2	2	0.022	0.047	0.073	0.108	0.136	0.150	0.150	0.141	0.129	0.1
	A2	3	0.062	0.151	0.183	0.255	0.314	0.351	0.365	0.360	0.347	0.3
	Baa2	4	0.174	0.352	0.350	0.444	0.511	0.549	0.563	0.563	0.563	0.5
Sub-investment grade	Ba2	5	1.110	2.111	1.954	2.294	2.418	2.342	2.136	1.890	1.676	1.5
	B2	6	3.904	5.729	4.471	4.884	4.874	4.509	3.930	3.289	2.705	2.2
	Caa2	7	15.894	11.760	7.339	7.021	6.300	5.349	4.341	3.411	2.643	2.0
	Ca	8	54.147	10.977	5.315	4.427	3.569	2.793	2.133	1.603	1.202	0.9
	C	9	100.000	-	-	-	-	-	-	-	-	-

Source: National Treasury of South Africa, Risk Integrated, Moody's

Going forward, NTSA intends to calculate the present value of expected losses for the lifetime of a guarantee. To do so, annual expected losses need to be discounted to the present and summed up. To use a simple example, imagine a guarantee on a one-year loan, with a face of value 100 and no interest payments. Assume the likelihood of the entity not being able to repay, or PD, at 15 percent. Further assume that if the entity were unable to repay the loan, it would have cash of 30 (LGD) to service at least part of the loan. In this case expected loss = 100 x 15 percent x 70 percent = 1.05. At a discount rate of 10 percent, the present value of expected loss would be 1.05/1.1 = 0.95. Table 7 provides an illustrative example over a multi-year period.

Table 7: Illustrative example of expected loss from a guarantee

Year	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Credit rating	6	6	6	6	6	6	6	6	6
Annual PD	1.11%	2.81%	3.63%	4.50%	5.19%	5.59%	5.67%	5.49%	5.15%
LGD	50%	50%	50%	50%	50%	50%	50%	50%	50%
Principal outstanding end of year	100	100	100	100	100	100	100	100	100
Principal payment	0	0	0	0	0	0	0	0	0
Interest payment	5	5	5	5	5	5	5	5	5
Annual expected loss	0.03	0.07	0.09	0.11	0.13	0.14	0.14	0.14	0.13
Discount rate	5.0%	5.5%	6.0%	6.5%	7.0%	7.5%	8.0%	8.5%	9.0%
NPV of annual EL	0.03	0.06	0.08	0.09	0.09	0.09	0.08	0.07	0.06
NPV of EL	1.66								

Source: Risk Integrated, authors

Note that expected loss may underestimate the value of a guarantee. The value of a guarantee may not only reflect the losses in expectation but also a risk premium due to the riskiness of losses. Risk averse market participants would require to be compensated for taking the risk of significantly larger than expected losses.

Importantly, the quantification of credit risk of Eskom beyond assigning credit ratings is work in progress and has not been finalized. NTSA has finalized the conversion of credit risk to PDs and is also considering estimating expected losses based on output from credit rating, as well as scenario losses as an output of scenario analysis. Measures such as expected loss and scenario losses can inform risk management tools discussed in the subsequent section, including risk-based fees, contingency reserves, and medium-term budgeting.

d) Set of risk management tools

South Africa could employ a combination of tools to manage the risks arising from the guarantee portfolio. These tools can be classified as risk mitigation and monitoring tools. Risk mitigation tools aim to limit the credit risk exposure *ex ante*, that is at the guarantee issuance stage through limits, and risk transfer mechanisms of the guarantee as well as during the lifetime of the guarantee through fees. Budget provisions and reserve accounts reduce the impact of the risk materialization on the budget so that the government does not have to borrow unexpectedly. Accounting for contingent liabilities from guarantees in the budget also improves decision making. Risk monitoring tools consist of financial tables recognizing the contingent liabilities and monitoring the risk exposure through internal or public reports. The use of risk management tools requires some form of assessment (qualitative and/or quantitative) of the creditworthiness of the beneficiary and the credit risk exposure in order to anticipate worsening credit risk situation.

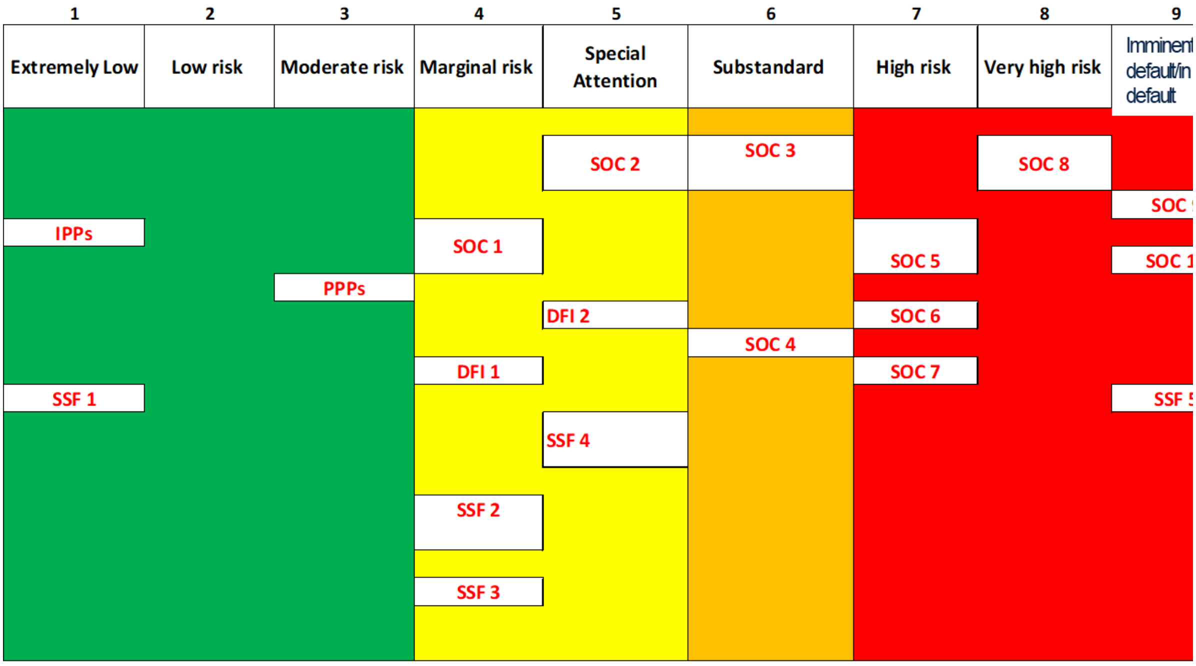
i) Fiscal Liabilities Committee

NTSA discusses South Africa's contingent liabilities portfolio at the Fiscal Liabilities Committee (FLC) that meets every quarter. FLC is composed of representatives from ALM Division (Credit Risk team, Governance and Financial Analysis, Sectoral Oversight), Budget Division, Public Finance Division, Intergovernmental Relations Division, Legal Services, and Economic Policy. The objective of the Committee is to promote sound management of the government's contingent liabilities. The decisions of the Committee are recommendations made to the Minister of Finance who ultimately is the one with the legal powers to either approve or reject them. The Committee's responsibilities center on two areas: development and adoption of tools to manage credit risk, and policy and operational decisions for the actual implementation of those tools. Thus, FLC is responsible for the determination of policies and processes for approving guarantees and guarantee-like transactions. The FLC uses credit risk mitigation tools including the adoption of credit risk fees and the determination of a limit for the amount of total government debt and explicit contingent liabilities. One of the committee's mandates is to explore how and whether to establish a contingency reserve account, funded or unfunded.[29] FLC is the instrument through which NTSA undertakes the general oversight of explicit and implicit contingent liabilities. Operational tasks of the FLC involve setting the conditions under which guarantees will be issued, engaging in appropriate actions in the case of defaults, and ensuring the implementation of the decisions by the Minister of Finance. The FLC would therefore also monitor adherence to these conditions and recommend appropriate action to the Minister in the case of non-adherence.

The output obtained from the credit risk analysis and quantification explained in previous sections serves as the basis for the advice the Credit Risk Directorate provides to the FLC on the state of contingent liabilities from guarantees (see Table 8 for an illustrative example) and alerts the committee to any improvement or deterioration on the quality of risk exposure from the overall guarantee portfolio. The Committee has deliberated on the risk-based fee policy, which was submitted to the Minister for approval. The Minister has approved the policy although it is yet to be implemented. Currently NTSA does not have a guarantee limit and the FLC is yet to make a decision on the matter.

[29] Funded would be where actual appropriations are made and transferred to an account, which is ring-fenced where unfunded, would be where the possible funding of credit events is incorporated into the existing contingency reserve that is a line item in the budget. The contingency reserve is only used in the case of emergency.

Table 8: Illustrative example of credit scoring results for the guarantee beneficiaries



IPPs: Independent Power Producers, SSF: Social Security Fund, PPP: Public-Private Partnerships, SOC: State-Owned Company, DFI: Development Finance Institution

Source: NTSA

ii) Monitoring and reporting

The Credit Risk Directorate presents information on individual ratings for the guarantee beneficiaries and also on a consolidated basis to determine the quality of government's portfolio of contingent liabilities. It also feeds into various internal and external reports NTSA regularly prepares. Reports targeted at external audiences (e.g. the Parliament, the public, the South Africa Reserve Bank, international financial institutions, investors, Office of the Accountant General) consist of NTSA's Annual report, Debt Management Report, quarterly contingent liability report and Budget review. They contain consolidated guaranteed debt stock numbers, annual financial statements, total guarantees issued, and amounts drawn during the previous period. The 2016 Budget Review included for the first time two new categories of obligations: public-private partnerships (PPPs) and PPAs. These published reports contribute significantly to NTSA's accountability and transparency. It is worth noting that due to possible negative impact on the entity, Eskom's risk rating and other individual risk ratings are internal and not publicly available.

The internal reports NTSA prepares target audiences such as the Minister of Finance, the Director General of NTSA, and senior management. These contain more detailed, sensitive information such as the findings of the credit risk analysis per institution, the credit risk rating matrix of guarantee beneficiaries based on their riskiness, the evolution of the credit risk exposure consolidated on a portfolio basis and actions envisaged for mitigating these risks.

As indicated previously, in 2017 the Credit Risk Directorate drafted a paper titled "Credit Risk Assessment Methodology: Electricity Sector" which shared its scorecard methodology within the NTSA (all units within the ALM Division and members of the FLC). This initiative contributes to institutional memory by capturing the credit risk team's thinking and describing in detail the selected methodology. It also helps build credibility in NTSA's credit risk management expertise by increased transparency and accountability. The methodology paper provides a basis from which the team can improve and introduce more advanced methodologies if necessary.

iii) New risk management tools under consideration

The Credit Risk Directorate aims to adopt risk management tools that would take into account the output of the credit risk assessment. These consist of making recommendations that may influence FLC decisions such as i) initiating and influencing discussion on risk appetite combined with guarantee limit, ii) making recommendations with respect to a contingency reserve account, iii) determining a risk-based guarantee fee policy and fee, and v) improving reports to FLC by adding more quantitative information on the performance on the guarantee portfolio and by individual company.

Guarantee fees

South Africa employs guarantee fees to compensate the government for the credit risk that it undertakes, to reduce moral hazard from the guarantee beneficiaries. Currently, the fees received by government form part of the overall departmental revenue and is not ring-fenced to fund credit risk materialization. NTSA is planning to charge lower fees for good credit quality to encourage the improvement of SOC balance sheets. In 1996, NTSA issued guidelines for the issuance of government guarantees, which are set to equal the benefits on borrowing cost margin of public entities borrowing without a guarantee. In practice, NTSA had introduced both an annual fee to new guarantees to recover the administrative costs and a commercial levy that was initially 0.5 percent and gradually increased to 3 percent by 2003. This fee would be applied yearly based on the disbursed guarantee amount. NTSA had the discretion of reducing or waiving the fee. In 2005, this structure was revised to charge a fixed annual guarantee fee of 0.30 percent on the disbursed guarantee with an annual administration of R75,000 for guarantees of less than five years and R50,000 for guarantees of more than five years. This meant the fee would not be based on the credit quality.

The development of more advanced and improved methodologies to assess the credit risk from guarantees recently led the Credit Risk Directorate to develop a framework to apply risk-based fees on the guarantees issued to SOCs. Consequently, in 2018, NTSA has adopted a new guarantee fee policy, with the intention to charge guarantee beneficiaries a risk-based fee, to be determined by the credit quality of the SOC. This new policy, which is yet to be implemented, envisions that the annual fee to be charged will depend on the entity's internal credit risk rating, the remaining maturity of the SOC's guarantee, and the outstanding amount of the guarantee. Additionally, the fee policy includes provisions to share the risk with the line ministry responsible for the SOC in cases where the beneficiary does not comply with the guarantee conditions or defaults on the underlying debt instrument. The new rule dictates that a fee waiver would be possible only when the SOC's financial outlook deteriorates due to a change in government policy. Additionally, a late fee payment penalty may be introduced.

The new guarantee fee policy refers to the possible establishment of a contingency reserve account as a buffer, fed mainly by the guarantee fees.

Additional tools being discussed

The team also intends to report credit related information on a portfolio basis (e.g. in addition to reporting on the volume and quality of exposure in the budget review, also share the weighted probability of credit event, amount of payment from the fiscus given credit event and maximum probable payments). And the team also intends to recommend actions for worsening credits to other stakeholders, including recommendations of actions or focus areas for the involved entity to improve the quality of the credit risk exposure.

Measures discussed in Chapter 2.c. (credit scores, PDs, scenario analysis, economic value of guarantees) can be used to inform the respective credit risk management tools. Indeed, once the work on the scenario analysis is finalized, NTSA will have developed the technical capacity and expertise to provide sound quantitative input to expand its toolkit and improve reporting. On the other hand, the adoption of some of the measures under discussion might prove to be difficult due to the need to incorporate qualitative factors into the guarantee decisions.

3. Conclusions

It is essential for a government to understand and monitor the contingent liabilities from its guaranteed debt portfolio in order to actively manage and monitor these risks, take precautions against increasing risks and provision for any possible materialization of risks.

The South African experience is a good illustration on how a government might develop methodologies to evaluate its exposure to credit risk from sovereign guarantees and enrich its risk management toolkit.

The methodologies discussed in this note and explored by the South African government consist of defining the risk exposure from guarantees issued to Eskom, identifying the key risk drivers, and undertaking risk analysis through three different approaches, namely credit rating, scenario analysis, and the Modified Merton model.

The note also illustrates how a strong risk assessment platform can help refine the risk management tools employed by a government and strengthen its risk monitoring practices.

South African experience shows that assessing and managing contingent liabilities is an iterative process and requires a tailor-made approach.

Abbreviations

ALM	Asset and Liability Management
FLC	Fiscal Liabilities Committee
GTAC	Government Technical Advisory Centre
IPP	Independent power producer
NERSA	National Energy Regulator of South Africa
NTSA	National Treasury of South Africa
PD	Probability of distress
PPA	Power purchase agreement
PPP	Public-private partnership
SOC	State-owned companies

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Linking Policy to Outcomes: a Simple Framework for Debt Maturity Management[1]

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Abstract

We characterize the long-run stable maturity distribution induced by a fixed issuance policy, defined as the maturity mix of new issues, thereby providing a method to link issuance policies with their long-run consequences. We derive closed-form expressions for a new class of forward-looking stable metrics, including per-period refinancing need, debt service cost, and average maturity—an indicator of the supply of long-term bonds. We use these metrics to provide a normative analysis of the classical debt-management tradeoff between refinancing risk and debt service cost. Our results indicate that the US Treasury could move closer to the "efficient frontier" by tilting its issuance towards notes.

JEL Classification: E62, G32, H63

Keywords: debt management, debt maturity, refinancing risk, government debt

1. Introduction

Total sovereign debt held by the public exceeds $56 trillion, $16 trillion of which has been issued by the US alone. Interest on this debt is an important fraction of public expenditure for many countries, and the corresponding securities are the cornerstone of global financial markets. It is surprising, therefore, that relatively little attention has been devoted to the decisions that determine the maturity structure of this debt. Government debt managers view the choice between short-term and long-term bonds mainly as navigating the "classical" tradeoff between cost and refinancing risk.[5] Although a substantial normative literature in finance and economics has proposed several additional

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[5] The Committee on the Global Financial System (2011) states "The general ... objective is to minimise the expected risk-adjusted cost of funding over the medium to long term." Similar statements are found in publication by the International Monetary Fund (2014), the Organization for Economic Cooperation and Development (Blommestein, 2005), and national debt managers (Her Majesty's Treasury, 2016; Dipartimento del Tesoro, 2017; Office of Debt Management, 2017).

goals for debt management policy,[6] little has been written about the managers' actual stated goals, and whether their actions are optimal given these goals.

In this paper, we take an initial step towards bridging this gap. We propose a simple, deterministic framework to link policy, defined as the maturity distribution of new issues, with outcomes, based on the long-run maturity distribution of outstanding issues that prevails if the policy is held indefinitely. Although the ultimate goal is a model that can aid in the formation of optimal dynamic policies in a stochastic environment, even the simplest static tradeoff is not well-understood.[7] Within our framework, we characterize the "efficient frontier" of issuance policies that strike the optimal tradeoff between cost and refinancing risk. We find that concentrated issuance at intermediate maturities is usually efficient. As is the case for other efficient frontier results, this insight arises from the mathematical structure of the problem, and therefore we expect some version of it to emerge in more detailed models. Our discussions with debt management practitioners confirm this conjecture: many numerical optimization models featuring stochastic economies (e.g. Belton et al., 2018) tend to prescribe concentrated issuance policies. However, our discussions also show that the intuition behind this result and the conditions under which it obtains are not widely understood.[8]

Another benefit of our approach is that it provides simple metrics grounded in theory that are likely to be useful in measuring and discussing debt maturity management. Right now, public debate is focused on the weighted average maturity (WAM) of outstanding issues and similar measures.[9] Our approach makes it clear that the WAM is not the best indicator of either cost or refinancing risk. The WAM is useful as an indicator of long-term bond supply—the main driver of fiscal insurance and other costs and benefits in the above-mentioned normative literature, but also a central determinant of bond prices (Krishnamurthy and Vissing-Jorgensen, 2012; Greenwood and Vayanos, 2014) and an important variable for macroeconomic policy and monetary transmission.[10]

By mapping an issuance policy into a long-run WAM, our framework can also capture the distinct, "nonconventional" tradeoff between refinancing risk and long-term bond supply. In general, our

[6] This literature has argued that government has a comparative advantage in the issuance of either short-term bonds (e.g., Missale and Blanchard, 1994; Greenwood et al., 2015) or long-term bonds (e.g., Holmström and Tirole, 1998; Angeletos, 2002; Barro, 2003; DeBortoli et al., 2017). In this study we abstract from these well-known effects to focus on our contribution.

[7] Like us, Faraglia et al. (2018) study the optimal maturity structure of new issues in the presence of refinancing risk and in the absence of buybacks. However, they optimize a very simplified maturity structure with two bonds—"short" and "long". We overcome this limitation (at the cost of many other simplifications) by using a very different methodology that lets us optimize a realistic maturity structure. A similar methodology is used by Bigio et al. (2018), but they do not focus on ongoing refinancing risk. Prior work (see fn. 6) blurs the distinction between new and outstanding issues by assuming (implicitly or explicitly) that the government can frictionlessly achieve whatever maturity structure it desires at every date.

[8] A notable exception is the Dutch State Treasury Agency's (DSTA) 2007 "Risk Management of the National Debt" report, which provides an informal argument for why "centralised" portfolios are "on the frontier." Based on this understanding, since then the DSTA has been using a concentrated issuance portfolio as the benchmark to measure its debt managers' performance. We thank Emile Spijkerman for bringing this to our attention.

[9] The WAM is defined as the weighted average remaining maturity of outstanding bonds where the weights are the par amounts. Academic studies rely on the WAM (Beetsma et al., 2017; Chadha et al., 2017; Ellison and Scott, 2017) or on similar and sometimes duration-weighted metrics such as average duration (Greenwood and Vayanos, 2014), amount of ten-year equivalents (Greenwood et al., 2014), and the fraction of long-term bonds (Krishnamurthy and Vissing-Jorgensen, 2012). Average maturity is regularly monitored and reported on by the US Treasury (Quarterly Refunding Documents) and other debt management offices (Blommestein, 2005). Prominent media mentions of average maturity include Gillian Tett, "Reasons to be cheerful about UK gilts," Financial Times, 3/4/2010, available at https://www.ft.com/content/88fb41f6-27c7-11df-863d-00144feabdc0.

[10] Long-term bond supply is the target of quantitative easing (Krishnamurthy and Vissing-Jorgensen, 2011). Relative supply also affects the amount of interest rate risk a government bond dealer has to take on per dollar of inventory—a salient consideration given the recent money market turmoil. While central bank policy interventions are carried out at a higher frequency via discretionary open market operations, our framework provides an easy way for a government debt issuer to assess the effect of its issuance policy on this variable in the long run.

approach provides a method to quantify the refinancing risk inherent in a candidate issuance policy, however conceived, and thus to examine the tradeoff between the fiscal authority's primary goal—ensuring uninterrupted financing of government—and any other macroeconomic or social welfare goals of that candidate policy.

These benefits come at the cost of some simplification, and the intuition we provide should be seen as a complement to other approaches currently being explored, such as general equilibrium analysis (e.g., Faraglia et al., 2018), numerical optimization (e.g., Glasserman et al., 2017; Athanasopoulou et al., 2018), and simulation (e.g., Belton et al., 2018). Nonetheless, we argue our three main simplifying assumptions described below are reasonable, and a policy that we characterize as optimal in our framework could be viewed as a long-run strategic benchmark.

First, our choice of studying refinancing risk in a deterministic framework may appear counterintuitive. However, refinancing risk depends primarily on two factors: the frequency of refinancing, and the volatility of borrowing conditions. While both factors can be affected by debt management policy, the former is largely driven by it, whereas the effect of policy on the latter is dominated by macroeconomic news and fiscal decisions outside the control of the debt manager. For this reason, we focus on the first factor alone in order to provide the cleanest insight possible.

Second, the assumption that policies are sustained indefinitely may appear unrealistic or suboptimal, but it is justified on both theoretical and empirical grounds. Because new issues affect the outstanding distribution only gradually, any policy should be sustained in order to achieve the desired outcomes. Moreover, for countries that follow a “regular and predictable” issuance policy (such as the US), the maturity mix of new issues is in practice very persistent.

Third, we focus on issuance as the primary driver of the outstanding maturity distribution. Although some countries make substantial use of repurchases in their debt management policy, the cost of repurchases and subsequent issuance remains a constraint (see, e.g., Faraglia et al., 2018). For the US, focusing on issuance alone is an especially good approximation. With nearly $16 trillion of outstanding debt held by the public, the roughly $4.6 trillion per year of new issues is by far the primary driver of the outstanding maturity distribution. The absence of buybacks induces “demographic inertia” in the outstanding maturity distribution, which enables us to use a technique analogous to population projections (Keyfitz and Caswell, 2005).

In Section 1, we introduce our notation and derive the long-run stable maturity distribution to which outstanding debt converges if the maturity mix of new issues is maintained indefinitely. A tractable, closed-form expression for the long-run stable maturity distribution has multiple benefits. First, it acts as a compass by showing the direction in which the outstanding distribution will eventually move if the issuer stays the current course—something that could otherwise only be revealed by simulation. The compass may help several actors: an issuer, to quickly evaluate a proposed change to its baseline maturity mix; an observer, to gauge the likely impact of anticipated changes to the prevailing issuance pattern; and an asset-pricing econometrician, to identify news about government bond supply.[11]

Second, a closed-form expression enables us to introduce a new class of forward-looking “stable” metrics that directly link issuance policy to long-term outcomes. We derive explicit expressions for the stable one-period share, i.e., the recurring per-period refinancing need and our indicator of

[11] Observable changes in the maturity distribution of outstanding debt and “news” can go in opposite directions; a policy change intended to decrease average maturity in the long run may cause it to increase in the short run, and vice versa. Most short-run changes in the outstanding distribution are not news: they are largely predetermined and leave supply expectations unchanged. Persistent changes in issuance policy are news: they imply a shift from one long-run distribution to another, and a corresponding shift in expectations.

refinancing risk;[12] the stable debt service cost; and the stable WAM, an indicator of long-term bond supply. These expressions show that, unsurprisingly, issuing longer-term bonds (a higher average maturity) results in a lower refinancing risk and a greater supply of long-term bonds. More surprisingly, issuing a more dispersed mix of maturities (a higher variance) also yields a greater supply of long-term bonds, but not a lower refinancing risk. The basic intuition behind this result is that refinancing risk depends on the average maturity of new issues, while the supply of long-term bonds is related to the average maturity of outstanding bonds. Because long-term bonds remain outstanding longer, the longer a bond's maturity, the larger the effect of sustained issuance on outstanding supply. For instance, a policy of issuing 15-year bonds only (mix A) entails essentially the same refinancing risk as a 50/50 mix of 1-month bills and 30-year bonds (mix B), but A results in a much lower supply of long-term bonds.

In Section 2 we take the perspective of an issuer facing an exogenous, upward-sloping long-run average yield curve. We characterize the "efficient frontier" of issuance policies that minimize stable debt service cost for a given level of refinancing risk (as measured by the stable one-period share). Our results suggest that the US Treasury could move closer to the frontier, i.e., reduce debt service cost without increasing refinancing risk, by issuing more medium-term notes and fewer bills and long-term bonds. This result should not be surprising because stable debt service cost is related to the stable supply of long-term bonds. Since concentrated issuance minimizes the supply of long-term bonds, it also minimizes cost, as long as the yield curve is not too concave. If the yield curve is sufficiently concave, the savings from issuing short-term bonds more than compensate for the increased stable supply of long-term bonds, and a "barbell" issuance policy becomes optimal. In practice, however, we show that the average yield curve over 1980–2018 was not sufficiently concave.

We also show that concentrated issuance is efficient even in the presence of a substantial liquidity penalty. This is an important robustness check because, for a large issuer, the assumption that the yield curve is exogenous is a strong one; in reality, a different issuance pattern may result in a different yield curve. While we do not directly model an equilibrium yield curve based on supply and demand, this result reduces potential concerns that an increase in the supply of intermediate maturities might increase their cost and thereby negate the benefits from issuing them.

Finally, Section 3 examines convergence. If the outstanding distribution does not converge to a stable distribution, our closed-form expressions are not applicable. When debt grows at a positive rate, convergence is guaranteed under some regularity conditions. When debt is constant, we show that a necessary and sufficient condition for convergence is the issuance of bonds with mutually prime maturities. Regardless of growth rate, we also show using numerical examples that the more prime factors in the maturities of new issues, the faster the convergence to a stable distribution (and therefore to a stable per-period refinancing need, a desirable outcome for an issuer). This result provides both a practical guideline for issuers and a possible explanation for the otherwise unexplained fact that 2-, 3-, 5-, and 7-year bonds are much more common than 4-, 6-, 8-, and 9-year bonds. Section 4 concludes.

[12] Debt managers usually define "refinancing risk" as the volatility of either funding cost or deficit (usually as a percentage of gross domestic product), Cost-at-Risk (CaR) and similar measures based on tail realizations, or, in extreme circumstances, as the probability of not being able to roll over. These definitions cannot be applied in our simple deterministic framework. However, it is easy to show by simulating a stochastic economy that the one-period share is highly correlated with all of these metrics. For instance, the 2017Q4 presentation of the Treasury Borrowing Advisory Committee to the US Treasury shows simulation evidence that the one-period share has a 98% correlation with the volatility of funding cost (p. 96, retrieved on 3/16/2019 at https://www.treasury.gov/resource-center/data-chart-center/quarterly-refunding/Documents/Q42017CombinedChargesforArchives.pdf).

2. A simple model of maturity structure dynamics

We represent the issuer's debt maturity structure as B_t, a vector with M elements whose m-th element $B_{t,m}$ represents the amount of debt outstanding at date t and due at date $t+m$.[13] One time period (the time elapsed between dates t and $t+1$) could be a year, a month, or any other discrete time interval.[14] Total debt $\bar{B}_t \equiv \sum_m B_{t,m}$ grows at a rate r due to exogenous financing needs (fiscal deficits, or more in general negative free cash flows).

Assumption 1 (exogenous debt growth rate):

$$\bar{B}_t = (1+r)\bar{B}_{t-1} \tag{1}$$

Thus, in our setup, debt growth is independent of coupon payments. Although, in principle, choosing a more expensive maturity mix could result in a higher debt growth rate, in practice r is largely out of the hands of the debt manager. Not explicitly modeling this feedback mechanism considerably simplifies the setup and allows for additional insight.

In addition, at each date t, an amount $B_{t-1,1}$ must be issued to refinance the maturing issues, resulting in the following incremental financing need:

$$\text{Financing Need}_t = \underbrace{B_{t-1.1}}_{Refinance\ maturing\ issues} + \underbrace{r\overline{B}_{t-1}}_{Finance\ debt\ growth} \tag{2}$$

Thus, at date t, the stock of outstanding debt of maturity m is given by the stock of debt of maturity $m+1$ from date $t-1$ plus the new issues of maturity m:

$$B_{t,m} = \begin{cases} B_{t-1,m+1} + N_m\,(B_{t-1,1} + r\overline{B}_{t-1}) & m \in \{1,2,\dots M-1\} \\ N_m\,(B_{t-1,1} + r\overline{B}_{t-1}) & m = M, \end{cases} . \tag{3}$$

where M is the longest maturity actually issued by the issuer, and N_m is the fraction of new issues with maturity m ($\sum_m N_m = 1$). We assume this fraction to be time-invariant.

Assumption 2 (fixed issuance policy):

$$N_{t,m} = N_m \; for\ all\ t, m. \tag{4}$$

A fixed issuance policy can be understood as a baseline policy from which an issuer could enact temporary deviations, either by following an optimal dynamic strategy, or "opportunistically" to exploit temporary market imperfections. However, it could also be understood simply as a policy of

[13] For the sake of exposition, we focus on what we think is the most important application of our notation: the maturity structure of an issuer's outstanding debt. Although our focus is on sovereign issuers, the notation can be applied to any issuer regular enough to have a policy. (Indeed, the same notation can even represent the dynamics of a rolling long portfolio of bonds held as investments under a constant purchase policy). Our notation can be applied to the entirety of the debt, or to subsets of it. For instance, if an issuer has two separate policies for bills (less than one-year maturity) and longer-term obligations (one-year maturity or more), our notation could describe either policy. The notation could also be expanded (at the cost of additional complexity) to analyze duration instead of simple maturity.

[14] At least for what concerns the results presented in this paper, the continuous-time model can be obtained simply as the limit of the discrete model as the time interval goes to zero. We choose to present our results in a discrete-time framework for simplicity and because, in practice, the issuer issues a finite amount of bonds at a finite number of maturities, and not an infinitesimal amount of bonds at infinite maturities.

"regular and predictable" issuance such as the one followed by the U.S. Treasury since 1975 (Garbade, 2007).[15]

Expression (3) can be more succinctly written in matrix form:

$$B_t = \mathcal{A} \cdot B_{t-1}, \tag{5}$$

where $\mathcal{A}$ is the $M \times M$ transition matrix

$$\mathcal{A} \equiv \begin{pmatrix} N_1(1+r) & 1+rN_1 & rN_1 & \dots & rN_1 \\ N_2(1+r) & rN_2 & 1+rN_2 & \dots & rN_2 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ N_{M-1}(1+r) & rN_{M-1} & rN_{M-1} & \dots & 1+rN_{M-1} \\ N_M(1+r) & rN_M & rN_M & \dots & rN_M \end{pmatrix} \tag{6}$$

Note that, in the special case $r = 0$, $\mathcal{A}$ simplifies to

$$\begin{pmatrix} N_1 & 1 & 0 & \dots & 0 \\ N_2 & 0 & 1 & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ N_{M-1} & 0 & 0 & \dots & 1 \\ N_M & 0 & 0 & \dots & 0 \end{pmatrix} \tag{7}$$

In this matrix, the N_m elements in the first column represent the new issuance process, and the diagonal of ones represents the "aging" process: bonds of maturity m become bonds of maturity $m - 1$, etc.

Finally, for notational convenience, we define the weighted average maturity (WAM) of a generic maturity distribution.

> **Definition 1 (weighted average maturity):** Let v be a vector representing a maturity structure, so that the m-th element represent the amount or the fraction of bonds with maturity m. Then, the weighted average maturity of v is
>
> $$\mu_v \equiv \sum_m m \frac{v_m}{\sum_m v_m}. \tag{8}$$

2.1 Long-run dynamics

The behavior of a maturity distribution may be counterintuitive because of the inertia of the outstanding bond portfolio. As an example, consider a constant-debt scenario with only three maturities ($m \in \{1,2,3\}$). The outstanding vector is $B_t = \{0.625, 0.250, 0.125\}$ and the issuance vector is $N = \{0.600, 0.250, 0.150\}$. In this example, the WAM of new issues ($\mu_N = 1.55$) is higher than the WAM of the outstanding ones $(\mu_{B,t} = 1.5)$, and therefore intuition may suggest that the outstanding maturity is bound to rise. However, outstanding WAM drops to 1.469 after just one period, and in the long run it converges to 1.452, lower than both the original outstanding vector and the

[15] In practice, modern US Treasury issuance practice has historically been stated and managed in terms of the auction sizes (in nominal dollar terms) of its regular notes and bonds. Because of Treasury's philosophy of "regular and predictable" issuance, the resulting issuance process has often been characterized by periods during which nominal sizes (and not issuance fractions) of individual maturities have remained steady. Nonetheless, the steady-distribution assumption is a reasonable approximation to the actual process over long periods.

issuance vector. This is the stable maturity structure, akin to the stable population structure of demographic models.[16]

In practice, it is not guaranteed that such a stable maturity structure exists, and if it does, it is unlikely that it will ever be reached. Fiscal deficits and interest rates fluctuate, and are possibly correlated and subject to secular trends; issuance strategies change. Nonetheless, we study the stable maturity structure because it represents the long-run consequences of the policy that induces it, and therefore reveals the policy's nature.

Definition 2 and Proposition 1 formalize our intuition about the stable maturity structure.[17]

> **Definition 2 (stable maturity structure):** A stable maturity structure x is a vector of outstanding debt such that, given a constant issuance policy N, its proportions remain constant:

$$x_{t+1} = \mathcal{A} \cdot x_t = (1+r)x_t. \tag{9}$$

Mathematically, x is the principal eigenvector of the transition matrix $\mathcal{A}$, and $1+r$ is the associated eigenvalue. Because it is an eigenvector, x is defined only up to a multiplicative constant (i.e. any vector with the same proportions also represents a stable maturity structure). We normalize x to sum to one so that it can be interpreted as a maturity distribution.

> ***Proposition 1 (closed-form expression for the stable maturity structure):*** *there exists a stable maturity structure x of the form*

$$x \equiv \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_{M-1} \\ x_M \end{pmatrix} = \frac{r}{1-\xi_1} \begin{pmatrix} \xi_1 \\ \xi_2 \\ \vdots \\ \xi_{M-1} \\ \xi_M \end{pmatrix}, \tag{10}$$

> *where*

$$\xi_m \equiv \sum_{j=m}^{M} (1+r)^{-(j-m+1)} N_j. \tag{11}$$

> *With zero debt growth ($r = 0$),*

$$x = \frac{1}{\mu_N} \begin{pmatrix} 1 \\ N_2 + N_3 + \cdots N_M \\ \vdots \\ N_{M-1} + N_M \\ N_M \end{pmatrix}, \tag{12}$$

> *where μ_N is the WAM of new issues.*

Section 3 discusses the assumptions needed to guarantee that x is unique and that the outstanding bond distribution actually converges to x under a fixed issuance policy N. In the rest of this section we define three stable metrics derived from the stable distribution. The value of these metrics lies in

[16] Lewis (1942); Leslie (1945); Leslie (1948).

[17] Proofs to all propositions are in the online appendix (https://ssrn.com/abstract=3547079)

the fact that, unlike metrics currently used in the public debate on debt management, they are forward-looking, easy to compute, and linked to well-defined debt management goals.

2.2 Stable refinancing need

The stable refinancing need, or stable one-period share, is our chosen indicator of refinancing risk. Debt managers usually define "refinancing risk" as the volatility of either funding cost or deficit (usually as a percentage of gross domestic product), Cost-at-Risk (CaR) or other similar measures based on tail realizations (Athanasopoulou et al., 2018; Date et al., 2011; Balibek and Köksalan, 2010), or, in extreme circumstances, as the probability of not being able to roll over. These definitions cannot be applied in our simple deterministic framework. Under any of these definitions, a more relevant metric is the fraction of debt maturing within a certain time frame since, from the issuer's perspective, once debt is issued funding is secured at a known cost. The greater the fraction of debt that needs to be reissued, the greater the uncertainty about both availability and cost of funding. In practice, it is easy to show by simulating a stochastic economy that the one-period share is highly correlated with all of these metrics. For instance, the 2017Q4 presentation of the Treasury Borrowing Advisory Committee to the US Treasury (see our fn.8) shows simulation evidence that the one-period share has a 98% correlation with the volatility of funding cost.[18] Indeed, several countries' debt management offices keep track of indicators such as the 1-year share or the 5-year share, i.e., the percentage of total debt that comes due within 1 or 5 years (Blommestein, 2005). In this subsection we derive the stable one-period share (i.e., x_1). In the Online Appendix, we derive the stable m-period share for arbitrary m.

> ***Proposition 2***: *The one-period share (i.e., the fraction of bonds due to mature within one period) converges to*
>
> $$x_1 = r\frac{\xi_1}{1-\xi_1}. \tag{13}$$
>
> *With zero debt growth (r=0), the one-period share converges to*
>
> $$x_1 = \frac{1}{\mu_N}. \tag{14}$$
>
> ***Corollary***: *With zero debt growth, the WAM of outstanding debt increases $(\mu_{B,t+1} > \mu_{B,t})$ if the WAM of new issues is greater than the inverse of the fraction of debt which is due to mature in one period ($\mu_N > (b_{t,1})^{-1}$, where $b_{t,1} \equiv B_{t,1}/\overline{B_t}$ is the one-period share of the outstanding maturity structure).*

Equation (14) and the corollary help make sense of the example of Section 1.1: with zero debt growth, whether the WAM of new issues is greater or less than the outstanding WAM has no bearing on the direction in which the outstanding WAM moves. In the example, $\mu_N = 1.55$ and therefore the outstanding WAM will trend downwards until $b_{1,t+k} = 1.55^{-1} = 0.645$. Note that zero debt growth is an extreme case. At the opposite extreme ($r \to \infty$), Proposition 1 implies that $x \to N$, i.e., new

---

[18] Choi et al. (2018) propose two related measures of maturity dispersion. The first measure is the inverse of the Herfindahl index of the outstanding maturity distribution. The second measure is based on the average squared distance between a firm's actual outstanding maturity distribution and a hypothetical uniform distribution. Although these measures are designed to capture within-issuer time-series variation in maturity structure, in principle they could be computed for the steady-state maturity structure, and they too would be correlated to the one-period share. E.g., the issuance policy that achieves the minimum 1-period share (100% bonds of maturity M) would also achieve a uniform distribution, maximizing these measures.

issues dwarf outstanding issues at every period, and the outstanding distribution is approximately the same as the new issue distribution. In this case, the difference between new-issue WAM and outstanding WAM is the only driver of changes in outstanding WAM $\left(\mu_{B,t+1} > \mu_{B,t} \Leftrightarrow \mu_N > \mu_{B,t}\right)$. In the general case for finite $r > 0$, which we characterize in the Online Appendix, the impact of new issues is in between these two extremes. Realistic values of r are usually sufficiently small to yield the same qualitative intuition as the zero-growth case.

2.3 Stable debt service cost

We define the stable debt service cost as the average coupon rate paid on the entire outstanding stable maturity structure. We make several assumptions for simplicity. First, we assume the issuer issues only par coupon bonds, and throughout the paper we use the terms “yield curve” and “coupon curve” interchangeably. Second, we assume that the coupon curve is exogenous and constant in time. Although this assumption is unrealistic, it helps gain intuition on the basic static tradeoff between cost and refinancing risk.

Under these assumptions, the stable debt service cost is

$$Y_x = \begin{cases} \dfrac{\Sigma_m m N_m C(m)}{\Sigma_m m N_m} \equiv \dfrac{\Sigma_m m N_m C(m)}{\mu_N} & if\ r = 0 \\ \dfrac{\Sigma_m [1-(1+r)^{-m}] N_m C(m)}{1-\xi_1} & if\ r > 0 \end{cases} \quad (15)$$

where $C(m)$ is the coupon curve. This expression can be easily derived from the definition of the stable distribution x. Intuitively, the fraction of m-period bonds issued in a given period is N_m; these bonds, once issued, remain outstanding for m periods, so that the stable distribution contains an amount mN_m, paying a coupon $C(m)$.

2.4 Stable WAM

We also calculate the stable WAM, an indicator of the supply of long-term bonds.

> ***Proposition 3****: With positive debt growth* $(r > 0)$*, the WAM of the stable maturity structure converges to*
>
> $$\mu_x = \frac{\mu_N}{1-\xi_1} - \frac{1}{r}. \quad (16)$$
>
> *With zero debt growth* $(r = 0)$*, (16) simplifies to*
>
> $$\mu_x = \frac{1}{2}\left(\mu_N + \frac{\sigma_N^2}{\mu_N} + 1\right), \quad (17)$$
>
> *where*
>
> $$\sigma_N^2 \equiv \sum_{m=1}^{M} N_m (m-\mu_N)^2 \quad (18)$$
>
> *is the dispersion of the new issue distribution.*
>
> ***Corollary****: Subject to a given per-period refinancing need, the stable supply of long-term bonds is minimized by issuing a minimally dispersed maturity mix (only one maturity,* μ_N*, or if*

that is not available, a mix of the two available maturities closest to μ_N. Conversely, a maximally dispersed maturity mix maximizes the supply of long-term bonds.

The no-growth expression (17) says that the WAM of the stable distribution is increasing in the WAM of the new issues, μ_N (first term inside the parenthesis) and in the variance of maturity of new issues, σ_N^2 (second term).[19] The same relations are not immediately visible from the expression with growth (16), but for sufficiently low r they still hold, because (17) is simply the limit of (16) for $r \to 0$.

The first term is intuitive: the longer the maturity of new issues, the longer the maturity of outstanding issues once their distribution becomes stable. The second term is perhaps more surprising, but it still has an intuitive interpretation. Compare the following two possible issuance policies: all 15-year bonds (mix A), and a 50/50 mix of 1-month bills and 30-year bonds (mix B). Both policies have roughly the same μ_N, but B will result in a longer stable WAM. Thirty-year bonds contribute more than proportionally to the stable distribution, because (i) they have a 30-year maturity, and (ii) they will remain outstanding for 30 years—hence, the squared (variance) term in expression (17).

The "$+1$" term inside the parenthesis in equation (17) is a bias due to the discrete nature of our model, in which maturities are expressed as an integer number of periods. For instance, if one period is one month, bonds with anywhere between 1 day and 1 month left to maturity are classified as "1-period" bonds; bonds with more than one month but less than two months left to maturity are classified as "2-period" bonds, etc., so that the maturity of the average bond is overstated by 1/2 period. In a continuous-time version of the model the length of the period becomes infinitesimal and this term disappears.

Expressions (16) and (17) provide an intuitive, yet non-obvious way of mapping changes in issuance policy into future changes in the supply of long-term bonds: when $\mu_x > \mu_B$, the issuer's policy is to lengthen μ_B (increase long-term bond supply), and vice versa—regardless of the direction in which the outstanding supply is currently moving. In turn, long-term bond supply is not only a driver of the classical debt-management tradeoff, discussed in the next section, but also a central variable for macroeconomic welfare, monetary policy, and asset pricing.

From a welfare perspective, the economics literature has highlighted the relative advantages of long-term and short-term bonds.[20] We do not take a stand on whether the optimal supply of long-term bonds should be maximized or minimized (although the refinancing risk constraint is only binding in the latter case). Instead, we simply provide a way to map an issuance policy into its consequences for the supply of long-term bonds.

From a monetary policy perspective, central banks worldwide have recently engaged in "quantitative easing" policies, i.e., purchases of long-term government bonds aimed at reducing their supply. Against this backdrop, it has been suggested that central banks and Treasury departments should coordinate their policies (Greenwood et al., 2014) so as to avoid working at cross-purposes. Although the two are often independent, our analysis contributes to this debate by highlighting a "free lunch"

[19] Although the second term contains μ_N in the denominator, the sum of the first and second terms is equal to $\mu_{2,N}/\mu_N$ where $\mu_{2,N}$ indicates the uncentered second moment of maturity or weighted average squared maturity. Because $m \in \{1,2, \dots M\} \geq 1$, the ratio $\mu_{2,N}/\mu_N$ (and therefore the whole expression) is increasing in μ_N.

[20] Advantages of short-term bonds include the intrinsic value of their money-like liquidity (Greenwood et al., 2015) and an implied commitment to lower inflation (Missale and Blanchard, 1994). Long-term bond advantages include fiscal insurance (Angeletos, 2002) and relative low cost due to clientele effects (Guibaud et al., 2013).

aspect of coordination: the fiscal authority could change its issuance pattern to reduce the outstanding supply of long-term bonds without seriously compromising its ability to manage refinancing risk.[21]

Finally, from an asset-pricing perspective, the recent quantitative easing programs have stimulated interest in the effect of long-term bond supply on the term spread (Krishnamurthy and Vissing-Jorgensen, 2011; Guibaud et al., 2013; Greenwood and Vayanos, 2014). By drawing a link between actions (changes in issuance mix) and outcomes (long-term bond supply), our framework enables observers to better identify news about long-term bond supply.

3 Optimal debt management

We now turn our attention to the classic debt management tradeoff between cost and refinancing risk, and discuss the resulting optimal maturity mix. A crucial assumption is, therefore, that short-term bonds are cheaper.

> **Assumption 3 (upward-sloping yield curve)**: the long-run average coupon curve $C(m)$ is a monotonically increasing function of maturity m.

The analysis in this section can be taken literally (i.e., $C(m)$ is the actual observable coupon curve), or more figuratively, to indicate that short-term bonds are less expensive on a risk-adjusted basis as in Greenwood et al. (2015). However, we believe that a more literal interpretation is justifiable: since we are explicitly modeling the way risk enters the government's optimization problem, we need not assume that the government faces the same marginal cost-risk tradeoff at all maturities.

We assume that the issuer has a target per-year refinancing need R, expressed as the percentage of debt maturing in a given year. For instance, if the government requires that only 20% of the bonds mature in a given year, we express the refinancing target as $x_1 = R = 0.2$.[22] The issuer can then optimize the maturity mix $N \equiv \{N_m\}_{m=1}^{M}$ to fulfill some other goal, such as debt service cost. Formally, the issuer minimizes

$$\min_{\{N_m\}_{m=1}^{M}} Y_x, \tag{19}$$

as defined in equation (15), subject to

$$x_1 = R, \tag{20}$$

$$\sum_m N_m = 1, \tag{21}$$

and

$$N_m \geq 0 \quad \forall m. \tag{22}$$

---

[21] Because it focuses on the long run, our analysis is more accurate if the goal is to minimize (or maximize) the supply of long-term bonds unconditionally. In contrast, monetary interventions like quantitative easing aim at high- or medium-frequency targets using discretionary sales and repurchases. Using issuance alone, adjustment may take time and the path need not be monotonic.

[22] Because the refinancing target is set at the yearly frequency, we set one period in our model to be one year, so that N_1 is the fraction of new issues with maturity 1 year, and so forth. Since Treasury's regular issuance includes bills of maturity as short as one month, it may seem more natural to set one period to be one month and express the annual refinancing constraint in terms of the 12-period share ($\sum_{m=1}^{12} x_m = 0.2$). While this problem can easily be solved numerically, it is not analytically tractable. Thus, in this example, we sacrifice a bit of precision to maximize insight. In order to fit bills with less than one-year maturity into our yearly-frequency framework, then, we divide their issuance amounts by the frequency. For instance, \$12 billion of 1-month (3-month, 6-month) bills only counts as \$1 billion (\$3 billion, \$6 billion). This adjustment reflects the fact that out of 12 m-month bills issued in one year, only m will be still outstanding at year end.

Note that (21) and (22) together imply $N_m \leq 1 \quad \forall m$.

3.1 Base case: efficient frontier

We begin by stating the following proposition.

> ***Proposition 4***: *If the long-run average coupon curve $C(m)$ is monotonically increasing (Assumption 3) and not too concave, it is optimal to issue a minimally dispersed maturity mix (only one maturity, m^*, or if that is not available, a mix of the two available maturities closest to m^*).*

In Section 1.4 we saw that a dispersed issuance mix results in a larger stable supply of long-term bonds. The intuition behind this result is similar, though not identical. Long-term bonds remain outstanding longer, and, under the assumption of an upward-sloping coupon curve, they have a higher cost. To expand on the example from Section 1.4, consider two possible issuance policies with approximately the same refinancing risk. Mix A requires the issuance of only 15-year bonds, costing 5.00%, and therefore $Y_x^A = 5\%$. Mix B requires the issuance of half 1-month bills ($N_1 = .5$), costing 1.00%, and half 30-year bonds ($N_{360} = .5$), costing 5.10%. Assume $r = 0$ for simplicity. Then, in the steady state induced by Mix B, $1/361$ of the outstanding obligations will have a cost of 1.00% and $360/361$ will have a cost of 5.10%, and therefore $Y_x^B = 5.09\% > Y_x^A$.

In order to overcome the supply effect, the savings from short-term bonds have to be very large. This may be possible if the long-run coupon curve $C(m)$ has regions of sufficient concavity (e.g., it has "corners," or overall is steep at the short end but with a rapid switch to flat at the long end). Experimentation with monotonic Nelson-Siegel curves under several sets of reasonable parameter values shows that in practice it is difficult to create a sufficiently concave coupon curve, and therefore the optimal issuance strategy is typically to issue bonds of just one maturity. In particular, the average yield curve that prevailed between 1990 and 2018, used in the calibration below, is not concave enough.

If minimally dispersed issuance is optimal, then constraint (20) and Proposition 4 together imply that the optimal maturity m^* is the one that results in the desired level of refinancing risk:

$$m^* = m^*(R) = \begin{cases} \dfrac{ln\,(1 + r/R)}{ln\,(1 + r)} & if\ r\ >\ 0, \\ 1/R & if\ r\ =\ 0. \end{cases} \tag{23}$$

For a given level of refinancing risk R, therefore, there exists an optimal maturity m^* (upper panel of Figure 1) and an associated cost of funding $C(m^*)$. The efficient frontier is the set of feasible $\{R, C(m^*)\}$ pairs given the maturities available to the issuer.

[Figure 1 about here]

In practice, the optimal issuance policy described by this idealized efficient frontier is typically inadmissible (e.g., because it rules out the issuance of 30-year bonds). However, it is easy to modify our framework to include lower and upper bounds to issuance shares ($N_m \in [N_m^L, N_m^U]$). Then, it is straightforward to identify dominant directions that reduce cost or risk as a guide to policy (see Cameron, 2018 and the lower panel of Figure 1).

3.2 Exogenous liquidity cost ($\boldsymbol{\ell}$): numerical results

Concentrated issuance can be problematic because it can result in large liquidity costs, which may negate the theoretical cost savings. The Committee on the Global Financial System (2011) states that debt managers "can reduce financial volatility by spreading maturity [and] avoiding concentrated placement," and there is evidence that both expected and unexpected supply shocks result in higher yields (e.g. Lou et al., 2013; Gorodnichenko and Ray, 2018). In general, for a large issuer like the US Treasury, the assumption that the yield curve is exogenous is a strong one; in reality, a different issuance pattern may result in a different yield curve. While we do not directly model an equilibrium yield curve based on supply and demand, to examine this possibility, we allow for a simple exogenous liquidity friction that reduces the issue proceeds. Reflecting Lou et al.'s (2013) evidence that "the issuance cost (as a fraction of the auction size) increases with the auction size," we choose a convex specification. For simplicity, we focus on the $r = 0$ case.

Under these assumptions, the stable debt service cost becomes

$$\begin{aligned} Y_x = & \underbrace{\frac{\Sigma_m m N_m C(m)}{\Sigma_m m N_m}}_{Stable\ coupon\ payment} + \underbrace{x_1 \cdot \frac{1}{2} \Sigma_m \ell N_m^2}_{Stable\ liquidity\ cost} \\ & \equiv \frac{\Sigma_m m N_m C(m)}{\mu_N} + \frac{\ell}{2\mu_N} \Sigma_m N_m^2, \end{aligned} \tag{24}$$

where ℓ is an exogenous liquidity cost parameter. This first term is the same as equation (15). Note that the second term is multiplied by $x_1 = 1/\mu_N$, the total refinancing need at any given period. If the stable per-period refinancing need is lower, liquidity costs will be less important.[23]

Although the resulting problem is well-behaved, it can only be solved numerically by making assumptions on $C(m)$, the par coupon curve, and ℓ, the liquidity friction parameter. Our assumptions are based on the market for US Treasury bonds. Given the long-term nature of the problem being studied, for $C(m)$ we take the average par yield curve between 1/2/1990 and 12/8/2018. For ℓ we use two values. A plausible value is $\ell = 0.03$, calibrated to obtain total liquidity costs close to 0.2% of issue size given the actual issuance mix. This magnitude is consistent with that estimated by Lou et al. (2013). An arbitrary but conservative alternative is $\ell = 0.3$, an order of magnitude larger. This magnitude represents the possibility that unprecedentedly concentrated issuance could result in a much larger liquidity friction. We set R, the one-period refinancing constraint, to 0.238, based on the weighted average maturity of 2017 issues ($R = 1/\mu_N = 1/4.20 = 0.238$). Finally, to maintain comparability with actual policy, we restrict the space of available maturities to the ones currently being issued (1, 3, and 6 months, and 1, 2, 3, 5, 7, 10, and 30 years).[24]

The results are reported in Figure 2. The result with no frictions ($\ell = 0$) mirrors the above analysis. By issuing a mix of 40% 3-year bonds and 60% 5-year bonds, the Treasury would obtain the same refinancing risk as under its current policy, but with a significantly lower coupon (3.92% instead of 4.64%). This result is driven by the fact that this extremely concentrated policy results in a long-term bond supply that is roughly one-third of the current policy. The results with liquidity frictions are qualitatively similar albeit less extreme. In every scenario, 5-year bonds are the relative majority of new issues, and in no scenario is it optimal to issue 30-year bonds. In the $\ell = 0.03$ case, the optimal strategy is to issue 2, 3, 5 and 7-year bonds. In the $\ell = 0.03$ case, the optimal strategy is to issue at all maturities between 6 months and 10 years included. In both cases, the stable average coupon is much

[23] Depending on the mechanism underlying the liquidity friction, the second term could be defined differently. One possibility is $1/2 \cdot \sum_{m1} (x_1 N_m)^2$, a liquidity cost that depends on the absolute amounts issued $(x_1 \cdot N_m)$, as opposed to relative concentration. Another possibility is $1/2 \cdot \sum_{m1_m} (x_1 N_m)^2$, a maturity-specific liquidity friction. While the first alternative does not change our later results, we leave the second one for future research. Bigio et al. (2018) study the effect of a maturity-specific friction, but their friction is linear in issue size.

[24] The US Treasury introduced 2-month bills in October 2018.

lower (3.97% and 4.18%, respectively), and in both cases the stable long-term bond supply is much smaller.

Of course, concentrated issuance results in lower coupon but higher liquidity cost. The only scenario that is directly comparable to the current policy is the $\ell = 0.03$ case, whose liquidity parameter is calibrated to match empirical estimates. Although the liquidity cost is more than twice as large (0.10% vs. 0.04% of total outstanding debt), the total cost Y_x is still much lower (4.08% instead of 4.68%). A difference of 60 bps/year on a total debt of $15.5 trillion amounts to $93 billion or 12% of the 2018 US federal budget deficit.

[Figure 2 about here]

Figure 2 also shows that, compared to the results in this section, actual issuance is far more concentrated at the very short end and at the very long end. On one hand, our results echo and provide an intuitive explanation for the Treasury Borrowing Advisory Committee's (TBAC) simulation-based recommendation to issue more intermediate-maturity obligations (Belton et al., 2018). If TBAC's recommendation is based on the primary dealers' information set and Treasury's own optimality criteria, therefore, the current issuance policy may in fact be suboptimal. On the other hand, this discrepancy suggests there may be other forces not captured by our simple optimization problem, such as market segmentation,[25] or additional goals such as the desire to maintain liquidity at key maturities (Garbade, 2015, p. 12) or to provide a reference yield curve as a public service (ibid., p. 62). The following paragraph discusses constrained optimization more generally.

4. Convergence

Convergence to a stable maturity structure, in and of itself, reduces refinancing risk. In order to smooth the redemption profile and manage refinancing risk, debt managers both execute buybacks and tactically issue maturities to "fill gaps" in the maturity structure. However, at least in the case of the US Treasury, tactical issuance conflicts with the desire to conduct regular auctions with predictable amounts. In this context, a stable maturity structure helps reconcile both goals because it implies both a constant refinancing need and fewer gaps to be filled.[26]

In this section we study the conditions under which a fixed issuance policy actually results in convergence to a stable maturity structure. The transition matrix $\mathcal{A}$ can have up to M distinct eigenvectors and associated eigenvalues. Convergence requires that x is the dominant eigenvector or, equivalently, that $1 + r$ is larger in absolute value than every other eigenvalue. This requirement is met under the following regularity assumptions.

First, we assume that total outstanding debt is stable or growing.

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[25] The academic literature has proposed "preferred habitat"—or clientele-based—theories of the yield curve that rely on the existence of investors specialized in holding short or long-maturity bonds (Modigliani and Sutch, 1967; Vayanos and Vila, 2009; Greenwood and Vayanos, 2010; Greenwood et al., 2010; Guibaud et al., 2013). The US Treasury itself usually motivates the introduction of new securities with their potential to "diversify Treasury's funding options and expand its investor base." See https://web.archive.org/web/20190619033238/https://www.treasurydirect.gov/indiv/research/articles/res_invest_articles_30yearbondarticle_0106.htm for the reintroduction of the 30-year bond, and https://web.archive.org/web/20190807235309/https://www.treasury.gov/press-center/press-releases/Pages/js505.aspx for Treasury Inflation-Protected Securities (TIPS).

[26] In addition to sovereign issuers, tactical issuance is documented for corporate issuers by Choi et al. (2018). The authors also show that corporate issuers manage refinancing risk by, among other things, increasing the dispersion of the maturity distribution of their outstanding debt. The arguments in our paper would apply to those issuers who issue sufficiently often to have an issuance policy.

Assumption 4 (nonnegative growth rate of debt): $r \geq 0$.

This assumption does not severely limit the generality of our findings. From a theoretical standpoint, a negative growth rate can lead to unusual dynamics which are not likely to represent the real-world dynamics of shrinking debt. From a practical standpoint, the long-term dynamics of shrinking debt are inherently less interesting, because the debt is being paid down, and less relevant, because in recent history issuer liability portfolios have had a tendency to grow over time, at least in nominal terms.

Second, we rule out the possibility of negative outstanding debt and negative net issuance.

Assumption 5 (no negative debt): $B_{t,m} \geq 0$ for all $m \in \{1 \dots M\}$.

Assumption 6 (no net repurchases): $N_m \geq 0$ for all $m \in \{1 \dots M\}$.

Neither assumption is especially restrictive. Assumption 5 rules out issuers that (i) have substantial, permanent holdings of bonds as assets, and (ii) manage these assets jointly with their liabilities. Assumption 6 rules out issuers that engage regularly in negative net issuance at a given maturity.

Finally, without loss of generality, we assume that M is the longest maturity issued by the issuer.[27]

Assumption 7 (positive issuance at the longest maturity): $N_M > 0$.

The following proposition formally states the conditions under which convergence to x is guaranteed.

Proposition 5 (conditions for convergence)*: Under Assumptions 4—7, with positive debt growth* $(r > 0)$*, convergence to a stable maturity structure is guaranteed. With no growth* $(r = 0)$*, a sufficient condition for convergence is that the issuer issue bonds of mutually prime maturities.*

The second part of Proposition 5 may be somewhat surprising. To gain some intuition, consider that the alternative to convergence to a stable maturity structure is cycling between two or more maturity structures. Issuing bonds of mutually prime maturities does not allow for such cycles. Moreover, the stable distribution x is a well-behaved function of r around $r = 0$, and therefore its properties do not change abruptly in a neighborhood of zero. Thus, when $r > 0$, even though convergence is guaranteed, mutually prime maturities result in faster convergence to a stable maturity structure, and therefore to a constant refinancing need.[28]

[Table 1 about here]

In practice, Table 1 shows that a higher prevalence of prime-number maturities results in faster convergence for three levels of debt growth ($r \in \{0\%, 5\%, 10\%\}$) and four issuance policies ($N \in \{3-5-7, 2-4-8, 1-3-5-7, 1-2-4-8\}$). The policy name indicates the maturities that are issued. For instance, "1-3-5-7" indicates that only 1-, 3-, 5-, and 7-year bonds are issued in equal amounts (25% each), and so forth. The top half of the table shows the stable refinancing need (x_1)

[27] If $N_{M-k} > 0$ and $N_{M-k+1} = N_{M-k+2} = \cdots = N_M = 0$, after a transition phase lasting k periods, the portfolio would never again have any bonds of maturity $M - k + 1$ or longer. Thus, one could simply define$M' = M - k$, and study the $M' - vector\ N'$ with $N_{M'} > 0$.

[28] Formally, the rate of convergence to the stable distribution is $\delta \equiv |\lambda_2|/|\lambda_1|$, the ratio of the absolute values of the second-largest and largest eigenvalues of $\mathcal{A}$ (Golub and van Loan, 2013). A lower δ means faster convergence: given any positive vector v and the principal eigenvector x, δ is the approximate factor by which the distance between $\mathcal{A}^k v$ and $\lambda_1^k x$ shrinks as $k \to \infty$. In the case $r = 0$, it is possible that the multiplicity of $\mathcal{A}$'s largest eigenvalue is greater than one, so that $|\lambda_2| = |\lambda_1| = 1$, and $\delta = 1$ (no convergence). For small $r > 0$ (i.e., $r \to 0$), the same policy would have a very slow rate of convergence: continuity implies that $|\lambda_2| \to |\lambda_1| \to 1$, so that $\delta \to 1$, and the time to convergence tends to infinity.

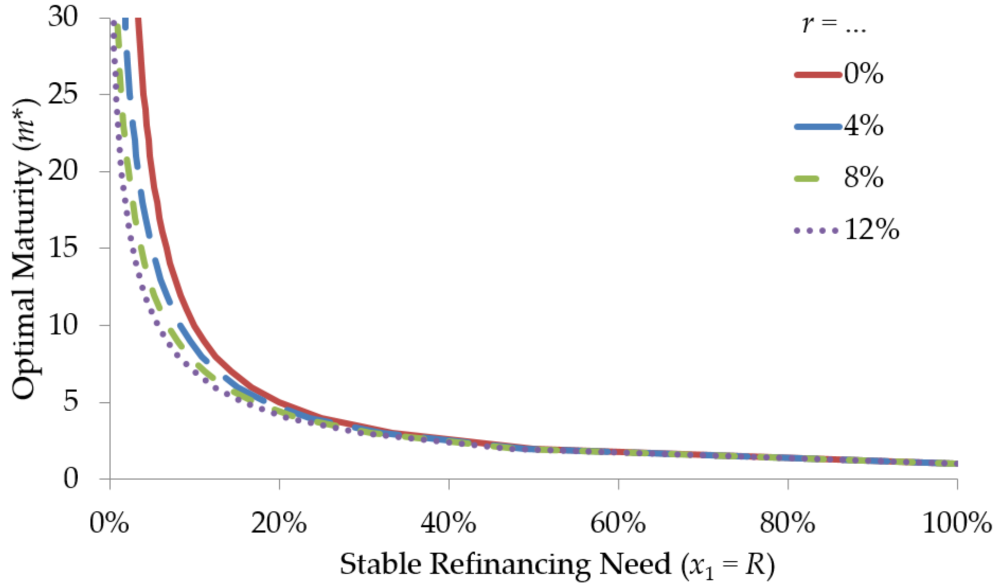
induced by each issuance policy, and the bottom half shows the jump in refinancing need between years 9 and 10 starting from an arbitrary non-uniform outstanding distribution (20% each of 1-, 3-, 5-, 7-, and 9-year bonds). A 3-5-7 policy converges and a 2-4-8 policy does not. Adding 1-year bonds causes every policy to converge (at the cost of a higher stable refinancing need), because 1 is mutually prime with every other number. However, a 1-3-5-7 policy still converges faster than a 1-2-4-8 policy.

Thus, issuing bonds with prime-number maturities reduces refinancing risk at no apparent cost to the issuer. This “free lunch” result provides a practical guideline for issuer and may offer a potential explanation for the revealed preference of most issuers for prime-number maturity bonds. Note, however, that maturities that are expressed as multiples of one year are mutually prime only if time is measured in whole years (as opposed to quarters or months). Thus, the observable issuance patterns induce smooth refinancing needs at the yearly frequency but do not prevent within-year seasonality.

5 Conclusions

We provide a simple, deterministic framework to describe debt management policy, defined as the maturity mix of new issues. In order to tease out the true nature of a policy, we assume that it is held indefinitely and characterize the long-run consequences for the issuer's outstanding maturity structure. Namely, we derive a closed-form expression for the stable long-run maturity distribution induced by the policy and we provide conditions for convergence to it. Based on this stable distribution we find simple, explicit formulas for one-number summary measures such as the fraction of bonds maturing at each period (i.e., the stable refinancing need), the stable WAM, and the stable debt service cost. We show that different debt management goals target different summary measures and are therefore more compatible than commonly thought. Our results suggest that the Treasury could keep refinancing risk constant while reducing debt service cost and, if that is a goal, the supply of long-term government bonds, by issuing more notes and fewer bills and bonds. In general, our framework enables issuers and observers to better understand the consequences of issuance policies, and thus should lead to a more nuanced policy debate and sharper asset pricing tests.

Figures



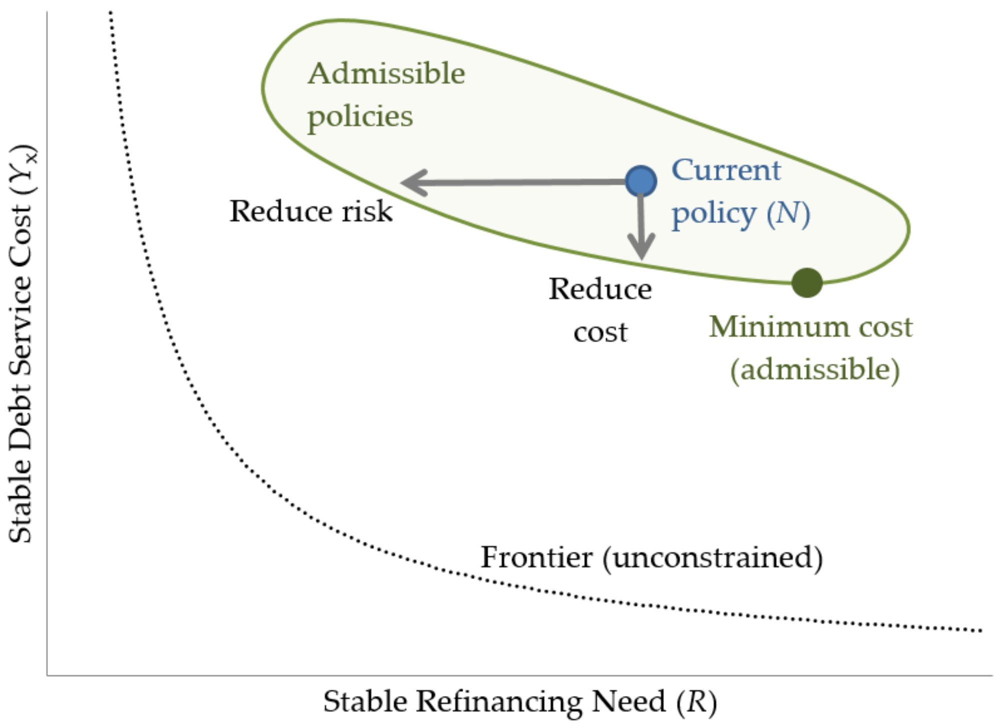
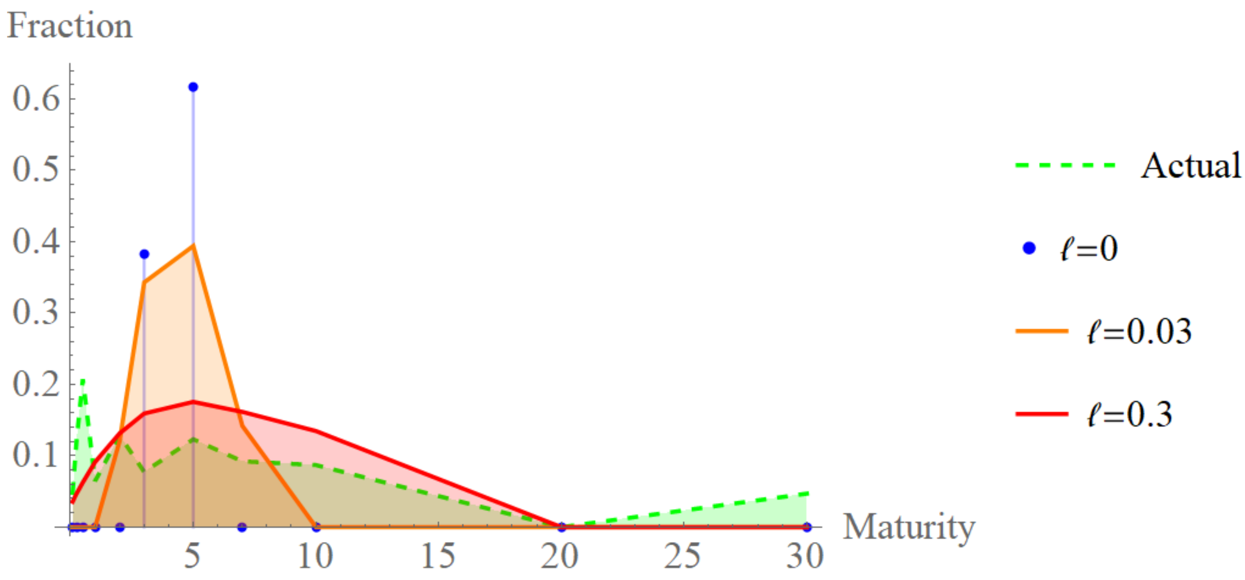


Figure 1: Above – optimal maturity $m^*$for a given level of refinancing risk R. Refinancing risk is defined as the stable refinancing need, i.e., the percentage of debt that rolls over in every period under the stable distribution. (Source: own calculations.) Below – optimization under additional constraints in our framework. (Source: original authors' graphic.)



	Actual	$\ell = 0$	$\ell = .03$	$\ell = .3$
μ_N	4.2	4.2	4.2	4.2
Refinancing need	24%	24%	24%	24%
Stable coupon +	4.64%	3.92%	3.98%	4.04%
Liquidity cost =	0.04%		0.10%	
Y_x	4.68%		4.08%	
μ_x	7.59	2.71	2.95	3.22
δ	0.927	0.939	0.889	0.887

Figure 2: Optimal maturity structure given a certain refinancing need and exogenous yield curve. "Actual" indicates actual Treasury issuance in 2017. "$\ell = 0$", "$\ell = .03$", and "$\ell = .3$" are optimal issuance solutions given progressively increasing liquidity frictions. μ_N is the average maturity of new issues. Y_x is the stable cost of debt service; μ_x is the long-run average maturity of the outstanding distribution; and δ is the "rate of convergence" to the stable distribution (see fn.24). A lower δ means faster convergence. (Source: own calculations.)

Tables

	Issuance policy ($\boldsymbol{N}$)			
	3-5-7	2-4-8	1-3-5-7	1-2-4-8
Stable refinancing need ($\boldsymbol{x_1}$)				
$\boldsymbol{r}$ = 0%	0.2000	0.2143	0.2500	0.2667
5%	0.1837	0.2028	0.2400	0.2620
10%	0.1692	0.1930	0.2138	0.2588
Jump in refinancing need between years 9 and 10 ($\left(\lvert \boldsymbol{b_{10,1}} - \boldsymbol{b_{9,1}} \rvert\right)$)				
$\boldsymbol{r}$ = 0%	0.074	0.398	0.075	0.131
5%	0.042	0.256	0.046	0.084
10%	0.024	0.168	0.029	0.055

Table 1: Speed of convergence to the stable distribution under a constant issuance policy N. The table shows sample results for three growth rates ($r \in \{0\%, 5\%, 10\%\}$) and four issuance policies ($N \in \{3-5-7, 2-4-8, 1-3-5-7, 1-2-4-8\}$). For instance, “1-3-5-7” indicates that only 1-, 3-, 5-, and 7-year bonds are issued in equal amounts (25% each), “2-4-8” indicates that only 2-, 4-, and 8-year bonds are issued (33.3% each), and so forth. The top panel shows the stable per-period refinancing need expressed as a fraction of total debt. The bottom panel shows the jump in refinancing need between year 9 and year 10, assuming the issuer starts from a non-uniform distribution of outstanding issues (B_0 consists of 20% each of 1-, 3-, 5-, 7-, and 9-year bonds). (Source: own calculations.)

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An Integrated Approach to Cost-Risk Analysis in Public Debt Management

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Fabrizio Tesseri[4], Federica Verani[5], Davide Vergni[6]

Abstract

Public debt management requires accurate analysis of the cost and the risk associated with feasible choices of public debt portfolios. The Italian Treasury employs an in-house, custom-built set of models and software tools aimed at selecting portfolios of securities that satisfy the government's borrowing needs while fulfilling all the relevant regulatory constraints, thereby delivering suitable tradeoffs between cost and risk on an efficient frontier. In this paper, we present a description of the approach followed by the Italian Treasury, including the study of the dynamics of the cash flow generated by the public debt and the development of stochastic models for the evolution of the main risk factors (i.e., interest rates and inflation). Then, we describe how several dynamic metrics of cost and risks are integrated within a scenario generator in a modular software package called SAPE (Sistema Analisi Portafogli di Emissione – System for the Analysis of Public Debt Issuances). This system supports the public debt manager by providing accurate quantitative estimates of the expected effects of their choices taking into account not only shocks to interest rate curves but also exogenous forecasts about the future behavior of the risk factors. The software can also be used as an accounting tool for the outstanding securities of the Italian public debt, and includes various satellite modules for the evaluation of other relevant metrics, such as the Credit Value Adjustment for derivative instruments.

JEL classification: H63, C15, C53, E63, E43

Keywords: Debt, Debt Management, Sovereign Debt, Statistical Simulation Methods, Forecasting and Prediction Methods, Simulation Methods, Comparative or Joint Analysis of Fiscal and Monetary Policy, Stabilization, Treasury Policy, Interest Rates: Determination, Term Structure, and Effects

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1. Introduction

Public debt management is the process of designing and executing a strategy for the management of government debt with the ultimate goal to satisfy the financing needs of the government. In this process it is necessary to consider a number of relevant issues, related to cost, risk, maturity structure, and choice of instruments from a broad universe of assets. Debt managers generally rely on a cost-risk analysis of their stock of liabilities to make choices of debt instruments and portfolio composition.

This kind of analysis requires a broad set of tools. A key component of the toolkit required is a formal framework that allows to produce stochastic simulations of multiple term structures of interest rates and macroeconomic variables. From these simulations, which constitute a set of possible future scenarios for the interest rates' evolution, debt managers can determine the relationship between cost and risk they face under different feasible portfolios. The process is, in practice, made much more complex by a number of exogenous factors (i.e., factors not under the control of debt managers) that include, for example, the influence of central banks on the path of interest rates, political risk, global risks of various form, and regulatory constraints. Surprisingly, the literature in this area is scant, with few papers attempting to describe the modelling strategies and challenges faced in the process of evaluation of the cost and risk trade-off associated with different financing strategies. Stochastic simulation modelling is used in public debt decision making by many governments around the world. Just to cite a few we mention Canada (see Bolder 2002, 2003, 2011), the Swedish National Debt Office (see Bergstrom, Holmlund and Lindberg 2002), the National Bank of Denmark (2005), the UK Debt Management Office (see Pick and Anthony 2006), the French Treasury (see Renne and Sagne 2008), the Turkish Treasury (see Balibek and Memis 2012) and the U.S. Treasury (see Belton et al. 2018). For an overview of stochastic debt strategy simulation modelling in OECD countries, see Risbjerg and Holmlund (2005) while a general discussion on debt strategies in Europe can be found in Balling, Gnan and Holler (2013). There are also more academic works on public debt management that can be considered as food for thought for debt managers, see for example Dottori and Manna (2016). Finally, concerning practical applications, mathematical methods on cash flow forecasting and cost-risk analysis for public debt has been endorsed by the World Bank, which has developed a toolkit specifically designed by its debt and risk management experts (see Panzer 2015).

The Italian Treasury employs an in-house, custom-built set models and software tools aimed at selecting portfolios of securities that satisfy the government's borrowing needs while fulfilling all the relevant regulatory constraints. In this paper, we present a description of the approach followed by the Italian Treasury, including the study of the dynamics of the cash flow generated by the public debt and the development of stochastic models for the evolution of the main risk factors (*i.e.,* interest rates and inflation). Then, we describe how several dynamic metrics of cost and risks are integrated within a scenario generator in a modular software package called SAPE (Sistema Analisi Portafogli di Emissione – System for the Analysis of Public Debt Issuances). This system supports the public debt manager by providing accurate quantitative estimates of the expected effects of their choices taking into account not only shocks to interest rate curves but also exogenous forecasts about the future behavior of the risk factors. The software can also be used as an accounting tool for the outstanding securities of the Italian public debt, and includes various satellite modules for the evaluation of other relevant metrics, such as the Credit Value Adjustment for derivative instruments. We provide both a description of the general framework and several illustrations of the way this set of tools is utilized in practice.

2. Mathematical Model

The study of the evolution of the public debt and the assessment of the cost and risk of a portfolio of government securities with respect to a set of scenarios of the future interest rates, require a setup that represents in a quantitative way all the elements that contribute to the cash flows of all the relevant securities in the portfolio. The Italian Treasury Department issues six different types of domestic securities including three with a floating rate and a small number of foreign securities for a total amount of 2,004 billion euro plus a derivative portfolio with a notional of 99 billion euro at December 2019. Each type of security can be issued with different maturities and the total number of different securities is about twenty (see Table 1).

Tabel 1 Italian Government debt: breakdown by instruments with their features.

Securities	Amount (mln €)	%	Maturities (months)	Coupon	Indexed
BOT	113,929	5.68	6, 12	Zero Coupon	
CCTeu	125,586	6.26	60, 84	Floating Coupon	Euribor 6M
CTZ	51,139	2.55	24	Zero Coupon	
BTP	1,440,016	71.83	36, 60, … , 360, 600	Fixed Coupon	
BTPs €i	151,707	7.57	60, 120, 180, 360	Floating Coupon	HIPC
BTP Italia	77,558	3.87	48, 72, 96	Floating Coupon	FOI
Foreign Debt	44,567	2.22	36, …, 600	Fixed / Floating	Euribor, CPI

The key elements needed for a reliable and effective debt management process are the stochastic models for the evolution of interest rates and the mathematical representation of the cash flows as a function of the complete debt portfolio.

3. Interest rate scenarios

A key input to implement the cost-risk analysis of the Italian public debt issuance portfolios are the out-of-sample scenarios for the term structure of interest rates relevant to the set of securities issued by the Italian Department of Treasury and to the set of derivative transactions. A class of models of the term structure of interest rates has been developed for the Italian sovereign bond term structure, the Italian break-even inflation (BEI) term structure, and for the swap curves of both Euro and US dollar. The main goal of these models is to produce joint stochastic out-of-sample scenarios for these different yield curves on the basis of calibrations that respect their observed in-sample properties, while ensuring internal consistency of the generated scenarios.

Starting from 2010, the development of the first release of the model was related to the sovereign (nominal) and break-even-inflation rates, with the purpose of pricing and forecasting nominal (BOT, CTZ and BTP) and inflation-linked (BTP€i) securities and then deriving endogenously the real curve. A similar approach has been adopted by the Federal Reserve for the estimation of the real curve referring to inflation-linked securities (TIPS). In this regard, see the work of Gürkaynak *et al.* (2008). Then the model was extended to the term structure of EUR swap rates in order to price and forecast the new sovereign (CCTeu) securities indexed to the Euribor rates and also allow the management of plain vanilla derivative contracts, such as interest rates swap with floating legs indexed to the Euribor rates. In 2012, the model was further extended including the specification of the term structure of USD swap rates, in order to manage cost-risk analysis on bonds denominated in foreign currency, price and forecast derivative contracts, such as cross currency swap, and improve the accuracy of EUR swap yield curve scenarios. The sovereign, break-even inflation (BEI) and EUR swap curves are estimated and simulated jointly, whereas the USD swap curve is modeled individually and so is considered exogenous to the others.

The last refinement of the model was then related to the development of a module linking the term structure of Italian break-even inflation rates to the scenarios generated for the Euro break-even rates, in order to price and forecast the securities designed for retail investors and indexed to Italian inflation, namely BTP Italia.

All these specifications are integrated in a module dedicated to the generation of stochastic scenarios, which interfaces the main module calculating cost and risk of the portfolios of issuances. The scenario generator also incorporates the possibility of using different stochastic models for generating medium/long-term scenarios for interest rates and inflation rates, allowing the evaluation of the expected performance, in terms of cost-risk analysis, of different strategies related to public debt issuance policies.

4. Modelling the dynamics of interest rates

The approach adopted at the Department of Treasury for modelling the different term structures of interest rates requires the execution of multiple steps. The first step relates to the seminal work of Nelson and Siegel (1987), extended by Svensson (1994). The Nelson-Siegel-Svensson (NSS) approach uses an exponential components framework to characterize the entire yield curve within a four-dimensional parameters framework. This setup essentially decomposes the yield curve into four factors: the level, the slope and, two curvature factors of the yield curve.

A single yield curve can be represented as:

$$y(\tau) = \beta_1 + \beta_2 \left[\frac{1-\exp\left(-\frac{\tau}{\lambda_1}\right)}{\frac{\tau}{\lambda_1}}\right] + \beta_3 \left[\frac{1-\exp\left(-\frac{\tau}{\lambda_1}\right)}{\frac{\tau}{\lambda_1}} - -\exp\left(-\frac{\tau}{\lambda_1}\right)\right] + \beta_4 \left[\frac{1-\exp\left(-\frac{\tau}{\lambda_2}\right)}{\frac{\tau}{\lambda_2}} - -\exp\left(-\frac{\tau}{\lambda_2}\right)\right] \qquad (1)$$

where $y(\tau)$ is the zero-coupon rate for maturity τ and β_1, β_2, β_3, β_4, λ_1 e λ_2 are estimated parameters, which have an economic interpretation that implies the following restrictions:

$$\beta_1 > 0, \qquad (\beta_1 + \beta_1) > 0, \qquad \lambda_1 > 0, \qquad \lambda_2 > 0.$$

This class of specifications is broadly adopted by many central banks and many financial institutions for the estimation of the term structure of interest rates.

The second curvature factor, β_4, allows more flexibility and is useful in the presence of multiple local optima and to better fit term structure data for long term maturities (> 10 years), which is very relevant for the case of the Italian sovereign bonds. Indeed, the Italian Treasury issues bonds up to 50-year maturity and the allowance for a second curvature factor has been found to be crucial to capture the very long end of the term structure in our NSS estimation.

The NSS specification has two humps, and their positions are identified by $\lambda_1$and λ_2. These parameters can be either estimated or fixed. Setting fixed values for λ_1 and λ_2 yields lower volatility in estimation and better control of the evolution process of β parameters.

The main steps carried out in the development of the entire set of models are the following:

- unrestricted *in-sample* estimation, using daily data, of the NSS parameters for each curve: sovereign (Bot, Ctz, Cct, Btp), BEI (Zero Coupon Inflation Swap based on euro area HICP consumer price index), Euroswap (Euribor + Eurirs rates) and USD swap (Libor + USD swap rates);

- identification of average values of λ_1 and λ_2 for all curves and new model estimation with the calibrated values of λ_1 and λ_2;
- time aggregation from daily to monthly frequency (applying NSS fit to the end of month estimates);
- calibration of parameters and specification of the dynamics for all β_1-β_4 of all the term structures through a vector autoregression (VAR) approach for the joint evolution of the betas of the curves;
- *out-of-sample* stochastic simulation of the model.

The *in-sample* estimation of the yield curves allows to derive endogenously the real rates curve and the swap spreads (with respect to sovereign rates). In detail, if we define the break-even inflation (BEI) curve as the rates vector that makes equivalent (for investors) to hold nominal or inflation-linked securities, we get:

$$\mathrm{BEI}_t(n) = y_t^{nom}(n) - y_t^{real}(n) \qquad (2)$$

which implies

$$y_t^{real}(n) = y_t^{nom}(n) - \mathrm{BEI}_t(n) \qquad (3)$$

A similar approach is commonly adopted on US data for the estimation of the real curve referred to US inflation-linked securities (TIPS). See Gürkaynak *et al.* (2008).

Similarly, the swap spread curve is obtained endogenously as the difference between sovereign (nominal) and swap rates:

$$\mathrm{SPREAD}_t(n) = y_t^{nom}(n) - y_t^{swap}(n) \qquad (4)$$

$for\ n = 0.25, 0.5, \ldots, 30$ years.

The fit of the in-sample estimates is, in general, excellent and we observe very small pricing errors for all four curves, as showed in the following graphs (see Figure 1, Figure 2 and Figure 3).

Figure 1 Nelson-Siegel-Svensson daily estimation (sovereign and break-even-inflation rates)

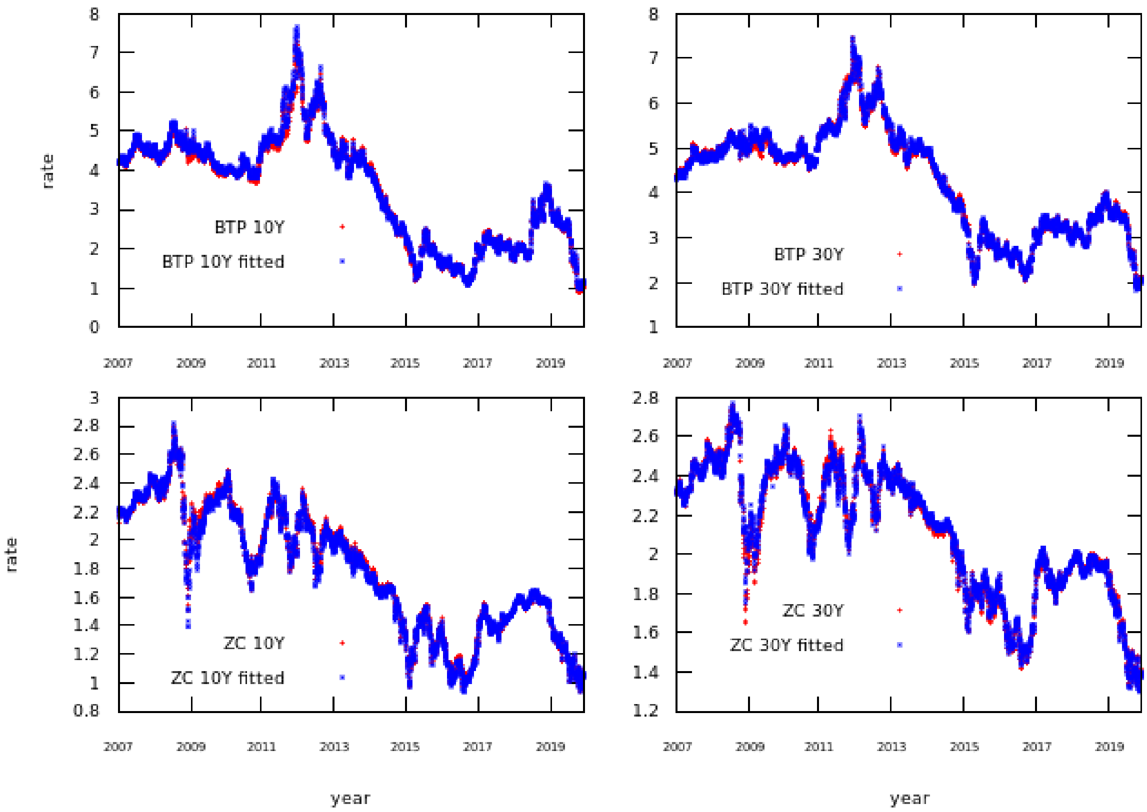


Figure 2 Nelson-Siegel-Svensson daily estimation (Euro and USD swap rates)

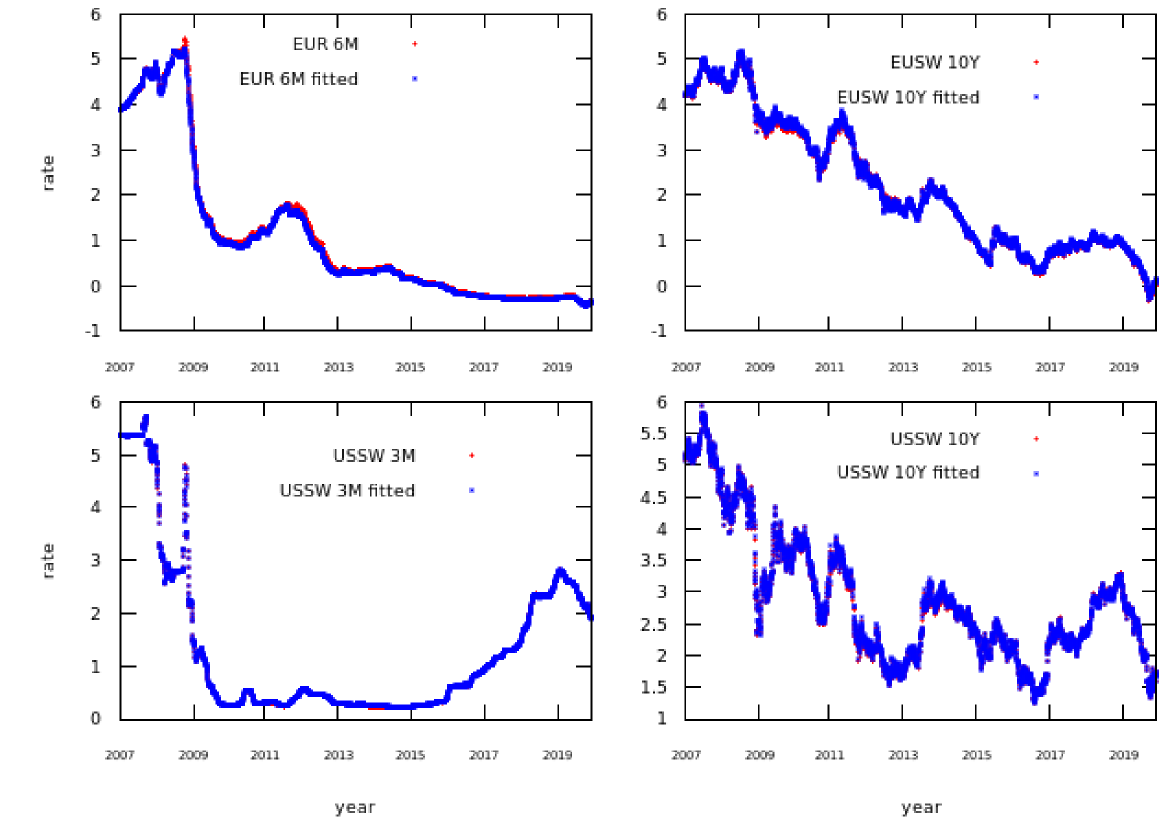
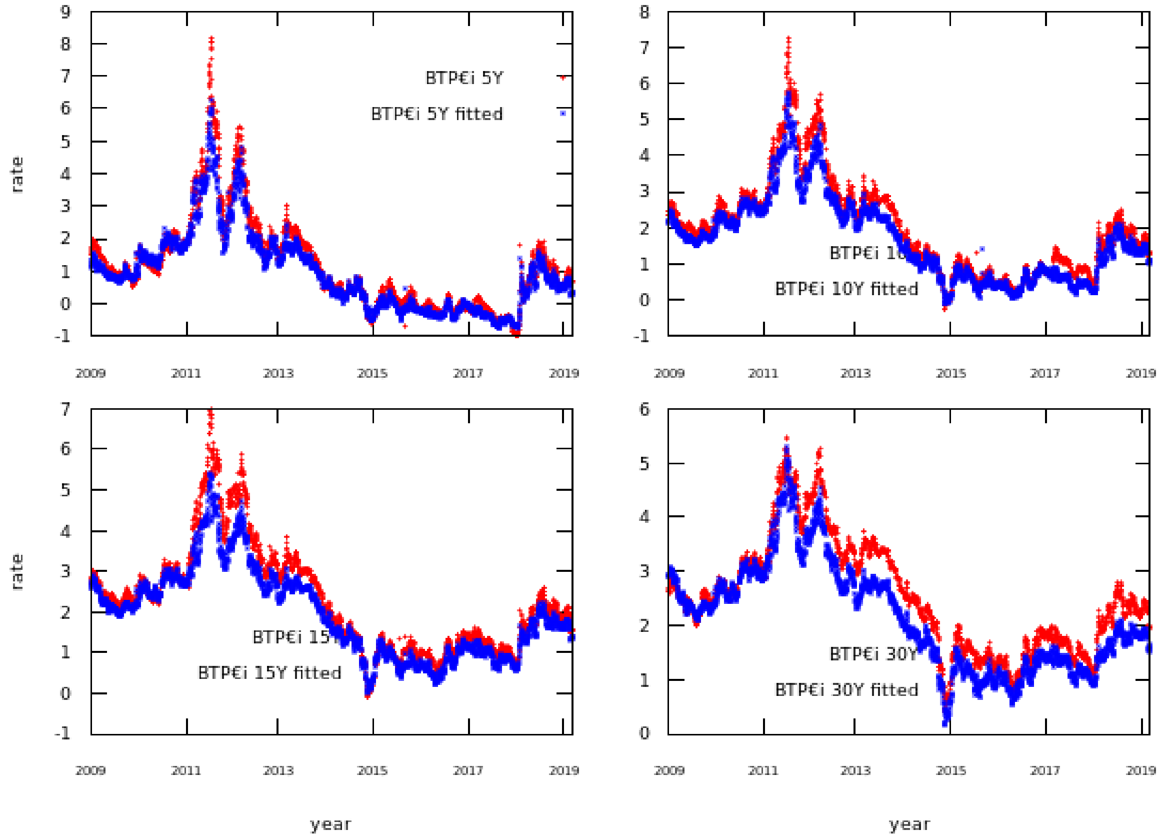


Figure 3 Nelson-Siegel-Svensson daily estimation (BTP€i real yields)



After in-sample estimation we perform a joint calibration of nominal, Euro BEI and euroswap curves that aims at finding out an evolution process for parameters β_1-β_4 that may produce out-of-sample forecasts (scenarios). As in Diebold and Li (2006), we adopt a multivariate specification based on a VAR model:

$$B_t = m + AB_{t-1} + e_t \qquad (5)$$

where B_t is a 12-element vector for the β parameters (four for each of the three curves), m is a vector of intercepts, A is a 12x12 coefficient matrix describing the autoregressive scheme of parameters. The innovations e_t are assumed to be normally distributed in the estimation, which is carried out by maximum likelihood.

The VAR model, after estimation and general-to-specific model reduction designed to eliminate redundant coefficients[7], is simulated out-of-sample to produce joint forecasts for the three sets of βs. This method ensures consistency for the out-of-sample scenarios of the term structures of sovereign (nominal), BEI and EUR swap rates. The USD swap curve is estimated and calibrated separately, and its level β_1 enters in the level equation of the swap curve in euro.

The original multivariate specification ensured fulfillment of the statistical properties of yields, observed in-sample. These properties relate to no arbitrage conditions through the variance and covariance of the rates from the term structure models.

[7] The general-to-specific procedure is performed iteratively, eliminating in every iteration the least significant coefficient in terms of its p-value.

However, after the global financial crisis, some of the no-arbitrage conditions are inconsistent with the data. Therefore, some of the recent simulations allow for this feature in the scenario generation. Stochastic *out-of-sample* simulations of the model are performed using a *bootstrap*[8] method applied to the VAR residuals. At least 1000 different scenarios have to be *boostrapped* in order to have stable results on average. The procedure is used to generate not only point forecasts, but also multiple sets of scenarios (distributions) consistent with the *in-sample* statistical properties of the yield curves. The parameters are regularly (re-)calibrated so as to include the most recent observations in the historical estimation sample and checking for structural stability, particularly after the shocks observed in recent years to the Italian sovereign rates and to the European swap curve.

Regarding the securities indexed to European and Italian inflation (BTP€i and BTP Italia) the scenarios produced for the BEI curve on Euro Area inflation are used to generate consistent projections for both the HICP (Euro Area) and FOI (Italy) consumer price indices.[9] In particular, the Italian break-even inflation rates are obtained through the simulation of a set of linear equations in which the Italian BEI rates are regressed on the Euro Area BEI rates. Further, considering the strong relationship between price indices and BEI behavior, we adopt a linear specification also for HICP and FOI, which are regressed on their lagged values and on the BEI values at 5-year maturity.

5. Anchoring the yield curves using exogenous information on short term rates

When using the methods described above, it is often the case that there is a specific prior on the behavior of interest rates that can be used in calibration. The prior could be a specific belief of the issuer or the market expectation (survey) of one or more interest rates over a particular horizon. This is typically a prior about future short-term rates. In this case, it is desirable to "anchor" the relevant rates and generate simulations that condition on such prior. In recent years a new module for “anchoring” yield curves has been developed, starting from the work of Altavilla *et al.* (2013), who proposed a methodology for tilting (or rotating) the yield curve using exogenous priors on short term rates (e.g. survey data).

The anchoring technique exploits the informational advantage of survey expectations about short yields in order to improve the accuracy of yield curve forecasts given by a base model. The anchoring methodology is independent from the base model, and the basic idea is to tilt the yield curves generated by the base model, incorporating the exogenous priors on short rates, without re-estimating the parameters or changing the original specification.

The method is based on the projection of the out-of-sample density forecasts f_t onto the space of densities that have conditional mean equal to the exogenous prior and that are closest to f_t, according to a Kullback-Leiber measure of divergence. Basically, if the vector of expected yields *h*-periods ahead has mean μ_{t+h} and variance-covariance matrix Σ_{t+h}, and at time t we have survey data on the first

[8] The innovations generated during the stochastic simulation with the bootstrap method are extracted randomly (with repetition) from the set of residuals of the stochastic equations of the β parameters observed in-sample. The use of this technique, compared to the extraction from a normal distribution (Monte Carlo), may be more appropriate in cases where the residuals of the dynamic equations are not normally distributed.

[9] Treasury Bonds linked to Euro-zone inflation are securities that provide investors with protection against price increases. Both the principal to be redeemed at maturity and their coupons, paid semannually, are adjusted for inflation in the Euro-zone, as measured by the Harmonised Index of Consumer Prices (HICP), excluding tobacco. Monthly data for the Eurostat index may be found at the Statistical Office of the European Communities website (Eurostat). Btp Italia is a government security that provide investors with the protection against an increase in the level of prices in Italy: both the coupons, which are paid semi-annually, and the principal, the revaluation of which is also paid semi-annually, are indexed to the Italian inflation, as measured by ISTAT – the Italian National Bureau of Statistics - through the FOI national index, “Prezzi al consumo per le famiglie di operai e impiegati”, with the exclusion of tobacco products.

(i.e., shortest) r maturities related to period $t+h$, $\mu'_{t+h,1:r}$, the tilted (anchored) vector is calculated, starting from the average scenario of the model, as follows:

$$\mu^*_{t+h} = \begin{pmatrix} \mu'_{t+h,1:r} \\ \mu_{t+h,r+1:m} - \Sigma_{t+h,21}\left(\Sigma_{t+h,11}\right)^{-1}\left(\mu_{t+h,1:r} - \mu'_{t+h,1:r}\right) \end{pmatrix} \quad (10)$$

where the variance-covariance matrix $\Sigma_{t+h,}$ can be rewritten as:

$$\Sigma_{t+h} = \begin{pmatrix} \underset{r\,x\,r}{\Sigma_{t+h,11}} & \underset{r\,x\,(m-r)}{\Sigma_{t+h,12}} \\ \underset{(m-r)\,x\,r}{\Sigma_{t+h,21}} & \underset{(m-r)\,x\,(m-r)}{\Sigma_{t+h,22}} \end{pmatrix}$$

If we consider, for example, the anchoring to an exogenous value of the rate with the shortest maturity (r = 1, e.g., the 3-months rate), the projection of the single term structure produced by the dynamics of the factors of the Nelson-Siegel-Svensson curve is obtained by setting the 3-months rate equal to the exogenous value (prior) and modifying the data for the other maturities according to equation (10).

Recently the anchoring module has been implemented into the scenario generator of SAPE and so this technique can be applied to any single scenario of the yield curves generated with the stochastic simulations of the baseline term structure model.

The first release of the anchoring module performed the tilt of the curves only on the first out-of-sample observation, in line with the results of Altavilla *et al.* (2013). Usually the exogenous prior is the sovereign rate of the zero-coupon instrument with the shortest maturity (BOT 3 months). Moreover, considering that the term structures of sovereign, BEI and EUR swap rates are simulated jointly, we developed a method for selecting the priors also on BEI and EUR swap rates, so as to ensure the consistency with the one set on the 3-months nominal rate. In detail, we set the other two priors taking the average of the 3-month euribor rates and of the 2-year BEI rates calculated on the first out-of-sample observation of the five baseline scenarios which are closest to the 3-months nominal rate prior, with the constraint that the selected scenarios must have the same direction (sign) in terms of rotation.

The second version of the anchoring module has been recently released, that makes possible the rotation (tilt) of the curves not only for the first out-of-sample observation, but also for the following ones, for example up to 12 months onwards. This extension allows to simulate the model, for example, granting the consistency with different scenario hypotheses related to the expectations in terms of issuance policy and monetary policy choices.

6. The debt portfolio cash flow and the balance constraint

By debt portfolio we mean the collection of domestic securities issued by the Italian Treasury that are still on the market, that is securities that have not yet reached their maturity. A quantitative description of the debt portfolio benefits from establishing precise notation and the definitions:

- The index k represents the type of security, where $k \in \{1..N_B\}$ and N_B is the number of different securities issued by the Italian Treasury. Securities of the same kind but with different maturities are considered different;

- The index t represents the months both in the balance period and in the planning period, where $t \in \{T_s..T_f\}$, T_s is the starting month and T_f is the final month;
- $u_k(t)$ indicates the nominal value of securities of type k issued at time t;
- $m_k(t)$ indicates the maturity, measured in years, of securities of type k issued at time t;
- $p_k(t)$ indicates the price of securities of type k issued at time t;
- $N_{c_k(t)}$ indicates the number of coupons that will be paid for bonds of type k issued at time t;
- $c_k(t)$ indicates the fixed coupon percentage for bonds of type k issued at time t or the fixed real coupon percentage for inflation indexed bonds of type k issued at time t;
- $c_k(l;t)$ indicates the floating coupon percentage paid for the coupon l of bonds of type k issued at time t;
- $m_k(l;t)$ indicates the time to maturity, measured in years, of the coupon l of bonds of type k issued at time t;
- $s_k(t)$ indicates the spread for the coupons of bonds k issued at time t;
- $r_d(T;t)$ indicates the zero coupon rate for domestic issuances for maturity T observed at time t;
- $r_s(T;t)$ indicates the euro swap rate for maturity T observed at time t;
- $HICP(t)$ and $FOI(t)$ are the European and Italian Inflation Indexes, respectively;
- $I_k(T;t)$ indicates the index coefficient at time T of bonds of type k issued at time t.

To describe the cash flows for the portfolio, we use the indicator function $\theta(s;t)$, whose value is 1 if $s = t$, 0 otherwise. The unitary cash flow at month s for bond k issued at time t is composed by three terms:

- The net income at issuance time t:
$$N_k(s;t) = \theta(s;t)\frac{p_k(t)}{100};$$
- The coupon payment at time $m_k(l;t)$ with $l \in \{1..N_{c_k(t)}\}$
$C_k(s;t) = \sum_{l=1}^{N_{c_k(t)}} \theta(s;t+m_k(l;t))I_k(m_k(l;t);t)c_k(l;t)\,;$
- The reimbursement at time m_k
$$R_k(s;t) = \theta(s;t+m_k)I_k(m_k;t).$$

Using the above defined functions, it is possible to represent the cash flow for the whole portfolio of domestic bonds at any time s as follows:

$$F_d(s) = \sum_{k=1}^{N_B}\sum_{t=s-m_k}^{s} u_k(t)\big(N_k(s;t) - C_k(s;t) - R_k(s;t)\big).$$

Besides the cash flow of the domestic portfolio, it is necessary to include the Primary Budget Surplus (PBS), the cash flow of the securities issued in foreign currency and derivative transactions in the balance equation. As to the Primary Budget Surplus, any forecast is difficult due to issues like political decisions and changes in the state of the economy. However, we assume that the PBS is given as an input parameter every month so defining a sequence PBS(s). As to the cash flow in foreign bonds and derivatives, we consider it as another given quantity $F_e(s)$; however that quantity may be adapted according to the simulated interest rates scenarios for those components in $F_e(s)$ which are indexed to inflation or to some interest rate (e.g., an interest rate swap). The cash flow of bonds' issuances and payments goes through a Bank of Italy account, owned by the Treasury, called Treasury Cash

Account. By regulation, there is a positive lower bound, $\beta = 10$ billion euro, on the amount of money that account must hold. We indicate by $TCA(s)$ the amount of money in the Treasury Cash Account at time s. Then the balance constraint, i.e. the constraint that must be respected in order to balance the income and expenditure of the public debt, can be written as

$$TCA(s) = TCA(s+1) + F_d(s) + F_e(s) + PBS(s) \geq \beta.$$

This is the fundamental constraint that guarantees the payment of coupons and the reimbursement of bonds at maturity. For the historical issuances, the constraint has necessarily been respected, whereas in the simulation time window the issued quantities $u_k(t)$ have to be adapted to fulfill the balance constraint.

7. The ESA 2010 cost function

The definition of a suitable objective function is an element of pivotal importance in any decision making process. In public debt management, there is a natural cost to consider that is the cost of the debt service, *i.e.* the interest expenses. Actually, there are a number of possible choices for quantifying the interest expenses. However, since it falls within the regulatory parameters of the European community, we follow the European System of National and Regional Accounts (ESA 2010), that is the latest internationally compatible EU accounting framework for a systematic and detailed description of an economy.

The ESA 2010 criteria refer to a given time period, say $[t_1, t_2]$, and, loosely speaking, consider for each bond its total cost (original issue discount, coupons and uplift for securities inflation indexed) as distributed over its existence period, namely from issuance to maturity, taking the portion of the cost that has an intersection with the considered time period of the ESA 2010. To be more precise, each cost associated to a bond has a natural reference period (*e.g.,* six months for a coupon or the complete lifetime of the bond for the original issue discount) that can be indicated as $[t_s, t_e]$, and impacts on the ESA 2010 proportionally to the ratio between (N), the number of days of intersection between the ESA 2010 period and the reference period of the cost, and (D), the number of days of the reference period of the cost. In the following, we present the impact on the ESA 2010 of the various types of costs for a unitary quantity of a security of type k issued at time t:

- ESA 2010 cost in the period $[t_1, t_2]$ for the original issue discount
$$E_k^{oid}([t_1, t_2]; t) = \left(1 - \frac{p_k(t)}{100}\right) \frac{[t_1, t_2] \cap [t, t + m_k(t)]}{[t, t + m_k(t)]};$$
- ESA 2010 cost in the period $[t_1, t_2]$ for the coupons of the security of type k issued at time t
$$E_k^{coup}([t_1, t_2]; t) = \sum_{l=1}^{N_{c_k(t)}} I_k(m_k(l; t); t) c_k(l; t) \frac{[t_1, t_2] \cap [t + m_k(l-1; t), t + m_k(l; t)]}{[t, t + m_k(t)]};$$
- ESA 2010 cost in the period $[t_1, t_2]$ for the uplift
$$E_k^{uplift}([t_1, t_2]; t) = I_k(\min[t + m_k(t), t_2]; t) - I_k(\max[t, t_1]; t).$$

Finally, the ESA 2010 cost in the period $[t_1, t_2]$ for the whole portfolio of domestic bonds can be represented as

$$E([t_1,t_2]) = \sum_{k=1}^{N_B} \sum_{t=t_1-m_k}^{t_2-1} u_k(t)\left(E_k^{oid}([t_1,t_2];t) + E_k^{coupon}([t_1,t_2];t) + E_k^{uplift}([t_1,t_2];t)\right).$$

8. Analytical study on the ESA 2010 evolution

The above equation is a very general representation of the interest expenditure, since it accounts for any kind of security. Hereafter, we limit our investigation of the ESA 2010 dynamics to two types of securities, zero-coupon bonds and bonds with fixed coupons, and assume that:

1. each security with coupons is issued at par value, i.e., $p_k(t)$=100;
2. each security is issued the first day of a month and the time frame for the evaluation of the ESA 2010 cost is always an integer number of months;
3. the amount of each security issued every month does not depend on time but only on the type of security. If D is the initial debt at time $t = 0$, we suppose that D is distributed,
4. according to a fraction x_k, among the different securities k and the amount for each security is uniformly distributed across the maturity, m_k, of the security so that:

$$u_k = \frac{Dx_k}{m_k}.$$

The third assumption is the most important one. It means that the total debt and its composition remain constant: only maturing securities require new issuances. Coupons are paid, for instance, using the primary budget surplus. A simplified version of the ESA 2010 interest expenditure is useful to start the analysis of the monthly interest expenditure. The assumption that the government issues either zero-coupon bonds or par value bonds makes it possible to derive the ESA 2010 interest expenditure as a function of past interest rates. In particular, the ESA 2010 requirement of spreading the original issue cost along the whole life of a security implies that the cost of a zero-coupon bond in a given month, M, during the life of the bond k issued at time t, is equal to

$$E_k^{oid}(M;t) = \frac{r_d(m_k(t);t)}{12}$$

and a similar relation holds for the ESA 2010 costs of a coupon

$$E_k^{coup}(M;t) = \frac{r_d(m_k(t);t)}{12}$$

since, for fixed coupon bonds issued at par value, $c_k(t) = r_d(m_k(t);t)/2$, and that cost has to be distributed along six months. We can now define $\varphi(T)$ as the total ESA 2010 cost in a single month, T, as

$$\varphi(M) = \sum_{k=1}^{N_B} \sum_{t=M-m_k}^{M-1} u_k(t)\frac{r_d(m_k(t);t)}{12} = \sum_{k=1}^{N_B} \sum_{m=1}^{m_k} u_k(M-m)\frac{r_k(M-m)}{12},$$

where, to simplify the notation, we use the change of variables $m = M - t$ and $r_k(t) = r_d(m_k(t);t)$ without ambiguity, since in this paragraph we limit our analysis to a fixed domestic bond; $r_k(t)$ indicates the spot rate for issuances of the domestic bond k having maturity m_k issued at time t. Assumption 3 simplifies the above expression since $u_k(t)$ is fixed, depending only on the portfolio composition

$$\varphi(M) = \frac{D}{12}\sum_{k=1}^{N_B}\frac{x_k}{m_k}\sum_{m=1}^{m_k} r_k(M-m)\,.$$

If we define the average value of rate $r_k(t)$ in the period between $[M-m_k, M-1]$ as

$$R_k(M) = \frac{1}{m_k}\sum_{m=1}^{m_k} r_k(M-m)$$

the monthly ESA 2010 becomes

$$\varphi(M) = \frac{D}{12}\sum_{k=1}^{N_B} x_k R_k(M)\,.$$

We are now ready to write down the ESA 2010 simplified expression:

$$E([t_1,t_2]) = \sum_{M=t_1}^{t_2}\varphi(M) = \frac{D}{12}\sum_{k=1}^{N_B} x_k \sum_{M=t_1}^{t_2} R_k(M) = \frac{D}{12}\left(\sum_{k=1}^{N_B} x_k R_k\right)(t_2-t_1)$$

where R_k is the average of the spot rate associated to the security k in the period $[t_1, t_2]$. The above expression shows that, using reasonable approximations, the ESA 2010 cost has a very intuitive expression as a linear function of time with a coefficient that is the composition of the portfolio percentages multiplied by the average rates. The actual ESA 2010 dynamics that we compute with our software tool shows that the linear approximation can be considered a good proxy and the growth rate of the ESA 2010, i.e., the function $\varphi(M)$, can be considered as a simple but informative cost function.

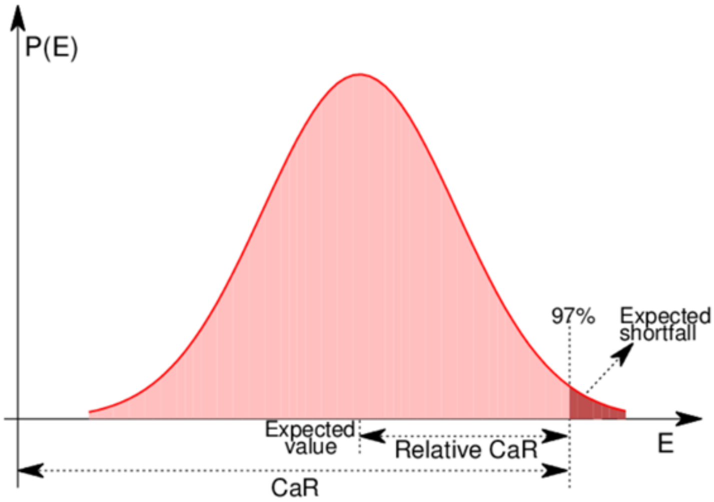
9. The Cost/Risk Analysis

Both mathematical models, the one used for the generation of possible scenarios of future interest rates and the other describing the cash flows of the public debt and the ESA 2010 cost function, can be used separately and in combination in several ways. First of all, it is possible to compute financial indicators useful for the compilation of accurate balance reports, since the model considers the real outstanding debt (including also issuances in foreign currencies and derivative contracts). It is also possible to estimate future interest expenditures due to changes either in the composition of the portfolio of public debt securities or to the dynamics of interest rates*, e.g.,* if they remain low for the next five years or they undergo shocks (what-if analysis). However, the most interesting analysis is probably the one based on Monte Carlo simulations in which the performance of different possible funding portfolios is compared with respect to a large number of possible scenarios of interest rates evolution. This is the so called *cost-risk* analysis that is a fundamental task that the public debt manager must be able to perform in a very reliable way. In the previous subsection, we described, in analytic form, the dynamics of interest-expenditure for a portfolio under certain assumptions. Hereafter, we extend and deepen the analysis considering the actual evolution of interest expenditure without imposing any constraint and we determine the probability distribution of the ESA2010 interest expenditure with respect to a stochastic distribution of interest-rate paths.

10. Classical measures of cost and risk

Classically, the choice of the debt portfolio relies on a trade-off between cost and risk measures that must be statistically defined and based on the government objective function. The most commonly used cost and risk measures are the mean and the standard deviation of the objective function (the ESA 2010 in our case), respectively, but other functions have been developed (see Fig. 4 for a pictorial representation of cost and risk measures) which are more suitable for the management of public debt, like the Cost at Risk.

Figure 4. Schematic representation of the ESA2010 Probability Distribution and associated cost and risk measures.



The Cost at Risk (CaR) is a key reference indicator in debt strategies simulation analysis because it depends on both the expected value and risk characteristics of the probability density function of the interest expenditure (Jorion 2006). The CaR is the maximum value of the interest expenditure that can be expected with a probability *p* over a given time horizon. In formula

$$\mathrm{CaR}_p = \min_x\{x \mid \mathrm{Prob}(E([t_1, t_2]; P, S) < x) \geq p\},$$

where we extend the notation introduced in the *ESA 2010 cost function* Subsection indicating with $E([t_1, t_2]; P, S)$ the ESA2010 cost in the period $[t_1, t_2]$ for a portfolio P of public debt securities, and for a scenario S of the interest rates' evolution. The quantity $E([t_1, t_2]; P, S)$ can be considered a stochastic variable since, for any portfolio P it depends on the scenario S. The CaR indicates the interest expenditure that the Government can expect not to exceed with a confidence level *p*. It offers a simple metrics of the interest cost that the government could incur under unfavorable circumstances. The higher the probability p, the greater is the consideration of unfavorable realizations of the interest expenditure and thus the greater is the attention to risk in the choice of the debt portfolio. Two other metrics of risk are often considered in relation to the CaR: the Relative Cost at Risk and the Expected Shortfall. The Relative CaR is given by the difference between the CaR and the expected value of the interest expenditure over a given horizon. It can be seen as a measure of the width of the interest expenditure probability density function. It is defined as

$$\mathrm{RelCaR}_p = \mathrm{RelCaR}_p - \langle E([t_1, t_2]; P, S)\rangle_S,$$

where, hereafter, with $\langle(\cdot)\rangle_S$ we indicate the average value of the quantity $(\cdot)$ with respect to the random variable S.

The Expected Shortfall (ES) is the expected value of the interest expenditure in case the CaR measure is exceeded. It is defined as

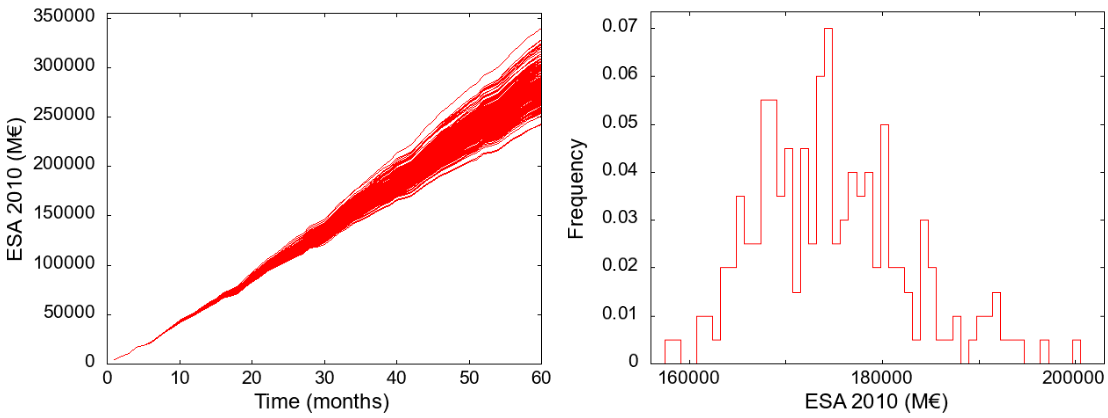
$$\mathrm{ES}_p = \langle E([t_1, t_2]; P, S)\rangle_{\mathrm{S|E} \geq \mathrm{CaR}_p}.$$

ES indicates the expected interest expenditure conditional on the realization of the 1 – *p* percentage of worst possible scenarios. It provides an estimate of the expected interest expenditure under extremely unfavorable circumstances. As the ES depends on the thickness of the upper tail of the probability distribution of interest expenditure, it complements the CaR measure in case of non-normality of the distribution of interest expenditure. As a matter of fact, it is worth noting that if the distribution of interest expenditure were normal, the above-mentioned statistical indicators would be fully determined by the mean and the standard deviation of the distribution.

11. Evolution measures of cost and risk

Before showing an example of cost-risk analysis, it is worth noting there is an important limit in the use of the statistical measures just described: they refer to a fixed time interval. The consequence is that the value of all the measures, and, therefore, the cost/risk analysis, depends on the chosen time interval. However, by using the results presented in the *Analytical study on the ESA 2010 evolution* subsection, in which we showed that, under certain assumptions, there is a linear dependence of the ESA2010 cost on the time interval, we may introduce new quantities that provide robust measures of cost and risk that are only loosely dependent on the time window. As a first example, in the left panel of Figure 8 we show the ESA2010 growth dynamics of the actual portfolio of the Italian government bonds on December 12, 2019 according to two hundred possible scenarios of interest rates.

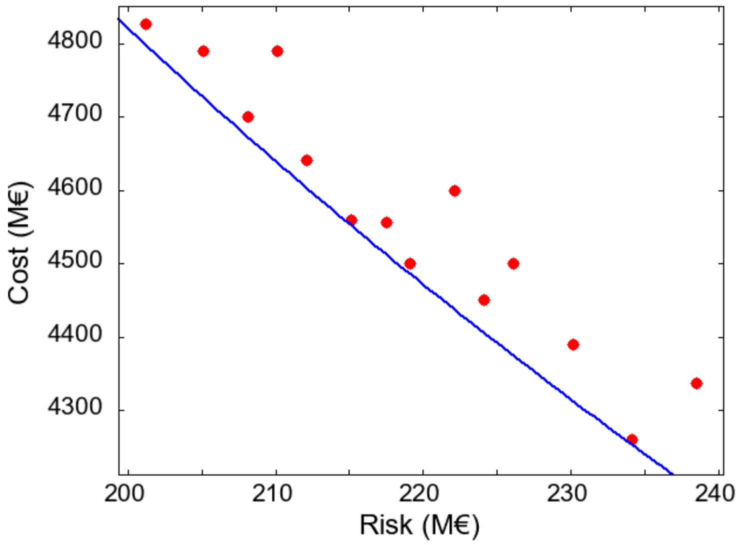
Figure 5. ESA2010 growth path (on the left) and ESA 2010 distribution after three years of simulation (on the right).



At any time of the simulation period (5 years in the present case), it is possible to compute the distribution of the ESA2010 interest expenditure (right panel). As a matter of fact, as showed in Figure 5 also the growth of the ESA2010 cost computed exactly, without any approximation, can be considered, with a good degree of approximation, as linear. In a way similar to what presented in the *Analytical study on the ESA 2010 evolution* subsection, we indicate with $\varphi(M; P, S)$ the ESA2010 cost in month M for a portfolio P of public debt securities and for a scenario S of the interest rates' evolution. To obtain the ESA2010 cost in the time window $[t_1, t_2]$ it is sufficient to compute the sum of the function $\varphi(M; P, S)$ in the period $[t_1, t_2]$: $E([t_1, t_2]; P, S) = \sum_{M=t_1}^{t_2} \varphi(M; P, S)$. Therefore, for the purpose of computing a reasonable approximation of the growth rate of the ESA2010 cost, it is possible to use the function $\varphi(M; P, S)$. However, since the actual growth of the ESA2010 is not perfectly linear, different growth rate metrics may be defined for specific needs of the public debt manager. It is possible to consider the initial growth rate $\mathrm{R}_{t_1}(P, S) = \varphi(t_1; P, S)$ (if one is interested in the early evolution of the debt), the best growth rate $\mathrm{R}_F(P, S) = \frac{\sum_{M=t_1}^{t_2} (M-t_1) \cdot E([t_1, M]; P, S)}{\sum_{M=t_1}^{t_2} (M-t_1)^2}$ (if one is interested in the typical growth), or the final growth rate $\mathrm{R}_{t_2}(P,S) = \varphi(t_2;P,S)$ (if one is interested in the long term growth).

Since with Monte Carlo simulations it is possible to evaluate the performance of the portfolio P over a large number of scenarios, we may define for each of the above mentioned growth rates a probability distribution and the corresponding measures of costs and risks. The idea is that instead of computing the costs and risks measures (such as the CaR) over the ESA2010 distribution at a fixed time, they are computed on the distribution of the chosen growth rate. Therefore, assuming, for instance, that a debt manager is interested in the typical growth rate of the ESA2010 cost, it is possible to generate an efficient frontier, associated to different debt portfolios, by using the average of the best fit to the growth rate $\langle \mathrm{R}_f(P,S)\rangle_S$ and its standard deviation $\sigma\big(\mathrm{R}_F(P,S)\big)$ with respect to a large enough set of scenarios (see Figure 6).

Figure 6. Efficient Frontier.



12. CVA modelling

This Section describes the development of the mathematical model and the scenarios generator, which are implemented in a satellite module of the system dedicated to the calculation of the Credit Valuation Adjustment (CVA) for collateralized derivative transactions.

Prior to introducing the details of the CVA, it is important to understand its purpose within the context of the so called Credit Support Annex (CSA). A CSA is an agreement that regulates the credit support (collateral) to mitigate the credit risk of OTC derivative transactions. It defines the conditions under which, at given dates, collateral is posted, or transferred, between the counterparties that enter into an OTC derivative contract, according to the following elements:

- *frequency*: time interval between two contiguous collateral postings;
- *minimum transfer amount*: the smallest amount of collateral exchanged; below this amount no collateral is posted;
- *threshold*: reference mark-to-market above which the collateral should be posted.

In order to meet specific needs, Italian Treasury customized the canonical CSA framework adding a potentially fourth element to limit the maximum amount of collateral to be posted at each date. This leads to a non-standard framework with increasing cash flows, which gradually should ensure a coverage of the credit risk with a limited burden for Italian Treasury.

Posting collateral against a derivative position usually cancels the credit risk of that position. Compared to a standard CSA, a non-standard framework reduces the credit risk of a certain amount. The metrics to measure this amount is then given by the Credit Valuation Adjustment.

Given a liability portfolio, the CVA is the difference between its value in absence of risk and the value calculated considering a counterparty's default. In other words, it is the credit adjustment applied to derivatives transaction to account for counterparty's default.

Let L_{spot} be the expected losses that can occur in the time interval [0, T]:

$$L_{spot} = lgd \cdot EE \cdot DP$$

where lgd is the loss given default, EE is the expected exposure and DP is the default probability. Assuming the recovery rate is equal to $(1 - lgd)$ and constant at default time, the CVA may be computed with the following expression:

$$CVA = lgd \cdot \int_0^T E^Q[D(t) \cdot EE \mid t = \tau] \, dDP(0,t)$$

The CVA calculation begins with the generation of a set of n scenarios. A scenario is a set of m forward-looking, monthly term structures of interest rates, each one representing the spot curve at i-th month in the future. The number of months usually fits the time-to-maturity of the longest swap in portfolio.

The scenarios are generated through the specification of a standard one-factor Hull & White model. With this model, an array of instantaneous forward rates (short rates), one per each month of simulation, is derived from the following formula:

$$dr(t) = [\theta(t) - \alpha r(t)]dt + \sigma dW(t)$$

where:

- $r(t)$ is the short rate
- $dW(t)$ is a Wiener process σ is the volatility of the short rate
- α is the mean reversion rate
- θ is a drift function

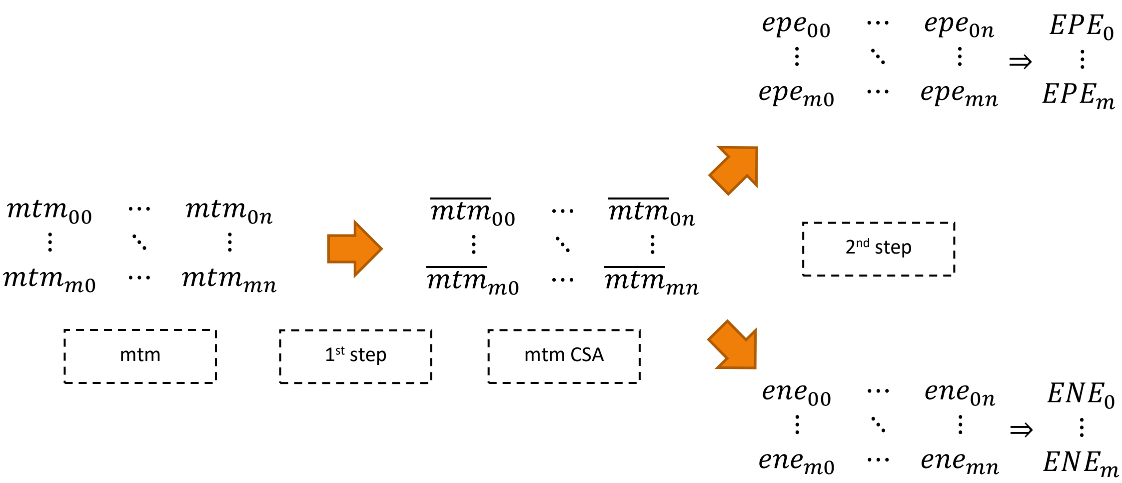
From the simulation of the short rate's path, a full yield curve is generated at each simulation date through an affine function. This term structure represents the single scenario and is composed by one hundred maturities, where each point is the forward rate calculated every six-months, from the maturity of six months up to fifty years.

Latest finance guidelines suggest discounting the future value of a derivative using the factors from an Overnight Indexed Swap curve. This requires to generate two correlated sets of scenarios having the same cardinality: the first on the swap IBOR curve, to determine the forward rates, the second on the swap OIS curve, to compute the discount factors.

The calculation of mark-to-markets is iterated for every swap in portfolio, for each of the n generated scenarios, devising an $n \times m$ array of mark-to-markets, where m is the number of months between the simulation date and the expiry of the swap with the longest maturity.

Generating the raw mark-to-markets rather than the final EE allows to perform further analysis and post-processing, such as the application of the non-standard CSA framework. In this case it has been adopted a two-step procedure where in the first step every mark-to-market is recalculated according to the non-standard CSA constraints described above, while in the second the positive filtered mark-to-markets are separated from the negative ones. Finally, both subsets of mark-to-markets are grouped into two m-sized arrays, which actually contain the Expected Positive (EPE) and Negative (ENE) Exposures for each month of simulation, as shown in figure 7.

Figure 7. EPE and ENE calculation.



Both sets of mark-to-market are stored in a m-sized array.

For each simulation month the Expected Exposure value is discounted by the spot OIS curve and multiplied by the corresponding default probability (DP) derived from the term structure of Credit Default Swap using a standard *moral hazard* model. The final value of CVA comes from the sum of all values in the dataset multiplied by the Loss Given Default.

Since the computational cost of this procedure is incompatible with response time requested by counterparties, there is the need to optimize it by processing multiple scenarios at once. Thus this application follows a multi-threaded approach which ensures a speedup that grows linearly with the number of threads.

In order to manage a heterogeneous set of instruments the logic behind calculations has been moved into a pricing library, to which the application is linked. Currently this library has the ability to price the following types of instruments:

- interest rate swaps
- cross currency swaps
- swaptions

Each instrument is modelled through a class which encloses complex data structures and algorithms needed to perform the calculation of mark-to-market. The major advantages of this solution are:

- reusability: the pricing library can be used, and effectively it is, by other applications
- extensibility: because of its structure, functionalities can be easily added to the library

For example, over time the library has been enriched to manage some features of the swap, such as amortizing swaps, different payment frequencies between the two legs of a swap and break clauses.

The last functionality models the possibility that a swap may be terminated before its natural expiration (early termination option (ETO), leading to a second dataset of raw mark-to-markets. In this dataset, the swap's cashflows after the early termination date are simply discarded and thus the contribution of the swap to the mark-to-market of the portfolio after that date is null.

13. Software Architecture

The Sistema Analisi Portafogli di Emissione (SAPE) software is a quite sophisticated tool [1], made of a set of modules that interact each other through specific Application Programming Interfaces (API) and conventions.

The core of the system is the *Computational Engine (CE).* The CE determines debt cash flows considering the outstanding government bonds and the future (simulated) interest rates. The CE indicates what will be the future issuances of any kind of security based on a given portfolio composition and an exogenous estimate of the budget surplus. In the CE there is full integration among the domestic debt, the foreign currency debt and the derivatives instruments, that results in a complete and detailed description of the portfolio of government securities. The CE computes all the quantities of interest for the public debt manager (*e.g.,* the debt cost according to the ESA2010 criteria, the *duration* of the portfolio, *etc…)* and provides input to the Cost/Risk analysis module. The CE can be used also as an accounting tool to double-check the output of other commercial software products in use at the Italian Treasury for the management of public debt. The CE module is written in C language for efficiency reasons.

A crucial component of the SAPE is the *Interest Rates generation* module that simulates the evolution of interest rates according to the different stochastic models described earlier in this paper, including, among others, the VAR model and the Hull-White one-factor model. All the scenario generators are written in C language.

The *Cost/Risk* module analyses and shows the results of Monte Carlo simulations comparing the performance of different portfolios under several measures of cost, including both the ESA2010 accrual cost and the cash-flow costs in a given time interval. The *Cost/Risk* module makes possible to trace an efficient frontier of the public debt, by choosing suitable portfolios and cost and risk measures. That module is developed part in C language and part in the Perl scripting language. One of the reasons for using Perl is that at the time we started the development of the SAPE, Perl offered a better support for managing (*i.e.,* reading and writing) Excel sheets, that are one of the main output formats required by the Italian Treasury staff.

Finally, there is the CVA module, designed to analyze collateralized derivative transactions as described in the previous Section.

The SAPE software requires input data coming from multiple sources:

i) the *GEDI* (GEstione Debito Italiano) system that provides all the information about new issuances, derivatives, non-domestic securities and interest rates real-time and historical data. Those data are stored in a relational database and retrieved using a Web service;

ii) *t*he *SAPEDB* database of historical issuances that provides information about the outstanding domestic bonds and the historical values of some macro indexes (euribor, HICP, FOI);

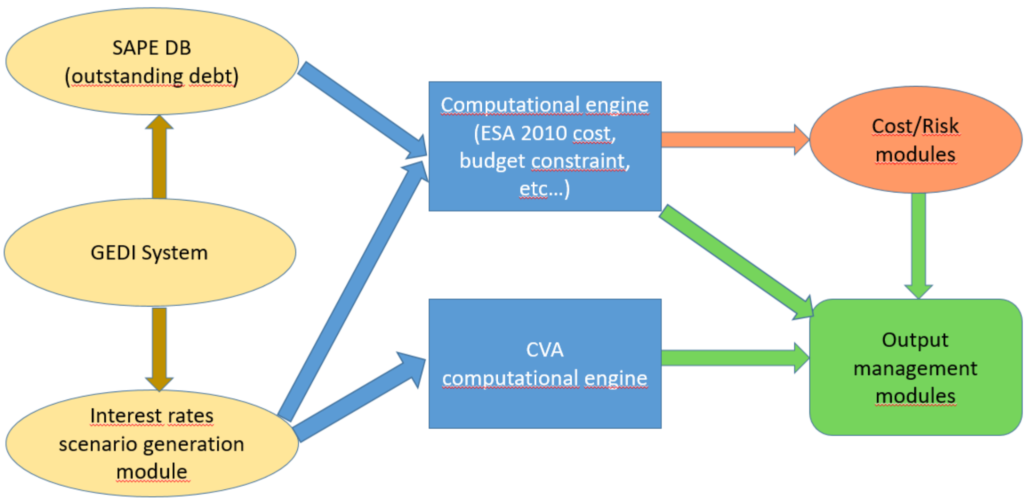
iii) the Interest rates generation module.

Finally, there is an ~~input/~~output module that stores all the relevant files of each simulation in a SQlite database. The database makes search and retrieval operations very easy and efficient. This, in turn, facilitates, for instance, the set-up of simulations that are like others carried out in the past. In addition, this module also deals with the creation of graphs and reports to present the results of numerical simulations in a way that is easy to interpret.

SAPE offers a comprehensive interactive GUI based on Perl/Tk that includes a context-sensitive help. However, it is possible to run many of the software modules also in background to produce results in *batch* mode. In particular, the interest rates generation module can produce thousands of scenarios that can be used for other purposes or simply to carry out a detailed statistical analysis of their behavior. All the software components are highly portable, and they may run on Mac OS X, Linux and Windows, the latter being the platform in use at Italian Treasury premises.

Figure 8 summarizes the SAPE organization and the relations among the modules. In particular, SAPEDB, GEDI and the Interest rate generator are data sources, whereas the CE and the CVA carry out the required computations whose results are analyzed and saved in the remaining two modules.

Figure 8 The organization of the SAPE software



14. Conclusions

The models used by the Italian Treasury for public debt management and the software that implements these models, described in this paper, are the result of a long lasting effort to support the Italian Treasury in their decisions relating to issuance portfolios. The mathematical model of the public debt securities actually issued by the Italian government allows for fine details to be incorporated in the calculations, in order to faithfully reproduce the cash flows of the entire public debt portfolio. This means that the model can be used both as balance computational tool and as an expenditure forecasting tool in a unified framework of analysis.

At the core of the forecasting modules, there is the interest rates scenario generator. Extensive work has been carried out to assure its reliability and guarantee robustness and consistency of subsequent analysis both in terms of cost/risk frontier and CVA computations. The cost/risk analysis relies on a dynamic computation of various cost and risk measures in order to reduce the dependence of the results on a specific computational time window as much as possible.

While the work done to develop the tools described in this paper has benefitted from much academic literature on term structure modelling and credit risk measurement, it should be clear that no existing model in the literature can be used to address the complex issues that surround the debt management operations of the Italian Treasury. This means that several of the research hurdles that were encountered had no solution in existing published research. In general, for example, a government issuing different types of debt instruments (e.g. nominal, inflation-linked, foreign currency denominated) needs tools that allow the generation of scenarios for multiple term structures of interest rates for these instruments simultaneously. Apart from the obvious complexity of endogenously generating multiple term structures, there is a further need to satisfy regulatory or self-imposed constraints in the determination of feasible issuance portfolios, which makes standard cost/risk optimization tools inadequate. This need for multi-term-structure, constrained modelling contrasts with the common approach in published research that tends to analyze a single term structure of interest rates in isolation. We hope that the description of this model and of the general framework within which the Italian Treasury operates in terms of debt management will spur further research among scholars interested in this area which can, in turn, help finding more effective solutions. Indeed, since new circumstances and requirements manifest themselves at regular intervals in the world of public debt management, research and development remains ongoing in terms of models, metrics, and consideration of new types of financial instruments that the Italian Treasury expects to propose to the market.

15. Appendix

15.1 Generation of interest rate curves

In this appendix we present some results about the scenarios generator model of term structures of interest rates and inflation implemented in SAPE. As stated above, the objective of the stochastic model is the production of scenarios that can be used for conducting cost-risk analyses on feasible portfolios of issuances of sovereign bonds. In this regard the parameters of the vector autoregressive (VAR) model are checked regularly for stability and re-calibrated by using most recent market data. Clearly the models considered here are not to be considered as structural models based (solely) on deep parameters, rather as reduced-form characterizations of the unknown underlying process generating interest rates and inflation data. Hence, instability of the parameters is to be expected and re-calibration is required from time to time.

Hereafter, we describe an example of scenarios generation for the cost-risk analyses carried out by the Italian Department of the Treasury. It is worth noting that the data do not necessarily correspond to a distribution of scenarios actually used by the Italian Treasury.

In the example presented below, the stochastic scenarios of the yield curves are generated using the calibration of the model based on the historical sample of data from January 2005 to October 2019. The term structures considered are obtained considering: 12 maturities (from 3 months to 50 years) for the sovereign curve, 10 maturities (from 3 months to 30 years) for the European swap curve, 15 maturities (from 2 years to 30 years) for the European break-even inflation, and 11 maturities (from 3 months to 10 years) for the USD swap curve. This calibration shows excellent in-sample behavior, with very small pricing errors across the daily historical sample. As an illustrative example, in Figure 8 and in Figure 9 is shown the fit of the estimated yield curves for the observations of October 2006 and June 2016 (end of month):

Figure 9 Actual vs Fitted in-sample yield curves

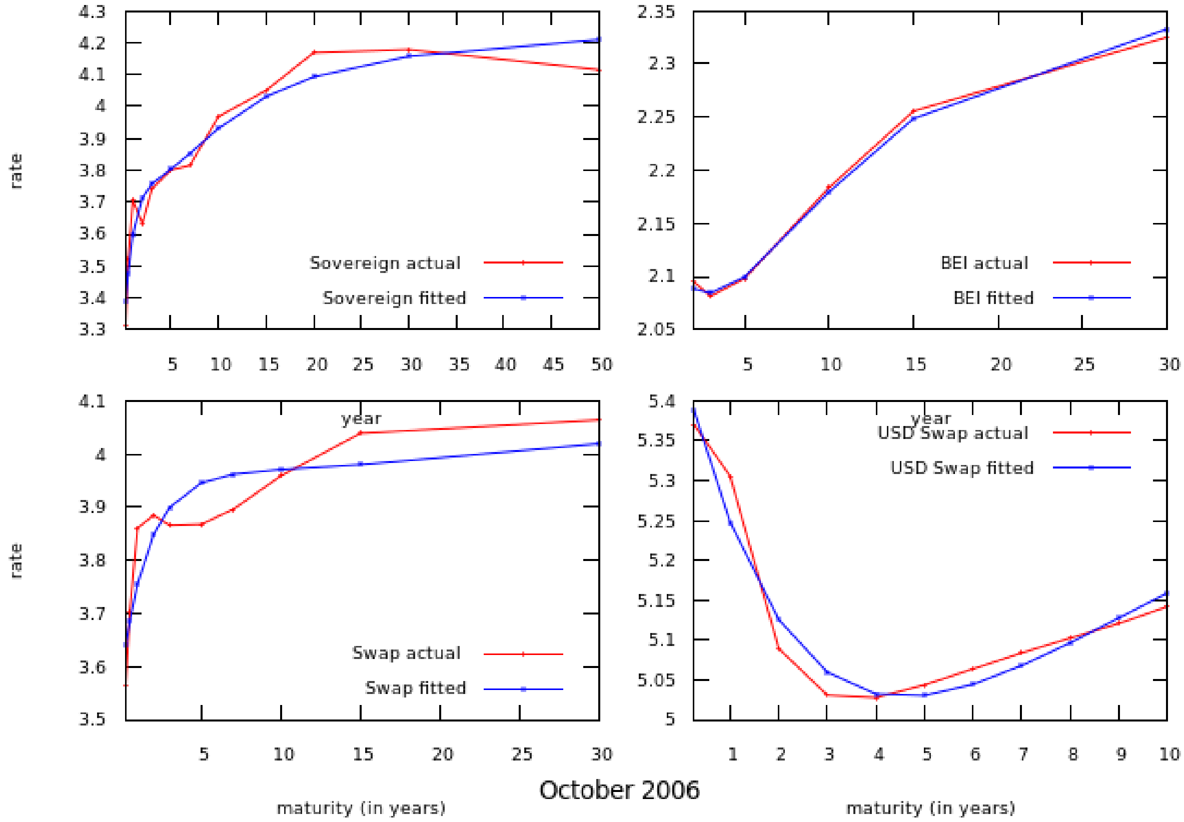
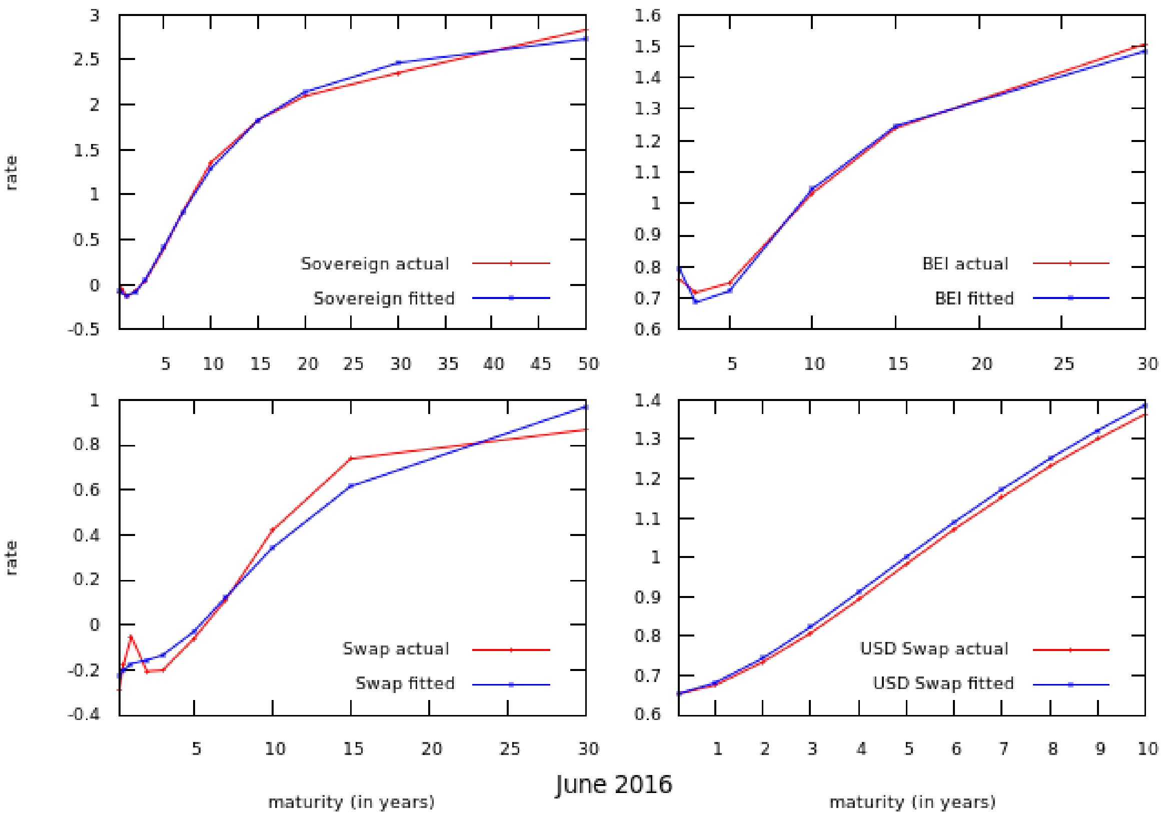


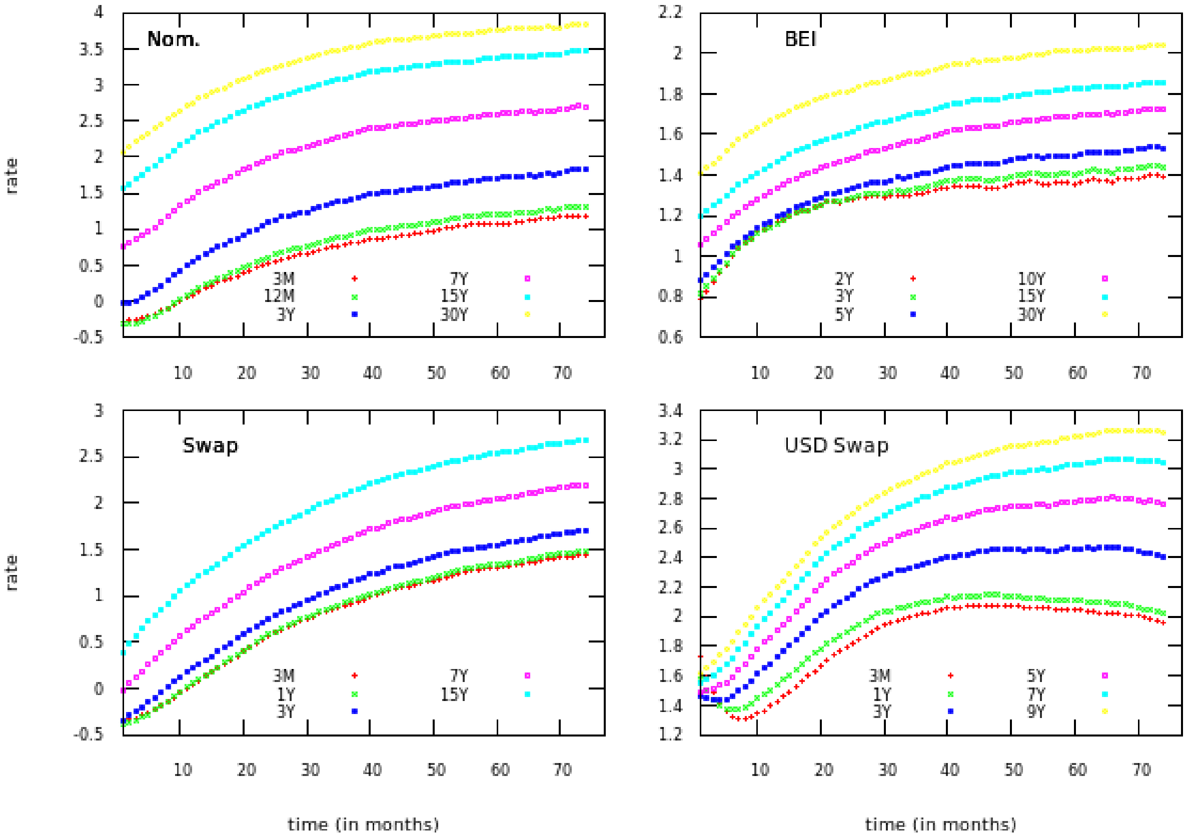
Figure 10 Actual vs Fitted in-sample yield curves



The time series of the β factors of the Nelson-Siegel-Svensson specifications, estimated in sample, are then projected out-of-sample through the generation of stochastic scenarios, obtained by bootstrapping the residual matrix of the VAR system. These scenarios are then used for the following cost-risk analyses on the portfolios of issuances, in combination with the liquidity and refinancing constraints of the Italian public debt structure. Overall, the procedure outlined above defines the stochastic component of the entire process of building the efficient cost-risk frontier on which the Treasury assesses its issuing policy for future periods.

For descriptive and interpretative purposes, it is interesting to analyze the out-of-sample behaviour of the yield curves, through a generation of 5,000 scenarios simulated from November 2019 to December 2025. If we consider a synthesis of the four different yield curves simulated by the model, Figure 10 shows the average out-of-sample behavior of the four term structures.

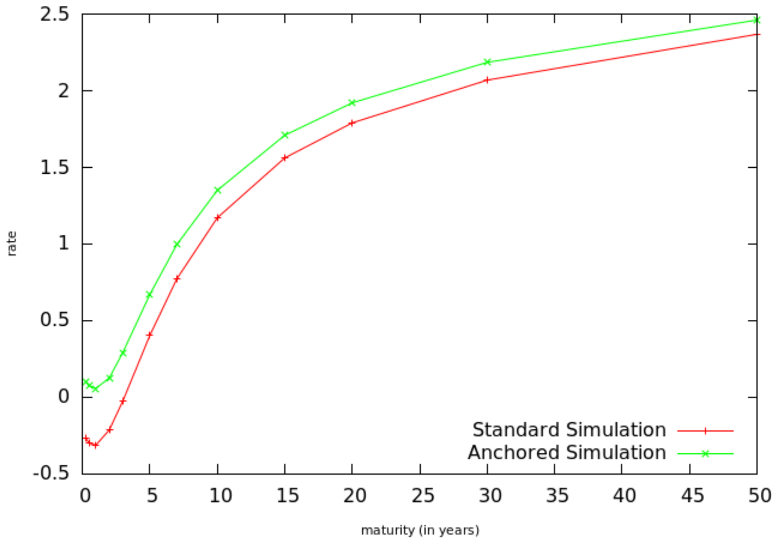
Figure 11 Average out-of-sample scenarios (Sovereign, BEI, Euroswap and USD swap time series)



It is also interesting to observe the behaviour of the curves in case of anchoring the short term sovereign rate (3 months BOT) to an exogenous prior. The anchoring module described in the main text is frequently used by the Italian Treasury for “what-if” analyses, granting the consistency with different hypotheses related to expectations in terms of issuance and monetary policy choices.

For example, assuming a prior of the 3-month rate equal to 0.1% in the first month of the out-of-sample simulation (November 2019), the average rotation (tilt) of the sovereign yield curve turns out to be as follows (see Figure 11):

Figure 12 Anchoring the Sovereign yield curve.



Consistently, all the 5,000 simulated scenarios are tilted applying the monthly increments of the baseline simulation to the first, anchored, out-of-sample observation.

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Optimal Composition of Sovereign Debt: An Adaptation from Modern Portfolio Theory

H.Hakan Yavuz[1] and Umut Gölbaşı[2]

ABSTRACT

Finding the optimal composition of the sovereign debt and the relevant borrowing strategies has vital value for debt managers as accurate strategies would help saving a significant amount of taxpayers' money. This is crucial especially when the level of debt is high. In that regard, exploring the optimal composition and applying targeted policies could contribute to efficiency and effectiveness of debt management policies. Even though converting the current liability portfolio swiftly in order to reach an optimal composition in the short-term would be infeasible due to borrowing constraints in some financial markets, yet it would be an important tool paving the way for approaching a more cost effective composition.

In this paper, we used these borrowing constraints in order to reduce the cost/risk calculation burden of numerous strategy alternatives. That is, setting lower and upper bounds for the shares of borrowing instruments eliminated many infeasible strategies and facilitated reducing the time spent in calculations substantially. Provided that a sovereign has the main requisites of a simulation module, financing program and macroeconomic forecasts, finding the optimal composition could be a straightforward process. Therefore, we believe that it would be a very efficient and clear way to find the optimal composition of debt stock for sovereigns which have several constraints on borrowing options.

JEL Classification: H63, G11, C63
Keywords: optimal debt composition, sovereign debt management, optimal borrowing strategies, simulation modeling

1. Introduction

Public debt managers meet public financing needs by raising funds in both domestic and external markets. These funding often consist of selling fixed income securities, at various maturities, currencies and interest payment structures. The goal of debt managers is to borrow at lowest possible cost, by taking into account risk preferences. Since there is a trade-off between cost and risk, less costly borrowing options usually bring along more risk.

One of the main risks faced by public debt portfolios relate to market risk. Market risk refers to the risk of increases in the cost of the debt arising from changes in market variables, such as interest rates and exchange rates (IMF, 2016). To manage market risks, debt managers use deterministic and stochastic decision-making methods. A widely popular metric to measure market risk is "Value-at-

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Risk", which is generally used by banks and other financial institutions. "Value-at-Risk" is used to control level of risk exposure of a portfolio, that is, extent of possible losses in market value of investments.

In debt management perspective, the focus is not the decrease in market value, but the increase in cost of debt. Therefore, in debt management offices variations of Value-at-Risk are used to control risks, which are "Cost-at-Risk" and "Cash Flow-at-Risk" models. In this context, debt managers need to choose a borrowing strategy based on their risk preferences. Even though there is a bunch of research on finding the optimal composition of sovereign debt on theoretical grounds, the usefulness of these findings in practice is open to debate as the complexity of these methodologies makes them very difficult for high level decision makers to be adopted. In this paper, we propose a plain method to find the optimal composition of public debt derived from a relevant borrowing strategy. To apply the method presented in this paper, the risk managers only should have three modules at their disposal, which can be summarized as follows:

- ***A simulation module*** either stochastic or deterministic, which gives cost and risk characteristics of different borrowing strategies at the end of simulation horizon,
- ***A financing program*** which calculates borrowing need and
- ***A debt stock database*** to be used in simulation module, and a set of macroeconomic projections.

Against this background, the rest of the paper is organized as follows. Section 2 describes the simulation model used by Turkish Treasury for Debt Strategy Analysis, which is the starting point of the procedure of finding the optimal composition. Section 3 describes the method in two stages. First, an efficient frontier is determined among some possible set of borrowing strategies. This set of strategies is specified considering borrowing constraints of Turkey, which can also be constraints of other developing countries. Then a relevant strategy is determined from this efficient frontier. This section also addresses how we reached optimal composition by using the efficient frontier. Finally, Section 4 provides a brief conclusion and main findings of the paper.

2. Turkish Treasury Simulation Model for Debt Strategy Analysis

Turkish Treasury Debt Simulation Model (TDSM) is a stochastic model to assist the borrowing strategy decision making process in Turkish Treasury. TDSM is an in-house built, Matlab based model which has been used since 2003 with several improvements. Briefly stated, it takes initial debt stock, non-borrowing financing sources (i.e. primary balance, change in cash balance, privatization revenues etc.) historic macroeconomic data and borrowing strategies to be tested as inputs. It first simulates macroeconomic variables, then calculates borrowing need and produces related statistics of different borrowing strategies at the end of 5-year horizon as output.

First, the process starts with reading debt stock data, which includes all required information[3] about debt stock. Borrowing requirement stems from service of existing debt, service of future debt (debt issued in simulation horizon) and deficits in non-borrowing items stated above. Calculation of borrowing requirements arises from existing debt stock is fed by this database.

[3] Debt stock database contains following attributes of each issue: instrument type, currency type, amount, value date, maturity date, coupon rate, spread, yield to investor, coupon period and next coupon date.

Second, a financial scenario generator creates projections of interest rates, exchange rates, and consumer price indexes for the 5-year simulation period. A longer horizon could be able to better capture roll-over costs of the bonds issued in the initial years. However, as the simulation horizon lengthens, reliability of macroeconomic variable forecasts become more of an issue. Additionally, it is self-evident that longer horizon results in an increase in time spent in computations. In that regard, considering those pros and cons we kept the simulation period at 5 years.

In the simulation module, short-term interest rates are modelled by using Cox, Ingersoll and Ross (CIR, 1985) and Chan, Karolyi, Longstaff and Sanders (CKLS, 1992) models both with mean reversion properties. To overcome CIR's weakness in predicting long-term interest rates, a hybrid model with both mean reversion and dynamic term-structure fitting features is used to estimate and forecast yield curves for TRY, USD and EUR. As for the term structure part of the hybrid model, methodological approach presented by Diebold and Li (2006) is used.

Exchange rates and price indexes are modelled via geometric Brownian motion, which is a stochastic process based on random walk. Financial scenario simulation also incorporates correlation between macroeconomic variables. The correlation is created by decomposing the covariance matrix using Cholesky decomposition.

TDSM uses the Conditional Cost-at-Risk metric (also sometimes referred to as the expected tail loss or expected shortfall) which is an extended version of cost-at-risk. It focuses on the average of expected cost values in the worst-case scenarios which occur beyond the specified confidence level, rather than a single value on a percentile. This metric enables the user to capture tail risks and includes scenarios beyond confidence interval into decision making process.

Lastly, a cash-flow engine calculates risk and cost metrics of different borrowing strategies. This engine initializes itself with the debt database and borrowing requirements, loops over stochastically generated macroeconomic scenarios, issues new debt and redeems maturing debt. More details about Turkish Treasury Debt Simulation Model can be found in Balibek and Memis (2012).

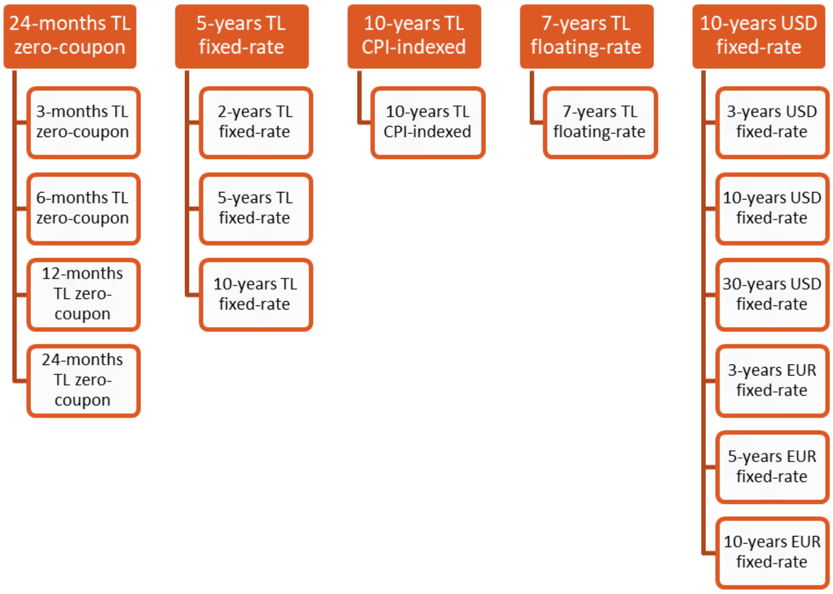
3. An Approach to Find the Optimal Composition of Sovereign Debt

Our approach aims to enable public debt management experts to utilize their borrowing strategy simulation modules in determining optimal debt composition, without requiring any other optimization program. The approach presented here is based on finding a relevant borrowing strategy that lets us reach the optimal composition of sovereign debt. Therefore, first we need to find an "optimal" borrowing strategy.

An optimal borrowing strategy could be found by employing non-linear optimization techniques. However, these techniques increase complexity of the process, which may slow down its implementation and may impede communication with top management. An approach to find optimal borrowing strategy is proposed by Bolder and Rubin (2007). In their work, they underline the computational challenge of optimizing a high-dimensional non-linear function and address the issue approximating the objective function by using function approximation techniques and then to optimize this approximation. Even though, this is a reasonable solution to the problem, the methodology must be simple enough to be communicated to the top level decision-makers.

To deal with computational expenses, complexity of optimization models and the comprehensibility issues, we propose another solution for finding the optimal debt composition. Also, we imposed some simplifying adjustments on borrowing strategies. To determine possible borrowing strategies, we set the granularity of borrowing to be 10% of total borrowing need. All possible strategies are generated via a simple VBA program. Given there are 15 possible debt instruments in Turkish Treasury Simulation Model, we determined 5 debt instruments, which could possess certain characteristics to represent a certain group of instruments (i.e. a single type of USD-denominated instrument is used to represent instruments in foreign currency). The representative instruments are provided in Table 3.1.

Table 3.1: Representative Instruments



Source: Authors' calculations

After finding the representative instruments, by considering risk characteristics of specific types of securities and using judgement about borrowing markets, we set lower and upper bounds to the issuance shares of securities. While doing so, to see the individual risk characteristics of securities we followed a method, in which all borrowing need in a strategy is met by a single security type and we tested 5 strategies. In our case, in spite of limited cost advantage, FX borrowing has the highest risk. On the other hand, highest cost expectation comes from a 100% CPI-indexed borrowing strategy.

Because of high exchange rate risk, we set 30% limit to FX borrowing and 60% limit to other TL borrowing alternatives. We set a zero lower bound to FX borrowing. On the other hand, as exclusion of a specific type of TL borrowing instrument usually affects the costs of other instruments negatively, we set 5% lower bound to TL securities. Upper and lower bounds can be seen in Table-3.2.

Table 3.2: Issuance Limits of Representative Instruments

	Lower Bound	Upper Bound
24-months TL zero-coupon	5%	60%
5-years TL fixed-rate	5%	60%
10-years CPI-indexed TL	5%	60%
7-years floating-rate TL	5%	60%
10-years fixed-rate USD	0%	30%

Source: Authors ' calculations

Our work comprises of two stages. First, an efficient frontier is formed among all tested strategies. Secondly, the relevant optimal strategy is chosen from the efficient frontier.

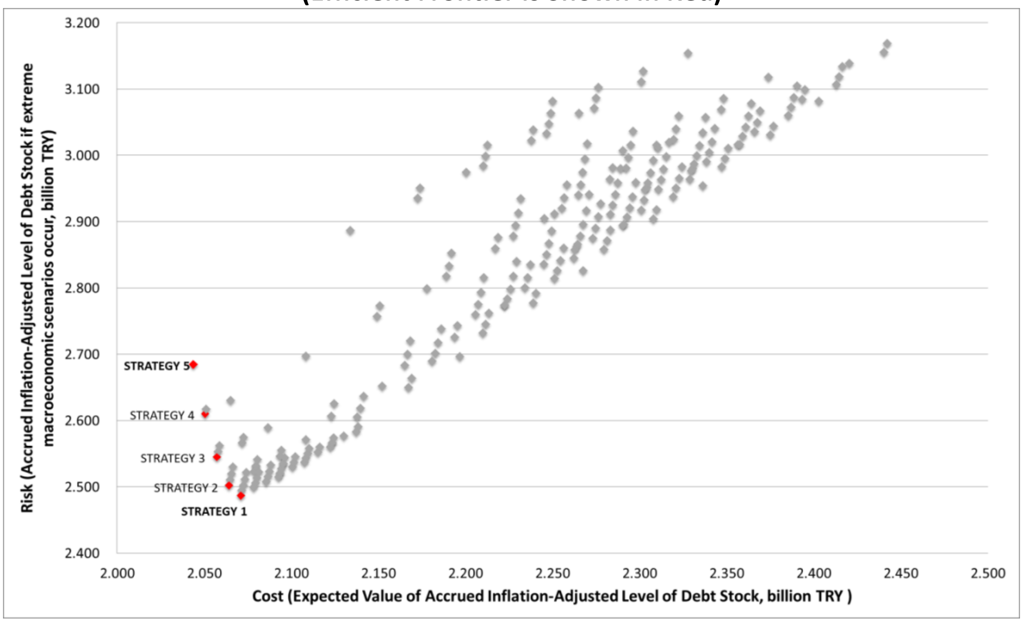
3.1. Finding the Efficient Frontier

To find efficient frontier, under 5-years simulation horizon, we started by testing cost and risk of 191 different borrowing strategies with 10% granularity. After that, the granularity was reduced to 5% and 53 additional strategies were tested. Evaluating 244 strategies with 5000 randomly generated scenarios took 9 hours 26 minutes for a 2016-made computer[4]. If we had not implemented simplifying adjustments mentioned in the previous section, computation time would increase exponentially to unfeasible levels. For instance, setting the granularity for the share of an instrument at 1% requires billions of strategies to be tested. This implies decades-long calculation time and will make it impossible to solve the problem by applying the simple method presented in this paper.

To capture optimal debt stock composition through the relevant borrowing strategy, we started with a state where there is zero debt stock and we kept each strategy unchanged during the course of simulation period. Also, we kept borrowing needs during simulation period same as what real debt stock and mean macroeconomic projections imply. Thus, risk and cost levels of different strategies were not affected by initial zero-stock state. In that regard, starting with zero-stock state enabled us to reveal optimal debt stock composition by using relevant borrowing strategy.

As cost indicator we used the value of "Accrued Inflation-Adjusted Debt Stock" at the end of 5-year analysis horizon. This metric captures accrued interest of CPI-linked bonds and effects of currency fluctuations on stock. Extreme values of these stock figures at the end of analysis period are regarded as the risk indicators. Extreme values occur when extreme macroeconomic scenarios occur. In our work, we aimed optimizing this metric. Figure 3.1 provides the results of 244 different borrowing strategies.

Figure 3.1: Cost-Risk Chart of 244 Different Borrowing Strategies (Efficient Frontier is Shown in Red)



Source: Authors' calculations

[4] Processor: Intel® Core™ i5-6500 CPU 3.20 GHz, x64 based processor. RAM: 8GB.

A visual analysis of Figure 3.1 exhibits that there are some strategies that drag both cost and risk in positive direction. This situation stem from some instruments that have both high cost and risk values. In fact, this methodology can be used to find whether there are any such questionable securities exist in treasury's toolkit. Even though these controversial securities deteriorate the debt portfolio from a cost/risk perspective and signal the debt managers not to use these instruments at all, demand dynamics in the borrowing market might force debt managers to issue certain amount of these instruments. This is a factor, which we need to consider while setting lower bounds to TL instruments. In addition, high correlation between costs of borrowing instruments limits the diversification gains and forces certain strategies containing certain instruments to stand out. To grasp this effect better, please see the compositions of efficient strategies presented in Table 3.3.

Table 3.3: Compositions of Efficient Strategies

Strategies (from lowest to highest risk)	Zero coupon	Fixed-rate coupon	CPI-indexed	FRN	FX-denominated
1	60%	25%	5%	5%	5%
2	60%	5%	15%	20%	0%
3	60%	15%	10%	15%	0%
4	60%	15%	10%	5%	10%
5	60%	5%	5%	5%	25%

Source: Authors' calculations

Instead of a single instrument type (zero-coupon in this case) be prominent, we would normally have expected a more diversified portfolio weights because of diversification gains. However, high correlation of costs between instruments that are all issued by a single issuer, almost cancels out diversification gains. Therefore, an instrument which has slightly better cost and risk characteristics dominates those efficient strategies. Moving from the lowest risk strategy (Strategy 1) to the lowest cost strategy (Strategy 5), an increase in share of FX-denominated instrument is apparent. The strongest cost and risk trade-off occurs between FX and TL instruments. This is because USD 10 year instrument has the lowest correlation with each other instrument. In that regard, new instruments such as a GDP-linked bond here may enhance risk and cost metrics of portfolios because of its lower correlation with other instruments (Yavuz, 2017). Thus, as the introduction of such instruments would change the correlations between instruments, it would lead to notable changes in the efficient frontier (Figure 3.1) and efficient strategies (Table 3.3).

Table 3.4: Correlation Matrix (Jan 2010- Sep 2018)

	Zero2Y	Fixed5Y	CPI	FRN	USD10Y
Zero2Y	1.00	0.98	0.82	0.88	0.75
Fixed5Y	0.98	1.00	0.82	0.87	0.75
FRN	0.88	0.87	0.80	1.00	0.55
CPI	0.82	0.82	1.00	0.80	0.57
USD10Y	0.75	0.75	0.57	0.55	1.00

Source: Authors' own calculations

3.2. Selecting the Relevant Strategy from the Efficient Frontier

Modern Portfolio Theory, pioneered by Markowitz (1952), proposes an approach to reach optimal portfolio composition. But, this approach is to determine optimal asset composition for investors holding different assets. We therefore modified this approach considering borrower position of sovereigns. Details can be found in the Appendix.

First, for each point on the efficient frontier, we calculate the delta of risk value (marginal conditional cost-at-risk (MCCaR)[5]) and the additional cost occurred by the issuance of one additional unit of that instrument for each instrument type. Then, we calculated the marginal risk/marginal cost ratios for each instrument type. After that, among the points on the efficient frontier, the one in which marginal risk/marginal cost ratio is the closest to each other is regarded as the optimal portfolio. This states that, at their current proportions in the portfolio, the trade-off between the cost and risk is equivalent for all instruments and therefore the portfolio is balanced in an optimal way in terms of marginal cost and marginal risk.

$$\frac{\mathrm{MCCaR}_{p1,i1}}{\mathrm{Marginal\ Cost}_{p1,i1}} = \frac{\mathrm{MCCaR}_{p1,i2}}{\mathrm{Marginal\ Cost}_{p1,i2}} = \cdots = \frac{\mathrm{MCCaR}_{p1,i5}}{\mathrm{Marginal\ Cost}_{p1,i5}}$$

$$\frac{\mathrm{MCCaR}_{p2,i1}}{\mathrm{Marginal\ Cost}_{p2,i1}} = \frac{\mathrm{MCCaR}_{p2,i2}}{\mathrm{Marginal\ Cost}_{p2,i2}} = \cdots = \frac{\mathrm{MCCaR}_{p2,i5}}{\mathrm{Marginal\ Cost}_{p2,i5}}$$

$$\ldots \quad = \quad \ldots \quad = \quad \ldots$$

$$\frac{\mathrm{MCCaR}_{p5,i1}}{\mathrm{Marginal\ Cost}_{p5,i1}} = \frac{\mathrm{MCCaR}_{p5,i2}}{\mathrm{Marginal\ Cost}_{p5,i2}} = \ldots = \frac{\mathrm{MCCaR}_{p5,i5}}{\mathrm{Marginal\ Cost}_{p5,i5}}$$

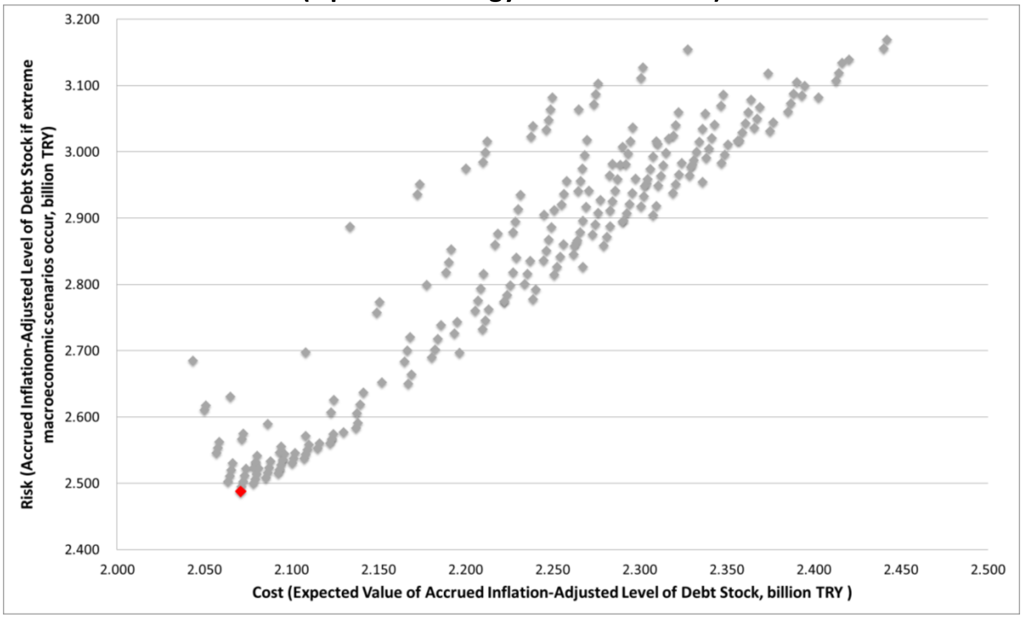
where p = 1…5 denotes portfolios on efficient frontier, i = 1…5 denotes instrument types in each portfolio.

We checked the condition above by comparing ranges, standard deviations and mean absolute deviations of each strategy. According to the calculations, those three metrics are minimum in the composition which implies minimum risk (Strategy-1 in Figure 3.2). Therefore this composition is also determined as the optimal composition. The composition consists of 60% zero-coupon, 25% fixed-rate coupon, 5% floating-rate, 5% CPI-indexed TL denominated bonds and 5% foreign currency denominated bonds. This composition enables the total risk to be reduced by 13 percent and the cost by 9 percent, in comparison to the composition in which all instrument types have equal shares. This amount, of course, can vary depending on the current composition and the strategy that is planned to be applied, yet considering a level of debt stock around USD 200 billion; even the slightest reduction might lead to considerable cost savings.

An important point to consider here is that the macroeconomic assumptions which are the starting point of the weights that lead to the optimal composition and the simulation values obtained based on these assumptions may change over time. Therefore, these assumptions are critical when moving to the optimal composition.

[5] MCCaR can be interpreted as a change in the CCaR for a $1 or 1% change in the position. Although that is not strictly correct, it is a reasonable approximation of the concept behind marginal CCaR, which is to reflect the impact of a small change. In a diversified portfolio, marginal CCaR may be used to determine the contribution of each borrowing instrument to the overall CCaR and the marginal CCaRs for all positions may be proportionately weighted to sum to the total CCaR.

Figure 3.2: Cost-Risk Chart of 244 Different Borrowing Strategies (Optimal Strategy is shown in Red)



Source: Authors' own calculations

4. Conclusions

Sovereign debt managers have the duty of providing the necessary funding for the public expenses in a timely and consistent manner. For that reason, debt management is a continuous process that needs utmost care. In many countries, the public debt stock stands as the biggest liability portfolio in the country. Therefore, even minor improvements regarding the composition of the stock and the borrowing strategies could have major impacts on the cost of debt financing and accordingly the welfare of the citizens. However, it is not always the case that the debt managers have the possibility to use the borrowing instruments in desired size, maturity, level, currency and interest type.

In most of the emerging markets, the development level of the borrowing markets draws the limits for the diversity of borrowing instruments. Those limitations also oblige the use of several instruments more than the desired levels, causing a sub-optimal composition of debt stock and borrowing. Yet, some other factors such as the desire to diversify the sources of funding, reaching out to new investors, providing a variety of investment tools to investors and supporting national reserves might induce the use of instruments, which are not optimal from a pure cost-risk perspective. Such instruments may not directly contribute to the debt management, but they might support other targets such as playing a benchmark role for the corporates, sectoral development and reserve management.

Against this backdrop, we proposed a simple approach to find the optimal composition of debt and the relevant borrowing strategies to reach such composition. The sole requirements are a simulation module, a financing program and a debt stock database. By using these three tools, the user needs to decide the granularity and the upper-lower bounds for the strategies that need to be tested. However, it is important to underline that the models always produce output based on the inputs provided. In that regard, the macroeconomic assumptions play a key role for attaining credible results. Moreover, such assumptions might change over time. For that reason, frequencies of such analysis and calibration procedures for the portfolio are important issues that need to be considered as well.

Nowadays, in the era of advanced technologies we believe that computational needs are not a burden anymore. For instance, in our case with 10% granularity and 5 tenors, we got the simulation results for 244 different borrowing strategies in less than 10 hours even though our models and modules are not optimized for computational efficiency. Such speed could also enable daily calibration and use of active debt management tools, once the optimal structure is obtained.

All in all, the methodology presented in this paper provides a simple and coherent way for practitioners who would like to improve the composition of the debt stock and would like to discover the relevant borrowing strategies for more efficient management of debt.

APPENDIX: Method Used in Finding Optimal Debt Portfolio

According to approaches based on Modern Portfolio Theory, optimal portfolio is defined as the composition, in which the ratio of excess return divided by the per unit change in the risk value of the portfolio when an additional investment of that position is added to the portfolio, is equal to the same constant for each position. In other words, optimal composition is obtained when this ratio for a position is equal to the ratios of other positions.

To recall, Sharpe ratio is a ratio shows the return of an instrument above risk-free return (excess return) per unit of standard deviation of the portfolio.

$$\text{Sharpe ratio} = \frac{Portfolio\ Return - Riskfree\ Return}{Portfolio\ Standard\ Deviation} \quad (1)$$

Value-at-Risk is defined as the value that can be expected to be lost during severe adverse market fluctuations. (Marisson, 2002) If we take Value-at-Risk instead of standard deviation as risk indicator, the ratio turns into as equation (2).

$$\frac{Portfolio\ Return - Riskfree\ Return}{Portfolio\ Value{-}at{-}Risk\ (VaR)} \quad (2)$$

This ratio maximizes when the weights of each position makes the equality below hold for each position or instrument type.

$$\frac{\text{Return}_{instrument\ i} - Riskfree\ Return}{(\text{Marginal Value}-\text{at}-\text{Risk}_i)} = \frac{\text{Return}_{instrument\ j} - Riskfree\ Return}{(\text{Marginal Value}-\text{at}-\text{Risk}_j)} \quad (3)$$

Since there is no "return" and "risk-free return" notions for sovereign Treasuries, we looked at how an additional issuance of an instrument changes the risk taken and the cost borne relative to other instruments. Therefore, considering sovereign borrower position, the general equation in question is modified and applied as follows:

$$\frac{\text{MCCaR}_{1,1}}{\text{Marginal Cost}_{1,i1}} = \frac{\text{MCCaR}_{1,2}}{\text{Marginal Cost}_{1,2}} = \cdots = \frac{\text{MCCaR}_{1,I}}{\text{Marginal Cost}_{1,I}}$$

$$\frac{\text{MCCaR}_{2,1}}{\text{Marginal Cost}_{2,1}} = \frac{\text{MCCaR}_{2,2}}{\text{Marginal Cost}_{2,2}} = \cdots = \frac{\text{MCCaR}_{2,I}}{\text{Marginal Cost}_{2,I}}$$

$$\ldots \quad = \quad \ldots \quad = \quad \ldots$$

$$\frac{\text{MCCaR}_{P,1}}{\text{Marginal Cost}_{P,1}} = \frac{\text{MCCaR}_{\boldsymbol{P},2}}{\text{Marginal Cost}_{\boldsymbol{P},2}} = \ldots = \frac{\text{MCCaR}_{\boldsymbol{P},\boldsymbol{I}}}{\text{Marginal Cost}_{\boldsymbol{P},\boldsymbol{I}}}$$

Turkish Treasury adopted "Conditional Cost-at-Risk" method to compare alternative borrowing strategies and to determine a benchmark borrowing policy. According to this method, the average of cost values, which are expected to occur in the tail of the cost distribution, is accepted as risk measures. The cost distribution is obtained via Monte Carlo simulations with 5000 iterations. Occurrence of those tail scenarios depend on the occurrence of tail scenarios in financial scenario generation module (i.e. macroeconomic scenario simulations).

In Marginal Cost and Marginal Risk calculations, one percent of total borrowing requirement is set to be one unit of additional issuance. However, to isolate the effect of this issuance to risk and cost measures, this additional issuance is not meet by decreasing the issuance of other debt instruments but by increasing the borrowing 101 percent of borrowing requirement. Since Marginal Risk/Marginal Cost ratio is examined only within a strategy for each type of instruments in that strategy, 101 percent borrowing has no effect on comparing between different borrowing strategies.

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Specialists' Incentives on Government Bond Markets: Lessons from the Italian Case

Filippo Mormando[1] and Luciano Greco[2]

Abstract

MTS Italy is the Italian government bonds wholesale secondary market that operates under the *specialist system*. In order to encourage specialists to provide a high level of liquidity, the Italian Treasury monitors and publicly ranks their performance. This paper investigates whether the ranking system, through its explicit and implicit incentives, effectively affects market makers in their quoting decisions and, consequently, the liquidity conditions of order books. The empirical analysis, based on difference-in-differences models, identifies these effects on specialists' quoting behavior. Furthermore, the paper highlights a heterogeneous impact among market makers, suggesting these operators are differently exposed to the potential benefits of a ranking system. These results provide important implications for policymakers in the design of financial markets and suggest that traditional microstructure models and empirical studies can be enhanced by taking into account incentives provided by the ranking regime when it exists.

JEL Classification: D47, G12, G14, G18, H63.

Keywords: Market microstructure; Market makers; Monitoring rules; MTS.

1. Introduction

In recent years, the debate about the restructuring of the regulatory framework of financial markets has increased significantly. In Europe, the structure and the design of Government bond markets are one of the main concerns of regulators and policymakers. Studies, linked to the European sovereign debt crisis, have clearly highlighted that market microstructure and liquidity risk are crucial components that affect sovereign borrowing cost, especially during periods of distress and turbulence (D'Agostino and Ehrmann (2014)).

For sovereign issuers, a good functioning of the secondary market provides an essential supportive environment for the primary market, by which the sovereign entities issue their bonds to investors. A good design of secondary market implies a reduction of liquidity risk and the corresponding premium demanded by investors, leading to lower bond yield and sovereign debt cost.

In the European case, the Secondary markets for government bonds operate under the *market making system*. Market participants are divided into two groups: market makers and market takers. Market makers face quoting obligations: they quote continuously the bid price (on which market takers can sell the bond) and the ask price (on which market takers can buy the bond). Thus market makers offer market liquidity, and they are subject to several regulations on pre and post-transparency, on capital and organizational requirements.

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Looking at the Italian case, MTS Italy is the secondary wholesale market of Italian government bonds[3]. It is defined as a *wholesale* secondary market, implying only banks and institutional intermediaries may be admitted as dealers. Among market makers on MTS Italy, a group of selected dealers act as *specialists* of Italian public debt, facing, other than quoting obligations on MTS, other duties in terms of activity in the primary and in the repo markets. These operators benefit from some privileges, explicitly defined by the Specialists' Decree of the Italian Ministry of Economy and Finance (henceforth MEF or Italian Treasury). In order to verify the compliance on their duties and obligations, the Italian Treasury monitors their activity continuously on primary and secondary markets. At the end of each year, based on the overall evaluation, the MEF calculates the final ranking and publishes the first five specialists. Monitoring rules and the public ranking regime are employed by the Italian Treasury in order to push specialists to compete in the liquidity provision. These operators are so subject to both market makers' obligations and specialists' duties defined by the MEF.

The contribution of the present study is threefold. First, it highlights that liquidity conditions are affected by monitoring rules, not only due to their compulsory nature but also through the incentives linked to the correspondent ranking system. Second, this study suggests that specialists are exposed heterogeneously to the benefits (and costs) of being in the top positions of the final ranking. Third, these results significantly contribute to the debate about the restructuring of markets design, highlighting that monitoring and ranking regimes may increase market competition, leading to better market quality.

The paper is organized as follows. The next section presents the literature related to market microstructure models, regulatory changes, the correspondent impact on market makers' behavior, and a review of studies on liquidity conditions in MTS markets. Then, section 3 presents MTS Italy platform, the specialists' evaluation criteria, the ranking system laid down by the Italian Treasury, and the first testable prediction. Section 4 discusses methodologies, data, and the main results of the econometric analyses on the first prediction. Section 5 formally assesses the second prediction about the heterogeneous response of different market makers to the new market rules. Section 6 present other robustness checks of the basic analyses. Concluding remarks are offered in section 7.

2. Related literature

Market microstructure models examine the process by which institutional market rules, investors' demands and traders' heterogeneity interact and are translated into transactions and price variations. Market makers play a crucial role in this process: they stand ready to buy and sell a particular amount of an asset on a continuous basis at a publicly quoted price. If v_t is the public fair value of a risky asset at a some point in the time t, market makers set the bid price b_{vt} ($< v_t$), on which investors are able to sell the asset, and the ask price a_{vt} ($> v_t$), on which investors can buy the asset. The bid-ask spread should compensate market makers for their immediacy of transaction and for other costs that they implicitly and explicitly face: operation costs, participation costs, transaction costs, asymmetric information, imperfect competition, inventory control costs, funding constraints and search. Vayanos and Wang (2012) provide an exhaustive survey on theoretical work and empirical literature on these imperfections. Among implicit costs, the existing literature extensively studies asymmetric information costs (Copeland and Galai (1983), Glosten and Milgrom (1985), Easley and O'Hara (1987), Admati and Pflederer (1988), Foster and Viswanathan (1990), Holden and Subrahamanyam (1992), Romer (1993)) and inventory control costs (Garman (1976), Stoll (1978), Amihud and Mendelson

[3] MTS Italy is the most important electronic market for Italian government bonds since it has the highest market share in terms of trading activity among electronic platforms (Consob -- biannual bulletin June 2017).

(1980), Ho and Stoll (1981, 1983)). Asymmetric information costs arise when some investors are better informed about the true value of the asset. If market makers are not able to distinguish these investors, they set bid and ask prices taking into account the risk of dealing with a more informed investor. Inventory-control cost arises when imbalances of buying and selling flows increase. Market maker, setting their bid-ask spread, should consider the risk of holding inventories that may deviate from their desired position and causing losses if prices move against. If they already own a significant long (or short) position, they set the bid and ask prices in order to facilitate the turnover of the position.

Different from the previous literature that limits the specialist' choice to the bid and ask prices in order to compensate several implicit and explicit costs, Kavajecz (1998) proposes the first model in which a specialist chooses prices and depths jointly in order to maximize her profits. He found that prices and depths are used as substitutes: a narrow bid-ask spread induces small depth quotes whereas large depth quotes induce a wide bid-ask spread. These depths quotes are not, however, the familiar depth parameter discussed in the Kyle (1985) paper, rather they are quantities that specialists post in real time and that are available at the posted price (Kavajecz, 1998). Kavajecz (1999) and Caglio and Kavajecz (2006) link the specialist's choice of quoted depth and tightness of its bid-ask spread in order to face the adverse selection risk. Specifically, they found that specialists decide to reduce their exposure risk, reducing their quoted size, when they face an increase in the amount of adverse selection or in price uncertainty. These works are the main references for our study since it focuses on the opportunity for specialists, provided by the new monitoring rules, to manage both prices and quantities in their quoting proposals.

The second strand of literature refers to the empirical analyses on the impact of changes in quoting obligations on market makers' behavior. Only few of these changes affect directly the obligation on the minimum quantity set by market makers. McInish, Van Ness and Van Ness (1998) have examined how the change in the Actual Size Rule (ASR) affected Nasdaq market quality. They find a negative impact on the quoted depth and a positive effect on the number of small quotes in the 10 days after the implementation of the new rule. Porter et al. (2006) investigate the link between the ASR change and periods of market stress. They find that ASR may significantly reduce market quality in times of financial distress. Chung and Zhao (2006), employing both cross sectional and intertemporal analyses on Nasdaq stocks, find that dealers post large depths when their quotes are at the inside[4] and frequently quote the minimum required depth when they are not at the inside, leading to a negative intertemporal correlation between dealer spread and depth. Other previous studies of the spread-depth interaction focus on specialist quotes on the NYSE. However, our paper differs from these studies since the MTS setup is substantial different from equity markets. The main difference in the market structure is that in MTS, only the group of market makers quotes simultaneously the whole group of Italian government bonds, while in NYSE each stock has just one specialist that faces the quoting obligation and acts competitively with limit orders of other investors. Gozluklu et al. (2015), employing a dataset on Borsa Italiana, investigate how market quality has been affected by the reduction of the minimum trade unit (MTU). They find a substantial improvement of liquidity driven by the reduction in adverse selection and by the increase in retail trading. However, Gozluklu setup and other previous studies on the reduction of MTU (e.g., Amihud et al., 1999) differ from this paper since our focus is on quoting obligation and not on the opportunity to increase liquidity with low entry barriers in stocks trading.

In addition, a wide literature exists on the effect of other regulatory changes in financial markets. For instance, the effects of changing the minimum tick size has drawn considerable attention. The tick size

[4] Inside quote represents the best bid or ask prices of the quoting book. The inside quote is the prices at which market order will be executed.

is the minimum price movement of a trading instrument. Harris (1994) hypothesizes that a smaller tick size is likely to cause a reduction in the bid-ask spread since to the removal of the artificial ceiling allows investors to place limit orders at prices which were previously unavailable. Empirical studies, applied in different markets, confirm these hypotheses (Goldstein and Kavajecz (2000), Chung and Chuwonganant (2004), Ahn and al. (2007), Buti et al. (2013), Lepone and Wong (2017)). Other studies assess the impact of ban on stub quoting that should narrow volume weighted bid-ask spread and reduce the price impact leading to better liquidity conditions. Findings of Egginton and al. (2016) are consistent with these hypotheses. These studies differ from our paper since the rule changes concern different characteristics of the market design and because, as mentioned above, other important structural differences exist between MTS and equity markets.

Finally, this paper is related to the literature on MTS market, one of the most important electronic trading platforms of European government bonds with a peculiar organizational setup. As discussed above, this market differs substantially from equity markets. Cheung at al. (2005) provide a first extensive description of the European bond market and investigate some aspects of the microstructure of MTS markets, as the link between Euro MTS and domestic platforms. Coluzzi et al. (2008) analyze the microstructure liquidity evolution on MTS Italy employing a wide set of different liquidity measures. Later, Darbha and Dufour (2013b) review the microstructure of Euro area government bond market, including the high number of studies linked to the European sovereign bond crisis. Pelizzon et al. (2016) study the evolution of liquidity measures during the Euro-zone crisis in the MTS Italy, highlighting the links with sovereign risk and ECB's intervention through LTRO and OMT programs. Pelizzon et al. (2014) investigate the links between the cash (MTS) market and the correspondent futures market (Eurex) in price discovery and in liquidity discovery processes. Paiardini (2015) studies how economic news are incorporated in MTS markets. Cafiso (2015) investigates the connections between primary and secondary markets, employing data on the Italian case. Scheneider et al. (2016), employing a dataset that runs from 2011 to 2015, study the spillover effects of shocks in liquidity conditions among different segments of BTPs.

MTS provides also a platform to execute repos on government bonds[5]. Since market makers face order imbalances and manage scarcity risk, a good functioning of repo market is crucial in order to guarantee high level of liquidity in the cash market. Corradin and Maddaloni (2017) study how supply and demand shocks (e.g., ECB's intervention) affect the bond scarcity premia (specialness) in the repo market of Italian securities.

3. Institutional details

3.1 MTS Italy market structure

MTS was introduced in 1988 by the Italian Treasury and it was the first electronic market for government bonds in Europe. In 1997 it was privatized and it started expanding across other public debt issuers. The main reason for the launch of MTS was to create a supportive environment for the big changes that were ongoing in the primary market, namely the evolution in the placement technique of government bond from a system of firm sale to a predetermined group of banks to an auction-based system, where all market players can participate and bid competitively for the amount of bonds announced by the issuer. In 1998 MTS has become a *Regulated market* owned by the private sector. The set of rules according to which the market for wholesale trading in government bonds

[5] Miglietta et al. (2015) documents that the market share of MTS repo platform is close to 90%.

works is laid down by the Italian Treasury, while the supervision is under the control of Bank of Italy and Consob (the Italian supervisory authority for the investor's protection).

The Italian Treasury issued two main regulations in 1999 and 2009 that reaffirmed MTS as a pure interdealer platform with market making obligations, high levels of transparency both pre-trade and post-trade, even before MIFID 2 requirements. These decrees also set the rules for specialists. Measures to create an efficient secondary market were adopted within the general framework of public debt management policy, aimed at achieving a structural minimization of funding cost, increasing liquidity for government bonds through an electronic system, which makes transactions very easy to be executed, providing a clear picture of market conditions for the market participants by means of a continuous "on screen" availability of bid-ask prices, helping the issuer in the placement of specific bonds offered at auctions (Iacovoni, 2017).

Currently, MTS Italy is the domestic trading platform of Italian government bonds of MTS markets. It is defined as a wholesale secondary market, implying that only banks and institutional intermediaries are admitted as dealers and participate on their own account (or on behalf of institutional investors but as a direct counterpart).

Similar to the other MTS markets, the Italian platform is a quote-driven electronic order book market. Participants are divided into two groups: market makers and market takers. As discussed above, the role of market makers is to provide liquidity continuously, quoting two proposals (bid and ask prices) that are aggregated in the order book for each bond. Other participants, acting as price taker, can buy and sell a certain amount of a bond, hitting the proposals with a market order. Other important features of MTS markets are that the proposals are anonymous (the counterpart is revealed only if at least one of the two dealers settles bilaterally) and market makers are not forced to show the maximum quantity they are willing to trade. Market maker could show only a partial amount of its proposal, maintaining the priority for the entire size of the proposals (both disclosed and undisclosed quantities)[6]. However the undisclosed size has to be at least equal to the minimum lot size (€2 millions), defined by MTS market rules.

3.2 Evaluation criteria of Specialists in Italian Government bonds

In 1994, the Italian Treasury introduced a new category of operators: the specialists. Originally, this group was composed by selected primary dealers operating in MTS Italy. The aim was to enhance the demand at auctions, the liquidity conditions in the secondary markets and assisting the Treasury with advice on debt management policy issue (IMF Guidelines for Public Debt Management, 2001). Since 1994, the list of specialists has been modified several times: when a new specialist arrives (e.g., Barclays in September 2004, Nomura and HSBC in January 2005) or an old one decides to limit its participation in Italian sovereign bonds activity (e.g., UBS in July 2018). Note that specialists are necessarily market makers in MTS Italy, the contrary is not always true. However, as discussed in the following sections , the market share as fillers[7] in MTS Italy of the whole group of specialists is very high (*i.e*. more than 90%), indicating that the liquidity provided by market makers, that are not specialists, is negligible.

The Italian Treasury clearly explains in its decrees (e.g. *Selection and evaluation of Specialists in Government Bonds Decree*) which privileges are provided for banks that act as specialist in its

[6] Buti and Rindi (2013) find that operators have a strong incentive to choose a quantity very closed to the minimum size since they face exposure costs that arise when agents, submitting large orders, run the risk of being undercut by aggressive traders.
[7] As mentioned above, market makers set their quotes defining prices and quantities that they are willing to trade. When a price taker (the *aggressor*) decides to hit the proposals in the quoting book, the counterparts of the deals are market makers that act as *fillers*.

government bond market. The Ministry guarantees to the whole group of specialists exclusive access to reserved reopenings of government bond auctions[8], to the selection of lead managers of syndicated issuances, of dealers for bilateral buyback operations and for derivative transactions. In order to verify the compliance of specialists on their duties, the Italian Treasury monitors their activities on primary and secondary markets continuously. At the end of each year, based on the overall evaluation, the Italian Treasury calculates the final ranking and publishes the first five specialists on the Italian Public Debt website.

In its evaluation criteria, the Italian Treasury defines general principles, specifies the requirements which need to be fulfilled by each specialist (e.g. the allocation on an annual basis of a share no less than 3% of the total volume issued by the Treasury) and lists the specific criteria for monitoring specialists' activities, with formulas and practical information. The Ministry monitors that specialists efficiently and continuously participate in the placement auctions, in the secondary markets, in the repo market and contribute to the management of public debt through advisory and research activity.

With respect the activity on the secondary market, the Italian Treasury requires that each specialist has to contribute to the efficiency of the market and the orderly execution of trading[9] and determines the criteria to evaluate specialists so as to establish the contribution to the efficient functioning of the trading venues.

3.2.1 Specialists evaluation criteria introduced in 2015

Looking at the 2015 criteria, the most important criteria on the primary market activity, in terms of contribution for the ranking (33 points), is the Primary Quantitative Indicator. Each specialist is assigned a score in proportion to the share in the primary market allocation. The score begins to be assigned with the allocation of a share of at least 3% up to a maximum level of 6%. The score assigned to each specialist is given by: $(Q_s\text{-}3\%)*33/(6\% - 3\%)$, where Q_s is the specialist's share in the primary market.

Looking at the criteria on the secondary market, the Treasury defines four indicators: the quotation quality index (QQI), the traded volumes (TV), the number of bonds traded as filler (NBTF) and the large in size contract (LSC).

The QQI is an indicator based on high frequency snapshots, made on each market day, on the order book of each bond for each specialist. For each snapshot, the ranking of the specialist in the order book of the bond with respect the best ranked specialist (both for the bid and ask sides) is recorded. To calculate this indicator only proposals associated with visible quantities equal to €5 millions are considered. For each bond, the average ranking of the specialist is calculated relative to the market day. To calculate the average ranking, each position in the order book is weighted with increasing coefficients that are in proportion to the position in the order book with respect to the best price, in order to reward more those dealers that continuously show the best prices both for the bid and the ask sides. Thus QQI measures the contribution of each specialist in narrowing the best bid-ask spread. The higher is the contribution, the lower is QQI. At the end of the year, the specialist with the lowest QQI is assigned 8 points. The other specialists are rescaled with respect to the best one. The TV index measures the market share of trading activity of each specialist in MTS Italy. The parameter is calculated with two subsequent weightings, the first takes into account the type of bond traded (BOT,

[8] Reserved reopenings give to the Specialists the right to buy predetermined additional quantities of the issued bond at the price settled at the auction. The application deadline is fixed at 3.30 p.m. of the business day following the auction. Thus it represents a free call option on the issued bond. We refer to Coluzzi C. (2011) for an extensive discussion on the value of this option for specialists.

[9] Specialists Evaluation Criteria Decree Year 2018 , Article 3.

CTZ, BTP, CCT), the second discriminates the volumes traded as filler (weight equal to 1) or volume traded as aggressor (weight equal to 0.50). The best specialist is assigned a score of 8 points. NBTF measures the ability of each specialist to trade, as filler, the highest possible number of bonds on MTS. To the best Specialist are assigned 4 points and a score between 0 and 4 is proportionally assigned to the other specialists. Lastly, LSC measures the contribution of each specialist to provide size to contracts traded as filler. All contracts larger than or equal to a threshold size are selected. The threshold size, for each class of BTPs, is defined by averaging the size of contracts traded during the observation period within that class. Then the Treasury calculates the share of each Specialist as filler. The specialist with the highest indicator is given a score of 2 points.

Other indicators refer to the activity in the repo market, in the buyback or exchanges transactions and in evaluating the organizational structure.[10] The total maximum score is 100 points and specialists compete for the first five positions, in order to be published in the final ranking.[11]

3.2.2 Changes in evaluation criteria in 2016

The Italian Treasury may decide to modify monitoring and ranking criteria every year. As explained in the introduction, this paper employs the changes between 2015 and 2016 on criteria of the secondary market in order to verify whether and how market liquidity is affected by the ranking rules. As a matter of fact, the changes in the criteria for 2016 ranking modified some important features only in the segment of BTPs with residual maturity longer than 10 years, providing a quasi-natural experiment. The Treasury has changed several times the monitoring rules, but these changes are different from those occurred in the past: in most cases, rules were modified homogeneously among bond segments (i.e., introducing new criteria applied to the whole group of bonds); actually the changes of 2016 determined both temporal and units discontinuities. Therefore, the variation between 2015 and 2016 is suitable to detect the causal effect of monitoring rules on liquidity conditions.

The timeline of the events is as follows: On November 20th 2015, the Italian Treasury invited specialists to communicate their proposals for potential changes to be introduced in the 2016. On December 9th, the Treasury, collected specialists' comments, discussed with them its definitive proposal on how to modify the monitoring rules for 2016. On December 15th, the Treasury formally confirmed the set of changes for the new year. Lastly, on January 4th (the first trading day of the year), the new regulation has entered into force.

The changes with respect to 2015 were mainly designed to encourage market makers to provide higher liquidity in the group of BTPs with residual maturity longer than 10 years. With respect the quoting and trading activities on MTS, the Italian Treasury modified in two ways the calculation of the four indicators of secondary market. Firstly, the minimum size required for the evaluation of QQI on nominal BTP with maturity longer than 10 years was removed and became €2 millions, the minimum required size defined by MTS rules. Secondly, in order to offset the potential negative impact of this change on the depth of the quoting book, the Treasury doubled the weight for this group of BTPs in calculating QQI, NBTF and LSC indicators and increased the weights of these BTPs in calculating the

[10] The full list of criteria, coefficients of QQI and weights of TV are available on the website of the Italian Treasury at the link http://www.dt.mef.gov.it/en/debito_pubblico/specialisti_titoli_stato/criteri_val/index.html?selezione-anno=2015#selezione-anno, 5 March 2020.

[11] Note that, although the rules about mandatory exclusion from the list of specialists are clearly listed in the MEF's decrees, in the last decade no case of exclusion has occurred. Conversely, cases of banks that voluntarily decide to suspend their activity as specialist occurred several times. In this sense, there is not a competition to comply the minimum compulsory conditions set by the Italian Treasury, actually if banks compete for the ranking, they do that to be published in the five top positions.

trading volume share of each specialist in the secondary markets (TV index).[12] In this way, specialists face a trade-off in choosing their quoted depth: if they reduce to €2 millions their proposals, then they benefit from lower quoting risks but they also reduce their expected scores in the final ranking.

With the new monitoring rules[13], the Italian Treasury aimed at incentivizing market makers to narrow their bid-ask spread in the longer maturity BTPs group, allowing them to reduce their quoted quantities. However, modifying also the weights on TV, NBTF and LSC indices, each specialist should set its quoted prices and depths in order to maximize her expected returns from market making activity and her expected score for the final ranking.

3.2.3 Prediction n. 1

In the light of the previous discussion, we can summarize the following testable empirical prediction.

Prediction 1: Ranking system, acting on market makers' quoting decisions, affects positively the conditions of market liquidity.

Monitoring rules and ranking system may affect quoting preferences of market makers. In a *pure specialists* market, as the previous chapter has explained, the quoting book aggregates only specialists' proposals. Since ranking system increases competition among specialists, the final effect is a positive impact on aggregated liquidity conditions. In the empirical application, we use the changes between 2015 and 2016 to assess whether a variation in the monitoring criteria affects the microstructural liquidity offered by specialists. Since the dataset does not provide information at the individual market maker level, the focus is on the structure of the quoting books. However, the book is just the aggregation of the proposals provided by market makers; employing suitable liquidity measures, one may infer on the aggregated market makers' quoting decisions.

4. The causal effect of changes in monitoring rules on market liquidity

This section discusses econometric approaches to estimate the effect of monitoring rules and ranking systems on liquidity conditions of the quoting book (*Prediction 1*). The analysis employs the changes in evaluation criteria between 2015 and 2016. In practice, an analysis on individual level cannot be performed but, since the order book is the direct aggregation of the proposals of specialists, the paper estimates the causal effect of the new market rules on a set of liquidity measures of the quoting book. The changes in specialists' evaluating criteria entered into force from January 4th 2016 and affected some market making features and obligations in the segments of BTPs with residual maturity longer than 10 years. The impact of the regulatory switch on liquidity measures is investigated using a standard panel regression model with individual and time fixed effects.

4.1 Data and methodology

The analysis considers the period between September 1st 2015 and April 29th 2016 and selects bonds that, in line with the regulatory variation, were closed to the threshold of 10 years as residual maturity. These bonds are those included in two classes of BTPs defined by the Treasury for TV index around the 10-year maturity: seven bonds with residual maturity between seven to ten years (the control

[12] The weights for 2016 are reported in the Specialists Evaluation Criteria Decree, 2016, no. 104582, Art. 5, Par. 3, available at the link: http://www.dt.mef.gov.it/en/debito_pubblico/specialisti_titoli_stato/criteri_val/index.html?selezione-anno=2016#selezione-anno , 5 March 2020.
[13] Specialists Evaluation Criteria Decree, Ministry of Economy and Finance, Treasury Department, available at the link: http://www.dt.mef.gov.it/en/debito_pubblico/specialisti_titoli_stato/criteri_val/index.html?selezione-anno=2016#selezione-anno , 5 March 2020.

group that has not been affected by rules' change)[14] and eight bonds with residual maturity between ten to fifteen years (the treatment group)[15]. This specific classification is defined by the Italian Treasury in its Specialists Evaluation Criteria Decree to evaluate the specialist's activity in the primary and the secondary markets, with the aim to aggregate different bonds in more homogeneous classes. Boehmer et al. (2015) suggest that, analyzing regulatory experiments, the fundamental assumption that the control group is unaffected, may not hold in financial markets due to potential existence of spillover effects. However, in this framework no indirect and spillover effects should exist, since minimum obligations in the control group are unchanged and no rational behavior could explain different quoting preferences in these bonds. Secondly, MTS Italy is the only eligible trading platform and Primary Dealers (henceforth PD) are publicly ranked at the end of each year. The combination of these two characteristics makes the Italian case the most suitable framework to analyze how ranking system may affect market makers' choices: quoting obligations are applied to a single eligible trading platform (MTS Italy) and annually the first five positions of the ranking are published. The former feature helps the analysis limiting confounding effects and any potential endogeneity problems, since each market maker might have unobservable preferences about the trading venue[16] on which comply its quoting obligations. On the other side, the Italian ranking regime, characterized by a clear assessment, may boost competition among specialists and it provides high implicit benefits (e.g., reputation) due to its public nature.

The period that has been considered is suitable for the analysis for several reasons. First, as explained in section 3.2.2, the changes in monitoring rules between 2015 - 2016, affecting a restricted number of bonds, are appropriate to highlight the role of ranking system in influencing market makers' behaviors. During this period, the other relevant regulatory features remained unchanged. Note that, even if other regulatory changes or structural variations occurred in that period, these should impact differently the two segments of BTPs since the empirical analysis is conducted to find any significant difference between these two groups.

Second, since BTPs with maturity longer than 7 years and smaller than 15 years are selected, the paper discusses and controls whether any market factors could lead to divergence between these two groups. Looking at the spread between the yield of the BTP 10 years benchmark versus the yield of the BTP 15 years benchmark, it could help to understand how operators managed these two segments. The average spread of this period is 43.840 bps, the maximum value is 53.753 bps and the minimum value is 37.141 bps. If one looks to the annualized volatility (a financial indicator of risk and uncertainty) of this spread, computed on rolling window of 160 days (8 months), its central value in Sep 15 - Apr 16 period is 52.823%, the maximum is 71.734% and the minimum is 51.614%. Comparing with those values computed for 2010-2017 period[17] confirms that the period employed in the analysis is characterized by low level of instability and uncertainty.

Moreover, since market makers intermediate the allocation of the Italian bonds among investors, some facts about the demand and supply should be discussed first, in order to analyze whether structural variation in inventories' control cost occurred. First, the Italian Treasury follows a fully transparent calendar about auctions. Quarterly, the MEF publishes its *Quarterly Issuance Program* which announces new securities and reopenings of outstanding bonds that will be issued in the subsequent quarter. About longer BTPs, monthly the Italian Treasury supplies BTPs with 15y, 20y or

[14] In more details, the control group is composed of bonds with residual maturity at 4th January 2016 lower but close to 10 years. Isin codes: IT000366655, IT0004953417, IT0005001547, IT0005045270, IT0004513641, IT0005090318, IT0005127086.
[15] The treatment group is composed of bonds with the residual maturity greater but close to 10 years. Isin codes: IT0004644735, IT0001086567, IT0001174611, IT0004889033, IT0001278511, IT0005024234, IT000144378, IT0005094088.
[16] Regulated markets and multilateral trading systems.
[17] Respectively equal to 41.235 bps, 79.443 bps, -8.762 bps, 204.511%, 692.77%, 48.086%.

30y maturities at mid-month auction and 10y BTPs at the end of the month. In September 2015 - April 2016 period, 8 auctions both on 10y BTPs and on longer BTPs were conducted. Comparing the issued amounts through regular auctions during September 2015 - April 2016 and the average amounts of the same period during last five years (2013 - 2017), no substantial difference in the supply side can be identified. In the period 2015-2016, the issued amounts on 10y BTPs was €21.750 millions and on 15y BTPs was €5.956 millions . In the same periods over the last five years, the average issued amounts on 10y BTPs has been €21.825 millions and on 15y BTPs was €6.114 millions[18]. Lastly, from the demand side, this period benefits from the homogeneous buying activity of ECB through its PSP program: the QE on sovereign bonds has started in March 2015 and it has been modified only at the end of the period[19].

From a market perspective, it seems to be a good period to be analyzed with limited risks that contingent or long-run factors caused divergence in the inventories of market makers of 10 years BTPs versus 15 years BTPs. However, next paragraphs explain in more details how the analysis controls in the empirical setting for auctions and global trading activity of investors.

The following model is estimated:

Eq. 1
$$Y_{it} = \alpha_0 + \beta\ change_{it} + \gamma X'_{it} + d_t + a_i + \varepsilon_{it}$$

where $change_{it}$ is a dummy variable that assumes value one when observation is about a bond *i* that has maturity longer than 10 years in the 2016 year (treatment period). These observations are those referred to bonds that have been affected by the new set of market rules, implying the coefficient β represents the estimated effect of the regulatory switch on the outcome variables. Then, d_t represents time fixed effects and a_i is bond fixed effects. The model is estimated on three different outcome variables in order to verify different dimensions in the quoting response of market makers. In particular, the analysis estimates the causal effect on:

1. Bid-Ask Spread in percentage on the mid quote (BA_{it}): normalizing the absolute bid-ask spread with respect mid price allows to compare bid-ask spreads of different BTPs.
2. Total quoted quantity (Q_{it}): the average between the total depth quoted on the ask and on the buy sides.
3. Price impact of €20 millions (PI_{it}): the difference between the mid price and the realizable execution price of a deal of €20 millions (both on the bid and ask sides).

These outcome variables are selected among the most informative liquidity measures about the quoting activity of market makers on MTS Italy (Coluzzi et al., 2008). By employing these three measures, one can jointly infer about the choices of specialists about the level of tightness and the quoted size.

In order to conduct the analysis, monthly averages are employed[20]. The dataset is originally composed of the snapshots of the quoting book of each bond with a frequency of 5 minutes from 9.00 am to 5.00 pm for each trading day. For each snapshot, liquidity measures are computed and then are averaged in order to get monthly observations[21].

[18] The details of the Italian Treasury's issuance activity in 2013-2017 period are available in appendix n.1.
[19] On March 10th, 2016, the Governing Council of ECB took the decision to reduce its reference interest rates and to increase its monthly purchases of European sovereign bonds and other corporate bonds from €60 billion to €80 billion starting from April 2016.
[20] We have also employed weekly observations. The results confirm those with monthly data.
[21] Descriptive statistics of each outcome variable and other information about the dataset manipulation are available on request from the authors.

The covariates employed in the model are: idiosyncratic volatility, computed as the monthly average of daily min-max quoting prices range; specialness, computed as the monthly average of daily differences between the realized repo yield and general collateral repo yields on the TomNext segment; auction, a dummy variable that assumes value one if an auction of the bond occurs in that month. As previously discussed in the section of the literature review, these control variables are selected in order to check for different factors that *a priori* may affect liquidity conditions of bonds. Volatility is the key component of the risk in providing immediacy in execution service. Specialness replicates the inventory (opportunity) cost to hold negative (positive) net position. Auction variable refers to the supply activity of the Italian Treasury.

4.2 Results

The estimates of the causal effect of the regulatory change on the three liquidity measures are presented in Table 1.

	(1)		
	BA	*Q*	*PI*
β	-0.015	0.785	-3.982
Robust SE	0.003	1.715	0.694
p-value	0.001	0.654	0.001
Covariates	yes	yes	Yes
Obs	120	120	120
R^2	0.697	0.841	0.692

*Table 1: **Panel estimates.** The table shows the estimates of β coefficient of OLS panel regressions defined in model n. 1 with bond and time fixed effects with each observation defining a bond-month. The causal effect of the change in monitoring rules between 2015 and 2016 is estimated on three different liquidity measures of the quoting book: best bid-ask spread (BA), average bid and ask depths (Q) and price impact of a deal of €20 millions (PI). Under each coefficient, robust standard errors (clustering at the level of individual bonds) and p-value are presented.*

The estimates confirm our first predictions about the effect of the changes in monitoring rules on liquidity measures. We find a significant and negative impact on the bid-ask spread and no significant effect on the whole quoted quantities. The negative impact on the best bid-ask spread is 0.15% , equal to 15 price ticks on a bond with actual value of €100. Price impact is significantly and negatively affected by rules' change: new rules reduce the cost of execution of a €20 millions deal of 3.98 price ticks.

These results highlight that the liquidity measures are affected by the set of monitoring rules defined by the Italian Treasury. In the next sections, we provide some robustness checks in order to reinforce these results. Secondly, the combination of a narrower bid-ask spread and an unchanged total depth seems to be inconsistent with the theoretical predictions of Kavajecz (1998)[22]. In section 5 we put forward a possible explanation that combines the theoretical microstructure models and the role of public ranking system in pushing the competition among market makers.

[22] He found that prices and depths are used as substitutes: a narrow bid-ask spread induces small depth quotes whereas large depth quotes induce a wide bid-ask spread.

4.3 Robustness checks

In this section, robustness checks are provided in order to test the hypothesis of selection bias time invariant before the treatment, to exclude a delayed effect of the new rules, potential seasonal effects and to assess the role of market makers that are not specialists.

4.3.1 Selection bias time invariant in the pre-treatment period

As a first robustness check, the hypothesis that the selection bias is constant over time in the pre-treatment period has been tested. Three diff-in-diff models are estimated considering the three couples of months in the pre-treatment period (September 2015 – October 2015, October 2015 - November 2015, November 2015 - December 2015). Estimating the following model:

Eq. 2 $$Y_{it} = \alpha_0 + \alpha_1 D_i + \gamma\, X'_{it} + \alpha_2 T_t + \beta\, D_i T_t + \varepsilon_{it}$$

where D_i assumes value one if the bond *i* has residual maturity greater than 10 years and T_t is a time dummy variable, one should expect not to find any statistical significance of *β* coefficient, if the selection bias is constant in pre-treatment period.

	Sep 15 – Oct 15			***Oct 15 – Nov 15***			***Nov 15 – Dec 15***		
	BA	*Q*	*PI*	*BA*	*Q*	*PI*	*BA*	*Q*	*PI*
β	-0.007	0.590	-1.899	0.007	2.426	1.714	0.014	1.460	4.202
Robust SE	0.010	5.085	2.129	0.009	3.708	2.063	0.013	3.353	3.040
p-value	0.481	0.908	0.381	0.458	0.518	0.411	0.297	0.667	0.178
Obs	30	30	30	30	30	30	30	30	30
R^2	0.573	0.706	0.381	0.604	0.809	0.411	0.605	0.839	0.707

Table 2: ***Selection bias time invariant in pre-treatment period****. The table shows the estimates of β coefficient of OLS panel regressions defined in model n. 2 in the section 4.3.1. The selection bias is estimated on three different liquidity measures of the quoting book: best bid-ask spread (BA), average bid and ask depths (Q) and price impact of a deal of €20 millions (PI). Under each coefficient, standard errors (without any adjustments, in order to get less conservative estimates of potential risk of selection bias time variant) and p-value are presented.*

Table 2 shows the estimation results. As expected, the selection bias problem seems not to affect the estimates of the basic models, since *β* coefficients are not significant in any couple of months in the pre-treatment period. This result confirms the goodness of the design of the basic empirical setup, since in the pre-treatment period no significant difference between the two groups of BTPs is found.

4.3.2 Slow-acting effect

Secondly, the hypothesis that the regulatory change affects immediately market makers quoting choices without any delayed effect has been tested. Also in this case, three diff-in-diff models, considering the three couples of months in the post-treatment period (January 2016 – February 2016, February 2016 - March 2016, March 2016 - April 2016), are estimated. The models are the same of the previous robustness check and also in this case one should expect not to find any statistical significance of *β* coefficient.

Table 3 shows the results of the estimation of *β* coefficients. The absence of significant coefficients in the three estimated models suggests that specialists immediately react to the entry into force of new rules in January and no slow-acting effect is revealed.

	Jan16 – Feb 16			*Feb16 –Mar 16*			*Mar 16 – Apr 16*		
	BA	*Q*	*PI*	*BA*	*Q*	*PI*	*BA*	*Q*	*PI*
β	-0.003	-1.402	-0.869	-0.003	0.749	-0.549	-0.002	0.369	-0.699
Robust SE	0.018	4.299	1.864	0.007	5.076	1.510	0.006	5.585	1.419
p-value	0.697	0.747	0.645	0.664	0.884	0.719	0.696	0.948	0.626
Obs	30	30	30	30	30	30	30	30	30
R^2	0.498	0.762	0.659	0.465	0.676	0.698	0.444	0.617	0.677

*Table 3: **Slow acting effect**. The table shows the estimates of β coefficient of OLS panel regressions defined in model n. 2 in the section 4.3.1. The slow acting effect is estimated on three different liquidity measures of the quoting book: best bid-ask spread (BA), average bid and ask depths (Q) and price impact of a deal of €20 millions (PI). Under each coefficient, standard errors (without any adjustments, in order to get less conservative estimates of slow acting effect) and p-value are presented.*

4.3.3 The role of market makers that are not specialists

On MTS Italy, investors are divided into two groups: market makers and market takers. As mentioned above, among market makers a group of selected dealers act as *specialists*, facing quoting obligations that are set by the Italian Treasury. However, also a group of operators that are market makers but are not specialists exists. This presence may affect the analysis conducted in the previous section. The assumption of the basic model, that will be tested in this section, is that this group of operators, not affected by any rules' change, maintains unchanged its quoting behavior across the two groups of BTPs. Since the dataset does not allow to directly identify proposals of market makers and specialists, we introduce the analysis with some descriptive statistics and then we provide a formal test about this potential disturbance.

Firstly, some descriptive statistics on quoting books and trading activity could help to identify the dimension of this disturbance. Looking at the trading side, the market share of volumes traded as fillers[23] of these operators is 7,23% on all the segments of Italian government bonds (BOT, CTZ, CCT, BPT) and 8,44% if the sample of the fifteen bonds is considered[24]. Looking at the quoting activity, using the entire database of 16.296 observations (the snapshots of the books at 5 minute frequency in 168 trading days) on the fifteen bonds, the average number of proposals is 20.16, very close to the number of specialists. If the assumption about the constant presence in the quoting book of proposals posted by the specialists is true, this average indicates a negligible contribution of *market makers who are not specialists* in the quoting activity. If one looks at the maximum number of quotes contemporaneously present in a snapshot, it is 28 for two bonds[25] and the average across the fifteen bonds is 26.46. Note that the difference between the maximum number of quotes and the number of specialists it is not necessarily only representative of the proposals of *market makers not specialists*. A second reason that may implicate a higher number of proposals is the possibility for specialists to post in the quoting book a second quote for each side of the market (Mormando and Greco, 2018).

In order to formally assess whether *market makers not specialists* have modified their quoting behavior, distorting our previous estimates of the causal effect between the new regulation and liquidity measures, we introduce two more liquidity measures. These measures are related to the

[23] Market maker quotes her proposals (a combination of prices and quantities) that can be filled by investors. If investors are looking to sell (buy) a security, market makers purchase (sell) that security. Market maker is in this respect the *filler* and the investor is the *aggressor*.

[24] Information provided directly to the author by MTS.

[25] The ISIN code of these two bonds are IT0005094088 and IT0005001547. The table A2 in appendix presents the details about descriptive statistics of the number of proposals in the quoting book for each bond in the sample.

trading volumes, linked to the quoting decisions, of the *market makers not specialist*. In more details, the *volumes traded as fillers* of the entire group of *market makers not specialists* and the correspondent *proportion calculated on the total trading activity* are used as outcome variables. Even if these are trading measures, these are strictly related to the quoting activity, the focus of the paper. As a matter of fact, the trading activity as filler (not as aggressor) is directly linked to quoting behavior: the probability that a proposal of a market maker will be hit by orders flows is function of the position of this proposal in the quoting book. Narrower the bid-ask spread, higher the probability to deal as filler.

To assess the role of this group of operators, the previous model 1 is estimated. From these regressions, one should expect not to find any statistical significance of *β* coefficient, since this group of market makers has not been affected by any regulatory modification.

	(1)	
	Vol MM	*Perc MM*
β	-12.128	-0.026
Robust SE	8.639	0.018
p-value	0.182	0.175
Covariates	Yes	Yes
Obs	120	120
R^2	0.415	0.308

*Table 4: **Panel estimates on outcome variables: VolMM and PercMM**. The table shows the estimates of β coefficient of OLS panel regressions defined in model n. 1 in the section 4.1. The causal effect of regulatory changes is estimated on two different liquidity measures of the trading activity of market makers that are not in the group of specialists: volumes traded as filler (Vol MM) and the fraction of these volumes on the total trading volumes (Perc MM). Under each coefficient, robust standard errors (clustering at the level of individual bonds) and p-value are presented.*

As expected, *β* coefficient is not found significant in both specifications. It means that the group of *simple* market makers do not change their quoting behavior on BTPs with different maturities along the period considered. The result strengthens the conclusion that the causal effect estimated in section 4.2 is related to quoting behavior of specialists, that are affected by new monitoring and public ranking rules.

4.3.4 Is there any seasonal bias?

In previous sections, a crucial underlying assumption is that no relevant seasonal effect exists between the two groups of BTPs during the pre-treatment period (September-December) and the post-treatment period (January-April). In order to test whether this effect may invalidate the estimated causal effects of previous sections, the same analysis is conducted on the same period of one year later, from September 2016 to April 2017. Between these two years, the MEF did not modify in any relevant way the criteria on quoting and trading activity of specialists on MTS. The more significant change is the reduction of the maximum score assigned to the best specialist in the QQ Index, from 9 to 8 points. However this change, differently from the case of 2015-2016 period, has affected the entire group of BTPs. A second relevant change is linked to the decision of creating new benchmarks for the maturities of 20 years and 50 years during 2016. The MEF issued for the first time on April the new 20 years BTP benchmark and on October the new 50 years BTP. In 2017 criteria, the MEF has integrated the weights for the primary and secondary markets' criteria in order to take into consideration the contribution of these two new segments. However, the previous analysis is not affected by the potential disturbance of these segments since the selected group of BTPs under treatment is composed by bonds with residual maturity lower than 15 years, bonds with a maturity sufficiently far from 20 years.

2016-2017 period is suitable for the purpose to test whether any relevant seasonal effect exists also because the structure of the Italian Treasury supply and market demand seems to be unaffected by relevant shocks in the difference between the two segments. As shown in Table A1 in the appendix, the issued amounts of 10y and 15y BTPs is close to the average of the last 5 years and to the amounts of the same period of 2015-2016. From the demand side, on December 8th 2016 Governing Council of the ECB decided that from April 2017, the net asset purchases were intended to continue at a reduced monthly pace of €60 billion until the end of December 2017. This change, that covers only marginally the period analyzed, did not provide any relevant information about differences on net purchase activity between the two groups of BTPs.

Looking at the test, this section presents the estimates of regression based on the model 1, considering the September 1st 2016 – April 28th 2017 period and selecting bonds that during these 8 months were included in the two classes of BTPs around the 10y maturities: eights bonds with residual maturity between seven to ten years[26] and seven bonds with residual maturity between ten to fifteen years[27]. In the estimated model, the treatment dummy ($change_{it}$) coincides with a dummy that is equal 1 for observations of 2017 period for bonds with residual maturity longer than 10 years. The models are estimated using the three basic outcome variables (*bid ask spread*, *quoted quantity* and *price impact*). The expectations are to find no relevant causal effect of the dummy, since no relevant change in monitoring criteria occurred.

[26] Isin codes: IT0005001547, IT0005045270, IT0004513641, IT0005090318, IT0005127086, IT0004644735, IT0005170839, IT0001086567, IT0005210650.

[27] Isin codes: IT0001174611, IT0004889033, IT0001278511, IT0005024234, IT000144378, IT0005094088, IT0003256820.

	(1)		
	BA	*Q*	*PI*
β	0.002	2.381	0.255
Robust SE	0.002	3.230	0.505
p-value	0.474	0.473	0.622
Covariates	Yes	Yes	Yes
Obs	120	120	120
R^2	0.855	0.599	0.826

*Table 5: **Panel estimates on September 2016 - April 2017 period**. The table shows the estimates of β coefficient of OLS panel regressions defined in model n. 1 in the section 4.1 with bond and time fixed effects with each observation defining a bond-month. The hypothetical seasonal effect between September-December 2016 period and January-April 2017 period is estimated on three different liquidity measures of the quoting book: best bid-ask spread (BA), average bid and ask depths (Q) and price impact of a deal of €20 millions (PI). Under each coefficient, robust standard errors (clustering at the level of individual bonds) and p-values are presented.*

The Table 5 shows the results of the estimated models. In the three specifications, the null hypotheses of no significance of the dummy have not been rejected. These results corroborate the validity of the estimated causal effect of monitoring rules' changes on the specialists quoting behavior, suggesting that the basic estimates of Table 1 are not distorted by any seasonal disturbance.

5. The role of public rankings as signalling

The previous section has found that a relevant link exists between the set of monitoring rules, laid down by the Italian Treasury, and the liquidity conditions of the quoting book. This result suggests that empirical research on MTS Italy should always take into consideration how these rules may interact with the research topic and whether any changes occur during the analyzed period.

In this section we put forward a possible explanation about the relation between liquidity measures and monitoring rules. This relation is not strictly related to the compulsory nature of the monitoring rules, actually it reflects the relation between the public ranking system and the quoting decisions of market makers that compete for the final ranking that is a public signal of their commitment in the liquidity service. In the next paragraphs we discuss the implication of the signaling role of public ranking system and we propose an empirical application in order to formally test whether it heterogeneously affects market makers.

5.1 The role of public rankings in the microstructure models

Market microstructure models[28] assume that, in a competitive environment, the individual market maker sets her quotes in order to get at least an expected zero profit level. In these models, the market maker gains from the markup of the bid and ask prices on the asset's mid fair price, whereas the costs are mainly related to fixed components, order processing costs, inventories control costs and asymmetric information costs. However, market making activities are carried out by desks of global investment banks or financial intermediaries. These operators, in order to decide whether to provide liquidity on a specific asset, take into consideration not only the expected direct costs and benefits, but also implicit and indirect ones. In the case of the market making on the Italian sovereign bonds,

[28] We refer to De Jong and Rindi (2009) for an exhaustive literature review.

specialists benefit quite homogeneously from their privileges explicitly cited by the MEF in its "Specialist Decree": exclusive access to reserved reopenings and to the selection of lead managers of syndicated issuances or in any other extraordinary transactions. However, the opportunity of being in the top positions of the public ranking system offers other potential benefits for specialists.

5.1.1 The signaling power of public ranking

Being in the top positions of the public ranking system offers to market operators several sources of potential returns from this positive signaling.

First, specialists, contributing in the efficiency of the secondary market, improve their reputation with the national Debt Management Office. This could lead to a higher probability to be selected as lead managers of syndicated issuances or as counterpart in bilateral transactions. From the specialist's perspective, these deals offer a good return in terms of trading revenues and commission fees. Secondly, since Ministry plays also a role as national regulator, some banks could consider positively the opportunity to strengthen the relationship with the Ministry, signaling their compliance in providing high liquidity levels in the market of Italian sovereign bonds.

Third, being in the top positions of the public ranking provides a signal on the specialist' skills and compliance in offering good execution service for buy-side or sell-side clients[29]. Thus they can use the segment of government bonds, characterized by high competition and low profitability, to increase fidelity of their customers in execution services in asset classes with low competition and high margins. Lastly, investment banks define bonuses for the trading desk or for individual traders linked, not only to the profit and loss performance, but also to the final ranking position.

Consequently and in summary, the public ranking offers a signaling for investment banks with the Debt Management Office, the community of buy-side and sell-side investors, and for traders within their organization.

5.1.2 Prediction n.2

This paper hypothesizes that the public ranking, through its implicit incentives and expected returns from being in the top positions of the final ranking, links monitoring rules with specialists' quoting behavior. Since these returns are heterogeneous among specialists due to the different expected reward of the signaling power of the public ranking, these benefits are individual based and vary across the market makers.

In the light of the previous discussion, we can summarize the second testable empirical prediction.

Prediction 2: Public ranking heterogeneously affects specialists.

The return from high ranking position is uncertainty and heterogeneous since each operator is differently exposed to the potential benefits of the ranking regime (e.g., higher reputation among the community of financial investors and with other sovereign Debt Management Offices, direct explicit privileges or cross-subsidies deriving from the execution services provided to customers in other asset classes). In the following sections, the empirical application tests this prediction.

[29] The buy-side clients is the community of financial investors, proprietary desk of banks, real money, pension funds and other kind of investors. The sell-side are typically Debt Management Office of other Countries.

5.2 The empirical application

In this section, we test the second prediction and we investigate whether specialists react differently to the changes of the ranking rules. The results from the starting model suggest that few market makers have decreased their bid-ask spread, and probably have reduced also their proposals' size, in order to compete for market orders flows and for getting higher scores for the quoting indexes. However, the total effect on the quoted depth is not significant, suggesting that market makers have defined different strategies.

In order to test the second prediction, the previous model 1 is estimated on three new liquidity measures as outcome variables:

1. Variance of quoted prices weighting for correspondent depths in the book (VAR_{it}),
2. Volume-weighted bid-ask spread in percentage on the mid quote ($VWBA_{it}$),
3. Average quoted quantity per proposal in the two top positions of the order book ($A2B_{it}$).

Figure 1 shows two examples of quoting book in line with the results got from the previous section and it helps to understand which contribution in the empirical test might offer the introduction of these three liquidity measures. For each quoting book and for each side of the market, the quoted prices (*P*), the correspondent quantities (*Q*) and the number of proposals (*N*) are shown. The example of the quoting book of 2016 year assumes that only two operators have modified their quoting strategies from 2015: the most competitive market maker has reduced the quoted quantities and has narrowed the bid ask spread, whereas the less competitive increases the quoted depths in order to offset the lower expected score got from QQ index (since its proposals have moved from the third level to the fourth). The second book shows a narrower *best bid ask spread* (9 price ticks vs 15 price ticks), an unchanged *quoted depth* of €100 million and a reduction of the *price impact* of a deal of €20 million (7 price ticks vs 7.5 price ticks).

2015

Level	Bid N	Bid Q_b	Bid P_b	Ask P_a	Ask Q_a	Ask N
1	10	50mm	99.95	100.10	50mm	10
2	9	45mm	99.90	100.11	45mm	9
3	1	5mm	99.85	100.15	5mm	1
4						

2016

Level	Bid N	Bid Q_b	Bid P_b	Ask P_a	Ask Q_a	Ask N
1	1	3mm	99.98	100.07	3mm	1
2	9	45mm	99.95	100.10	45mm	9
3	9	45mm	99.90	100.11	45mm	9
4	1	7mm	99.85	100.15	5mm	1

*Figure **1** : **An example of quoting books**. The figure on the left shows an example of quoting book with rules of 2015, the figure on the right shows an example of how the quoting book might be modified after the changes in market rules of 2016.*

We introduce the *variance* of bid (ask) prices in order to verify whether a greater prices' dispersion has occurred. Looking at the two examples, the concentration of prices in the first book is greater than the second, since the most competitive market maker is now able to narrow the bid and ask prices, reducing the quoted quantities. The *volume weighted bid ask spread* is introduced since it is a measure of the global bid ask spread of the book. In this case, we expect to find a negative relation with the new monitoring rules, but with a lower impact with respect to the *best bid ask spread* since the response of market makers are heterogeneous, with a stronger reaction of those operators that actively compete for being in the higher prices. Lastly, the *average quoted quantity per proposal on the two top prices* is employed to test if only the most competitive operators has chosen to set their proposal schedule employing the opportunity, offered by the new set of rules, to reduce the quoted quantities in order to compete in narrowing the bid-ask spread. The result on the quoting book is that depth at the top levels apparently rarefies, actually it is new quoted volumes in higher competitive prices that were unable to be quoted with old rules.

		(1)	
	VAR	*VWBA*	*A2B*
β	0.006	-0.012	-0.830
Robust SE	0.003	0.003	0.151
p-value	0.057	0.002	0.001
Covariates	Yes	Yes	Yes
Obs	120	120	120
R^2	0.324	0.675	0.739

*Table 8: **Panel estimates on outcome variables: VAR, VWBA, A2B**. The table shows the estimates of β coefficient of OLS panel regressions defined in model n. 1 in the section 4.1 with bond and time fixed effects with each observation defining a bond-month. The causal effect of the change in monitoring rules between 2015 and 2016 is estimated on three different liquidity measures of the quoting book: variance of prices (VAR), volume weighted bid ask spread (VWBA), average size of proposals in the best two prices (A2B). Under each coefficient, robust standard errors (clustering at the level of individual bonds) and p-value are presented.*

Table 8 shows the results of the estimated regressions. As expected, a significant and positive impact is found between the regulatory changes and the *variance* of prices in the order book. Conversely, a negative and significant causal effect is found between new rules and the *average depth per proposals in the top prices*. As expected, this reduction is due to the choice of the most competitive traders to quote proposals with lower depths. Lastly, a negative and significant impact is found on the *volume weighted bid ask spread*. This effect is lower than the effect on the *best bid-ask spread* measure: the rules' change has caused a tightening on the best spread of 0.15% (15 price ticks on a bond with actual value of €100) whereas the tightening on the volume weighted global spread is found to be around 0.12% (12 price ticks). Combining these results with those found in the basic model, one can conclude that new monitoring rules have increased the competition among specialists in tightening the quoting book, signaling their compliance in the liquidity provision. At the same time, no negative sign of depth depletion in the global liquidity measures is found.

The conclusion on the heterogeneity of the impact across specialists could be enhanced by the public rankings annually published in the Public Debt website. As a matter of fact, one possible alternative explanation for the results got from this section is that market makers homogeneously alternate, during a trading day, more and less aggressive quoting strategies in order to compete for trading flows and ranking. We argue that the new rules heterogeneously impact market makers since the rankings show a strong persistence of few specialists in the top positions. In 2015, 2016 and 2017 rankings, the first four specialists were the same, also with the same rank: MPS Capital Services, JP Morgan, Banca Imi and Unicredit[30]. There has not been a real turnover among specialists on the top positions in 2015-2016 period and the heterogeneity in the quoting preferences is a natural and inherent characteristic among operators.

[30] The annual rankings are available on the Italian Treasury website at the link http://www.dt.mef.gov.it/en/debito_pubblico/specialisti_titoli_stato/graduatoria_specialisti_titoli_di_stato/ , 5 March 2020.

These quantitative and qualitative arguments lead to consider more likely an heterogeneous impact of the new rules on the whole group of specialist. However, further research, with a different dataset on individual quotes, could specifically address this research question.

5.3 Robustness checks

The same robustness checks can be conducted on the model for testing *Prediction n.1*: we test the hypothesis of selection bias time invariant before the treatment, the hypothesis of a delayed effect of the entry into force of the new rules and potential seasonal effects that can affect the period September-April.

Starting from the first two tests, tables 9 and 10 show the results got from the tests about the presence of a selection bias time invariant in the pre-treatment period and a delayed impact of the new rules during the treatment period. The model of these tests is formalized in equation 2. As expected, both robustness checks confirm the absence of significant coefficients across the whole group of regressions, suggesting that the specialists immediately reacted to the entry into force of new rules without anticipating effects and selection bias disturbance in the pre-treatment period.

	Sep 15 – Oct 15			***Oct 15 – Nov 15***			***Nov 15 – Dec 15***		
	VAR	*VWBA*	*A2B*	*VAR*	*VWBA*	*A2B*	*VAR*	*VWBA*	*A2B*
β	0.009	-0.009	-0.063	-0.005	0.003	0.169	0.005	0.018	-0.224
Robust SE	0.007	0.019	0.146	0.008	0.017	0.140	0.007	0.022	0.145
p-value	0.197	0.644	0.671	0.496	0.847	0.238	0.804	0.418	0.135
Obs	30	30	30	30	30	30	30	30	30
R^2	0.849	0.515	0.402	0.784	0.847	0.354	0.803	0.534	0.327

*Table 9: **Selection bias time invariant in pre-treatment period**. The table shows the estimates of β coefficient of OLS panel regressions defined in model n. 2 in the section 4.3.1. The selection bias is estimated on three different liquidity measures of the quoting book: variance of quoted prices (VAR), volume weighted bid-ask spread (WVBA) and average depth per proposals at the best two prices (A2B). Under each coefficient, standard errors (without any adjustments, in order to get less conservative estimates of potential risk of selection bias time variant) and p-value are presented.*

Lastly, we verify whether any seasonal bias exists in the period from September to April. As in the case of robustness checks of Prediction 1, we replicate the same analysis of section 5.2 considering the September 2016 - April 2017 period.

	Jan 16 – Feb 16			*Feb 16 – Mar 16*			*Mar 16 – Apr 16*		
	VAR	*VWBA*	*A2B*	*VAR*	*VWBA*	*A2B*	*VAR*	*VWBA*	*A2B*
β	-0.021	-0.010	0.528	-0.006	-0.005	0.197	-0.008	-0.006	-0.026
Robust SE	0.007	0.018	0.203	0.006	0.015	0.142	0.006	0.015	0.145
p-value	0.005	0.577	0.016	0.297	0.733	0.179	0.194	0.676	0.858
Obs	30	30	30	30	30	30	30	30	30
R^2	0.910	0.511	0.875	0.918	0.481	0.911	0.892	0.445	0.884

*Table 10: **Slow acting effect**. The table shows the estimates of β coefficient of OLS panel regressions defined in model n. 2 in the section 4.3.1. The slow acting effect is estimated on three different liquidity measures of the quoting book: variance of quoted prices (VAR), volume weighted bid-ask spread (WVBA) and average depth per proposals at the best two prices (A2B). Under each coefficient, standard errors (without any adjustments, in order to get less conservative estimates of slow acting effect) and p-value are presented.*

The results, presented in Table 11, confirm the absence of any significant seasonal bias during the eight months of the analysis. In fact, in the three specifications, the null hypothesis of irrelevance of the dummy have not been rejected. These results corroborate the conclusions got in the previous section.

	(1)		
	VAR	*VWBA*	*A2B*
β	-0.006	0.003	0.075
Robust SE	0.004	0.002	0.091
p-value	0.175	0.304	0.423
Covariates	Yes	Yes	Yes
Obs	120	120	120
R^2	0.406	0.829	0.621

*Table 11: **Panel estimates on September 2016 - April 2017 period**. The table shows the estimates of β coefficient of OLS panel regressions defined in model n. 1 in the section 4.1 with bond and time fixed effects with each observation defining a bond-month. The hypothetical seasonal effect between September-December 2016 period and January-April 2017 period is estimated on three different liquidity measures of the quoting book: variance of quoted prices (VAR), volume weighted bid-ask spread (WVBA) and average depth per proposals at the best two prices (A2B). Under each coefficient, robust standard errors (clustering at the level of individual bonds) and p-values are presented.}*

6. Threshold date analysis

Lastly, an analysis with higher frequency data is conducted in order to verify whether specialists have adapted their quoting behavior aligned to the first trading day of the new year. This check verifies the speed of reaction of operators to the new obligations and, if a positive output is found, this evidence could reinforce the argument that the effects on the liquidity conditions in the BTPs with longer maturity are strongly related to the monitoring rules change, since it has been the only relevant event that occurred between the two years.

Formally, the daily averages of the liquidity measures for the control and treatment groups are computed separately. Then, the Bai and Perron test (Bai and Perron 1998, 2003) is employed in order to verify whether and when a structural change occurred on the differentiated series between measures of the two groups. The underlying assumption of this test is that the level of liquidity fluctuates around a stable mean in absence of structural changes, hypothesis coherent with the results of the previous robustness check. If new market making rules shift the long-run mean towards a different level, this test detects the dates when the changes have occurred.

In this robustness check, only measures that have been significantly affected by monitoring rules' change are selected: BA, PI, VAR, VWBA, A2B. In the following figures the results of the test applied to the five liquidity measures are shown. Each figure shows the time series of the aggregate liquidity measure for the treatment group (black line), control group (green line) and the correspondent differentiated serie (blue line in the second box). The red line in the second box represents the output of Bai and Perron test. The horizontal segment is the estimated mean for each sub-period. The break dates, binding for a maximum one breakpoint, are estimated by the Bai and Perron approach with 5 percent significance level and are also listed in Table 13 with the correspondent WD-max statistics of the test.

Liquidity Measure	**WD-max statistic**	**Date**	**Critical values**		
			10%	5%	1%
BA	19.4813	04 January 2016	8.02	9.63	13.58
VWBA	15.1614	26 January 2016	8.02	9.63	13.58
PI	19.8343	04 January 2016	8.02	9.63	13.58
VAR	18.2913	14 December 2015	8.02	9.63	13.58
A2B	252.8207	04 January 2016	8.02	9.63	13.58

*Table 13: **Bai and Perron test**. The table shows the outcome of Bai and Perron (1998) test applied to daily averages of five different liquidity measures. The null hypothesis is no structural break exists, the alternative is bound to one structural break. The WDmax statistics and the correspondent structural date are shown.*

This robustness check confirms the main results of the previous analyses. Bai and Perron test detects a perfect alignment between the structural breaks in market making activity and the new monitoring rules for the level of tightness of the market (BA measure), the price impact measure and the average proposals' size in top positions of the book. The signs and values of the variations are coherent with the results of the previous sections. With respect the VWBA measure, the test detects a negative effect 16 trading days later the introduction of the new regulation. Since this liquidity measure aggregates the behavior of the whole group of specialists, this result reinforces the idea that the responsiveness of market makers to monitoring rules' change could be heterogeneous among operators in terms of intensity and speed of reaction.

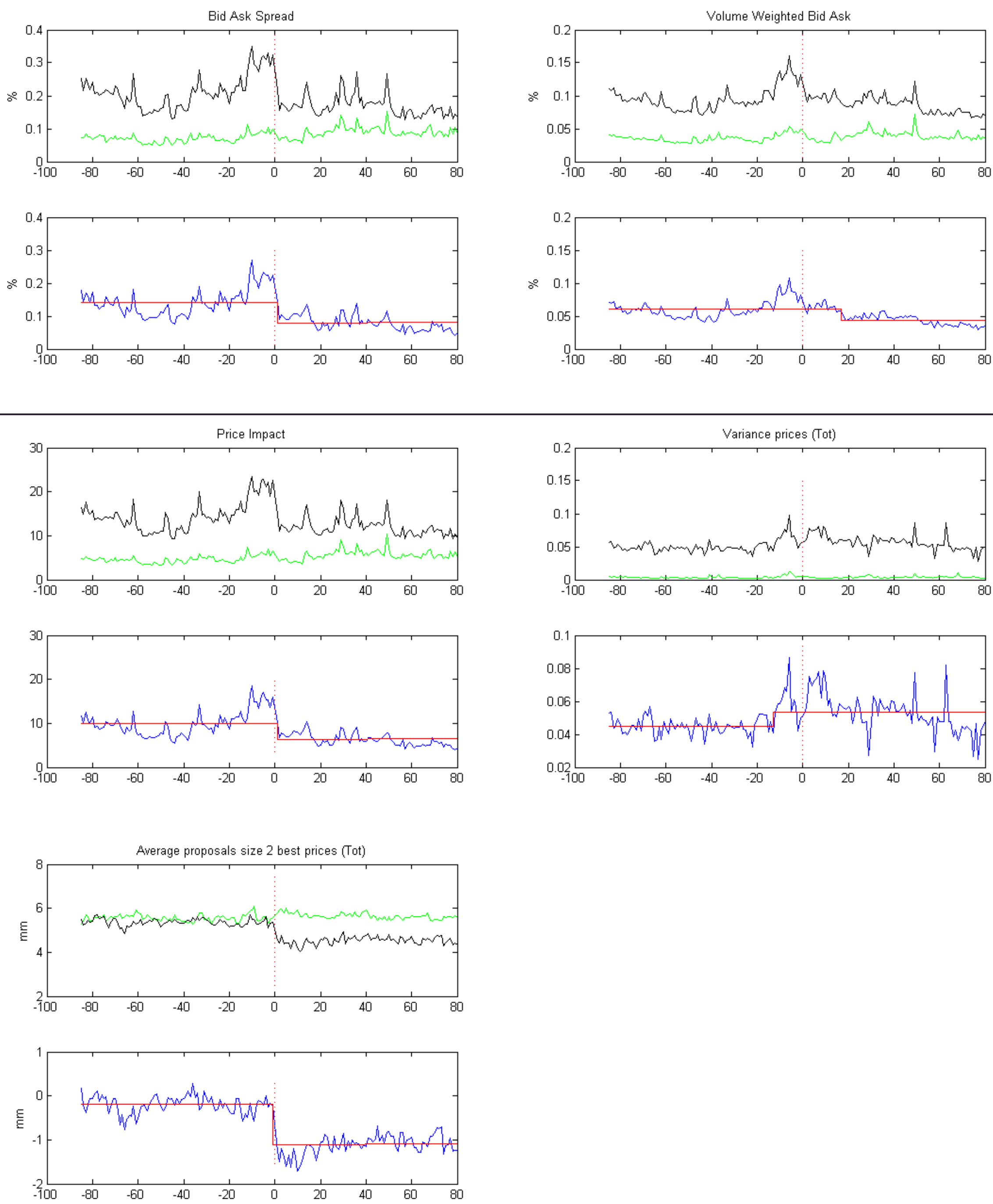

Figure 2: ***Bai and Perron test results****. For each liquidity measure, the test with 5 percent significance level is applied to daily series computed as the difference between the average liquidity measure of bonds of control group and the average liquidity measure of bonds of treatment group. Test allows for heterogeneity and autocorrelation in the residuals and different moment matrices of the regressors across segments.*

7. Conclusions

This paper has investigated the role of monitoring rules and specialists' ranking system on liquidity conditions of Italian government bonds. The contribution is twofold. To the best of our knowledge, this is the first study to statistically assess the causal effect of the public ranking on specialists' quoting behavior. Secondly, we argue that the positive effect of the monitoring rules and public ranking system on the market liquidity conditions is not due to the compulsory requirements of monitoring rules, but it is strictly related to the strong signaling power for the investors' community of the public ranking.

In the first part of the study, we explain in detail the features of MTS Italy and the expected positive effects of the specialists' ranking regime, set by the Italian Treasury, in order to improve liquidity in its wholesale market. Then, we exploit the changes in monitoring rules, occurred between 2015 and 2016, in order to quantify the global effect of public ranking on the quoting activity and on the related liquidity measures. In the second part of the paper, we find signs of a heterogeneous response to the new market rules across market makers.

Looking at the results, we find that changes in the monitoring criteria have a significant impact on the best bid-ask spread, that decreased in response to the new market rules, improving the tightness of the quoting book. At the same time, the volume weighted bid-ask spread decreased but the impact was smaller than in the case of best bid-ask spread. No significant effect on the total quoted depth in the book is found. Looking at the variance of prices, new rules affected proposals distribution in the top levels of the book. More precisely, the variance of prices significantly increased, whereas price impact and average quoted size in top positions decreased in response to new rules. These evidences suggest that the new market rules have heterogeneously affected the decisions of market makers: few specialists have reduced their quoted sizes in order to compete in narrowing the best bid-ask spread, the others have not modified their quoting behavior. The total impact on the quoting book is a higher level of tightness and no relevant variation on the level of the global depth. New monitoring rules have globally improved liquidity conditions in treated BTPs.

These results have some important implications for several policy debates. First, we highlight that ranking regime affects specialists' behavior. This result implies that, in a pure specialists' market, public ranking system may boost competitiveness among market makers in providing additional liquidity. A strong heterogeneity exists on the structure and rules of government bonds' markets of other European Countries. However, the Italian case is the most suitable framework to analyze how these ranking systems can affect market makers' choices since its quoting obligations are applied to a single eligible trading platform (MTS Italy) and annually the first five positions of the ranking are published. Second, since a heterogeneous impact among different players is found, a decrease in uncertainty about potential privileges and benefits could help the principal (in this case, the Italian Treasury) to obtain a more homogeneous response among market participants. Further research should investigate the extension of our results to other countries and formally assess the specialists' optimization problem and to identify the determinants of market makers' quoting choices taking into account the impact of ranking system, disentangling the impact of explicit and implicit incentives.

Appendix

1. Italian Treasury issuance activity (2013-2017)

	Sep 13 – Apr 14	*Sep 14 – Apr 15*	*Sep 15 – Apr 16*	*Sep 16 – Apr 17*	*Average*
BTP 10y	22.050	23.250	21.750	20.250	21.825
BTP 15y	6.000	8.000	5.956	4.386	6.114

Table A1. Treasury issued amounts on BTPs 10y and 15y segments in September-April period during 2013-2017 years

2. Descriptive statistics of the number of proposals for each bond in the sample

ISIN	Obs.	Mean	Median	Max	Var	Skew	Kurtosis
IT0005127086	16296	21.02	21.50	27.00	8.815	-1.986	10.791
IT0005090318	16296	19.57	20.00	25.00	7.306	-1.802	10.322
IT0004513641	16296	20.22	20.50	28.00	9.835	-1.451	8.561
IT0005045270	16296	20.48	21.00	26.00	7.945	-2.018	11.755
IT0005001547	16296	21.06	21.00	28.00	11.466	-1.065	7.201
IT0004953417	16296	19.87	20.00	27.00	9.502	-1.206	7.914
IT0000366655	16296	19.61	20.00	25.00	7.620	-2.056	11.404
IT0004644735	16296	20.29	20.50	27.00	9.166	-1.593	9.380
IT0001086567	16296	20.31	21.00	26.00	7.432	-2.548	14.069
IT0001174611	16296	19.93	20.00	26.00	8.032	-2.282	13.023
IT0004889033	16296	20.51	21.00	25.00	8.351	-2.523	13.527
IT0001278511	16296	20.27	20.50	26.00	10.807	-1.605	8.654
IT0005024234	16296	20.94	21.50	27.00	9.080	-2.461	13.119
IT0001444378	16296	19.55	20.00	26.00	9.484	-1.759	9.905
IT0005094088	16296	18.88	18.50	28.00	12.635	-0.783	5.546

Table A2. Descriptive statistics of the number of proposals of the quoting book of the bonds in the sample. For each bond in the sample, the table presents descriptive statistics of the number of proposals in the quoting book. The dataset is composed by the snapshots of the quoting book of each bond with a frequency of 5 minutes from 9.00 am to 5.00 pm, in the period that runs from September 1, 2015 to April 28, 2016.

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Transmission of Monetary Policy through the Wealth Channel in Brazil: does Public Debt Matter?

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Abstract

This paper studies the transmission of the monetary policy through the wealth channel in Brazil. Using a structural Bayesian model, we analyze the importance of the different components of wealth in the transmission of the monetary policy in Brazil. The paper finds that the wealth effect works in Brazil only through the evolution of real estate prices. Both public debt and stock market wealth play no role in the transmission of monetary policy in Brazil. Unlike what is argued in the literature, the paper finds that the existence of public debt indexed to the short-term policy rate has no impact on the relevance of the wealth effect of government bonds.

JEL Classification: E21, E44, H63

Keywords: Public debt; Housing market, Wealth effect; Monetary policy.

1. Introduction

The literature indicates[4] that monetary policy can affect the aggregate demand through several channels such as credit, exchange rate, interest rate, wealth, and expectations. The transmission of monetary policy through the wealth effect measures the impact of changes in monetary policy on consumption due to endogenous variations of private wealth. The wealth effect occurs when a change in the interest rate causes an impact on the market value of the wealth stock. If consumption depends on the stock of wealth[5], then a change in the interest rate will have an impact in the value of the securities and, therefore, on the wealth, generating a change in consumption and, consequently, in prices.

Paiella (2009) discusses the different channels through which wealth would affect consumption. The first one (Direct wealth effect) is related to the impact of wealth on the household's budget constraint. The second (Common causality) argues that wealth and consumption are driven by common macroeconomic variables. The third one (Collateral or precautionary savings channel) states that an increase in assets prices could escalate the household's willingness to borrow money and, thus, boost consumer spending.

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[4] See Mishkin (1995) and Mohanty and Turner (2008) for a careful discussion.
[5] The stock of wealth can be composed of several assets, such as real estate, stocks, government bonds, private corporate bonds, cash, etc.

The early empirical literature found weak results with respect to the significance of the wealth channel. This shed light on the need for underlying conditions in order to trigger the effect. Firstly, assets must be perceived as wealth by households. Bernanke and Gertler (1999), for example, stress that some assets are not perceived as wealth in a household's budget constraint perspective. According to the authors, the stock market wealth effect in the U.S. is not that strong because individuals hold this type of assets through pension accounts.

A second condition is that only persistent shocks in wealth would have a sizeable effect on consumption. Lettau and Ludvigson (2001) show that consumption responds unequally to changes in consumer wealth, depending on whether such variations are transient or permanent. While transient variations have a low effect on consumption, permanent variations have a strong effect. Ludvigson, Steindel, and Lettau (2002) conclude that the wealth effect has a relatively small importance in the monetary policy transmission one year after the interest rate shock. The authors pointed out that the wealth effect triggered by a monetary policy shock tends to be small because the wealth effect caused by such a shock is transitory[6].

Based on these conditions, the empirical literature started to cluster the wealth in two groups: financial and non-financial wealth. The former usually studies the effects of stock and debt markets while the latter considers the impact of the housing market on consumption. The empirical evidence confirms the importance of such distinction. Sousa (2010) examines the relation between monetary policy and financial/housing wealth using quarterly data for the euro area. The author finds that a monetary policy tightening leads to a significant reduction in wealth. However, while financial wealth effects are of short duration, housing wealth effects are very persistent.

This paper focuses on the transmission mechanism through the wealth effect in Brazil. Brazil has certain characteristics that makes it an interesting case for analyzing the role of the wealth channel on the monetary transmission. The Brazilian economy has one of the highest short-term interest rates in the world. This problem is frequently attributed to the fact that the transmission channel of monetary policy is clogged and, therefore, a higher rate of interest is required to force the inflation convergence process. In this matter, there is an intense debate in the country about which channel would be a bottleneck in the transmission of monetary policy, leading to high interest rates.

In the case of the wealth channel, the debate is focused on the role of the public debt management, especially the issuing of interest rate indexed bonds (LFTs)[7] by the government and its impact on the monetary policy. According to one view, given the importance of the LFTs in the stock of public debt – around 40% of the total outstanding held by market players-, an increase in the short-term interest rate would not affect the wealth of the individuals since the price of the LFT is not sensitive to changes in the interest rate[8]. Assuming that consumption depends on the stock of wealth, raising the interest

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[6] In addition, the wealth effect virtually disappears when the structural VAR is remodeled due to the inclusion of a commodity price index because part of the wealth effect apparently associated with an increase of the interest rate is derived from the reduction of the real value of the assets caused by inflation.

[7] LFT is a type of bond that is indexed to the Selic rate – Central Bank policy rate. Therefore, the bond's pricing followsthe SELIC rate, which is Brazilian policy rate. As typical floater, the profitability is determined by the accrual of the daily SELIC rate recorded between the settlement date of the purchase and the maturity date of the security.

[8] It is possible to show that, considering that the LFTs in perpetual perspective pays a short-term interest rate i for each unit of time t in a daily basis, the market price of these securities is equal to the present value of the cash flow of the securities discounted by a short-term interest rate i, so that the market value of these securities can be synthesized by the following formula:

$$P_t = \sum_{t=0}^{\infty} \frac{iB}{(1+i)^{1+t}} = \mathrm{B}$$

Therefore, if there is an increase in the short-term interest rate, the price of the LFT will not decrease.

rate will not have the desired effect of decreasing consumption, since the stock of wealth will not be affected[9]. This topic is particularly interesting for emerging economies, given that they tend to issue more short-term fixed rate bonds or floaters, with an underlying lower wealth effect, than long-term fixed rate bonds, which tend to have a greater wealth effect.

The empirical literature analyzing the transmission mechanism of the monetary policy through the wealth effect in Brazil is scarce. Pires and Andrade (2009) studied the wealth effect caused by fixed-rate public debt securities, aiming to evaluate the effect of the composition of the debt in the monetary transmission. The authors conclude that the non-inclusion of the wealth effect, in terms of the pre-fixed public debt, in Brazilian models may underestimate the power of monetary policy. In addition, they inferred that the wealth effect may explain part of the ineffectiveness of monetary policy due to the existence of debt which is indexed to the short-term interest rate.

This paper contributes to the literature on the role of the wealth effect in the transmission of the monetary policy into different directions. We analyze the wealth effect using data of the different components of the wealth – public debt, stock market, and housing - thus avoiding the possibility that the composition of the wealth may block the assessment about the wealth channel and allowing for the analysis of the different types of assets and verifying whether the management of public debt plays a role on the transmission of monetary policy[10]. Unlike Pires and Andrade (2009), we are able to properly analyze the role of public debt by building data on public debt wealth using quoting debt by market price. Finally, the paper performs different empirical exercises through the estimation of a structural Bayesian Autoregressive Vector (BVAR) with different specifications for the identification of the shocks. Therefore, bringing more robustness to the results.

The results can be synthesized as follows. In the public debt models and the stock market models, it was not possible to reject the hypothesis that the wealth effect is statistically insignificant. Thus, for these assets, there was no evidence for the existence of the wealth effect. In the specific case of public debt, it cannot be said that the existence of bonds indexed to the short-term interest (LFTs) is responsible for the wealth effect of public debt being nil. The paper shows that even after removing the LFT stock from public debt, the wealth effect continues to have a statistically null impact on consumption. In opposition, we also show robust evidence that the real estate price plays an important role in the transmission of the monetary policy through the wealth channel. An increase in the interest rate leads to a fall in real estate prices and consumption.

The paper is divided into 5 sections, already taking this introduction into consideration. Section 2 discusses the construction of the data used in the empirical exercises. Section 3 explains the methodology used to perform the empirical exercise, detailing the specifications of the structural BVAR. The results are shown in section 4. Section 5 discusses the conclusions.

2. Data

This section encloses a description of the dataset. The sample is restricted to 2002 onwards, when the Monthly Employment Survey (PME) started disclosing labor income data. The model spans from 2002:1 to 2017:2 at quarterly frequency.

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[9] See Carneiro (2006), Franco (2006), Pastore (2006), Arida (2006) and Resende (2006) for further discussion.

[10] The paper is the first to analyze the wealth effect using different type of assets for Brazil and it is also one of the first papers to perform such analysis for an emerging economy. An exception is Koivu (2010) for China using the housing market and stock prices. The results point out that a loosening of monetary policy indeed leads to higher asset prices in China. Yet, the author concludes that changes in asset prices due to monetary policy do not affect household consumption in a robust way.

The Federal Revenue Service (RFB) provides the general statistics of Individual Income Tax (IRPF) returns. It is worth noting that both fixed income and investment funds are recorded at the market value of the final day of the year evaluated. In contrast, the shares are marked by the purchase price. Even though RFB data provide a glance of the individuals' wealth breakdown, the fact that several assets are recorded at acquisition cost, without market price valuation, impairs the analysis of the assets that make up the stock of goods and rights of agents. Yet, it brings an indication about the importance of the different type of assets in the household's wealth. Therefore, it is not intended to be a reliable measure the stock of wealth, but rather, capture the composition of wealth.

According to the RFB[11], in 2016, 38.31% of the declared assets and rights are classified as real estate. It should be noted that this percentage is underestimated, since real estate is registered by the acquisition price. Therefore, it is not quoted by market prices, which tends to be higher. The registration for the purchase price is also the case in the declaration of vehicles, which represent 6.66% of the Personal Income Tax (IRPF), and equity, covering listed and non-listed firms, corresponding to 10.36% of the Personal Income Tax (IRPF); therefore, the quasi- financial assets make up 55.34% of the IRPF. Financial assets, in turn, account for 30.20% of the assets and rights declared in the IRPF. In this category, we highlight the investment funds, fixed income, and shares segments, which represent 7.94%, 7.45% and 4.72% of the IRPF, respectively.

The paper builds data on wealth, labor income, consumption, interest rate, and commodity index from different sources. All variables were filtered to capture the cyclical component in these series by applying the Hodrick-Prescott (HP) filter. In addition, all monetary variables were calculated in real terms by using the prices of second quarter of 2017 as reference. The variables used are defined and constructed as follows:

Inflation: we used the CPI index (IPCA) measured by the Brazilian Institute of Geography and Statistics - IBGE (1993=100).

Labor Income: to calculate it we multiplied the real income per capita times the number of employed persons. For this variable, we used two series provides by the IBGE: PME and continuous National Household Sample Survey (PNAD). The former spans from 2002:1 to 2015:4 and aims to measure the labor income in six Brazilians metropolitan areas. The latter spans from 2012:1 to 2017:2 and measures the labor income in twenty Brazilians metropolitan areas. Since both series have a strong correlation (around 0.96), we created an index to extrapolate the PME labor income data from 2016:1 to 2017:2 by using the quarter variation of the PNAD continua[12]. Thus, the labor income was used in the form of natural logarithm.

Consumption: the nominal consumption was collected from the national accounts data provided by IBGE. In the modeling, the consumption was used in the form of natural logarithm.

Interest rate: we use the SELIC[13] rate at the end of the quarter, which was collected on the Central Bank website.

Commodity index: we used the commodity research bureau spot index for all commodities collected by Bloomberg. In the modeling, the commodity index was used in the form of natural logarithm.

[11] http://idg.receita.fazenda.gov.br/dados/receitadata/estudos-e-tributarios-e-aduaneiros/estudos-e-estatisticas/11-08-2014-grandes-numeros-dirpf/grandes-numeros-dirpf-capa

[12] In the empirical analysis, we also tested the PME and PNAD continua. As a result, we found out similar results when we compare it to the model output that takes this new index into account.

[13] The Special Clearance and Escrow System – SELIC is the Brazilian Central Bank's system for performing open market operations in execution of monetary policy. The SELIC rate is the Bank's overnight rate.

Internal Federal Domestic Public Debt (DPMFi) at market prices: the DPMFi was calculated by summing the following securities: LTN (fixed rate bullet bond), NTN-F (fixed rate coupon bond), NTN-B (CPI bond) and LFT. For each index of public debt, the stock was calculated by multiplying the bond quantity by the bond market price (PU). The bond quantities were extracted from the National Treasury, while the PU was collected at the Brazilian Financial and Capital Markets Association (ANBIMA). In the modeling, we use the natural logarithm of the DPMFi.

It should be noted that the valuation of the public debt as a stock of wealth can take place by marking prices at the curve or by marking to market value. Pires and Andrade (2009), for example, evaluated the wealth effect of public debt composition through data from the stock of government bonds marked on the curve. Under this method, the securities are priced according to the respective issuance Internal Rate of Return (IRR). Thus, according to this methodology, the stock becomes less sensitive to the interest rate oscillations, since the change in the interest rate only modifies the prices of the new bonds in issue, not affecting the prices of the old bonds, that is, those that were issued prior to said change. In contrast, in the marked-to-market securities, the securities are priced based on the market rate, which is calculated daily by ANBIMA. As a result, the stock tends to be more sensitive to changes in the interest rate, since the price of all the securities that belong to the stock is changed. In this sense, we used the concept of market rates which we believe is more appropriate for our analysis.

REPO: the stock of repo operations was collected at Central Bank website. In the modeling we used the natural logarithm of the stock of repo operations. Here, it is important to discuss a particularity of the implementation of the monetary policy in Brazil.

The Brazilian case has the peculiarity of the relationship between the LFTs and the Repurchase Agreements (REPOs) operations carried out by the Central Bank. These operations are the main instrument of the Brazilian monetary authority to operationalize monetary policy. Since REPOs are remunerated by SELIC in the same way as LFTs, it can be argued that there is a strong substitution between these two instruments[14]. In this sense, when analyzing debt management and monetary policy together one may see that REPOs operations have a dual behavior. On the one hand, they act as instruments for the SELIC to converge at the rate set by the monetary policy committee (COPOM). On the other hand, considering that this type of operation can be a substitute for the LFT, the REPOs operations could possibly block the wealth effect and, consequently, reduce the power of the monetary policy.

Taking into account this peculiarity of substitution of the LFTs by the REPOs operations, Barbosa (2006) studied the contagion effect of the indexation of the Brazilian public debt via LFT on the monetary policy. This contagion effect would cause, according to the author, the increase of the Brazilian short-term interest rate because the SELIC would be contaminated by the risk of the government bonds issued. Hence, the article analyzed the relation between the bank reserve market and the bond market with the risk premium of the Brazilian public debt. The latter factor would come from the underlining risk of issuing LFTs. As a result of this dynamics, the monetary authority's freedom to set the interest rate is limited by Treasury debt management.

Even though Barbosa (2006) argued that the contagion effect occurs in the direction that debt management limits monetary policy, it can be inferred that a two-way road conditioning occurs. The REPOs operations stock, which is classified as a liability in the Central Bank balance sheet, represents the excess liquidity of the financial system[15]. Thus, in the Brazilian case, there are four ways to wipe

[14] The LFTs are not a perfect substitute for repurchase operations, as they enable the investor to carry out directional trades, such as taking a short position in the bond received as collateral.
[15] For more details, see Pellegrini (2017).

out the liquidity of the system and, consequently, the REPOs operations stock: i) an increase of the rate of rollover of Treasury bonds; ii) an increase in the primary surplus; iii) a definitive sale of government securities of the Central Bank portfolio and iv) a reduction of international reserves. Therefore, since the REPOs operations stock is a response to the liquidity of the system, it can be said that the amount of repo operations depends on the public debt rollover rate. However, it can also be said that the debt rollover rate depends on the amount of debt repurchased, due to the substitutability between these two instruments. Hence, the choice of public debt composition also takes into account the REPO operations. In this context, to evaluate the impact of LFTs on the obstruction of transmission channels of monetary policy, it is necessary to analyze, in addition, the volume of REPOs operations carried out by the Central Bank.

We also measure the wealth effect of real estate and equity holdings (stock market). Although we do not have an official indicator for the stock of wealth and its composition, according to data from the RFB of the year 2016, approximately 38% of the assets and rights declared in Personal Income Tax (IRPF) are real estate. It should be noted that the property and rights of the IRPF are recorded at acquisition cost, so that they are not adjusted for market values. As for the equity holdings, it represents the third largest quasi-financial wealth group. Hence, it is expected that both the real estate and stock market wealth effects will be significant.

In theory, when interest rates rise, real estate prices tend to decrease, as real estate financing lines decrease, reducing the demand for real estate. Given that the supply of real estate shows little flexibility in the short term, it is highly likely that there will be, *ceteris paribus*, a cool down in real estate prices[16]. Similarly, the rise in interest tends to cause downward pressure on stock prices as the aggregate demand for the economy tends to lower down with rising interest rates, reducing overall sales volume and consequently projected corporate profits.

Real estate: we use the Brazilian central bank (BACEN) real estate price index. This index was expressed in natural logarithm form.

Equity (stock Market): we use the Brazilian stock exchange benchmark index IBOVESPA index as a benchmark of the stock market. This index was collected in the BACEN website and was deflated from the IPCA of the second quarter of 2017. In the modeling process, the IBOVESPA was expressed in natural logarithm form.

3. Methodology

We follow the methodology proposed by Ludvigson, Steindel and Lettau (2002). We will measure the fall in consumption caused by an interest rate shock for each type of asset. In order to isolate the wealth effect, separating it from other transmission channels, it is necessary to carry out an exercise of decomposing the monetary policy shock on consumption. In order to do so, we analyzed how consumption responds to a shock in the interest rate in two situations, namely: i) the response to the shock to the connected wealth channel and ii) the response to the shock when the wealth channel is turned off.

Ludvigson, Steindel and Lettau (2002) constructed a Structural VAR. The authors chose to include the following variables in the VAR: i) inflation (π); ii) real labor income (y); iii) real consumption (c); iv) real wealth (a) and v) interest rate (i).

[16] It is worth noting that we did the robustness exercise proposed by Ludvigson, Steindel and Lettau (2002) to assess if results driver is the reduction of the real value of the assets caused by inflation or the interest rate shock.

$$B_0 Z_t = k + B_1 Z_{t-1} + B_2 Z_{t-2} + \dots + B_P Z_{t-P} + u_t \quad \text{Where } Z_t = (\pi, y, c, a, i) \tag{1}$$

The authors use different hypotheses to identify the structural innovations in the VAR by imposing a set of restrictions on the matrix B_0 that determines the contemporaneous relations on the model. Similar to what was done by those authors, we consider that the consumption is contemporaneously affected by wealth. The interest rate (Selic) also reacts contemporaneously to shocks in consumption and labor income, but these variables are sensitized with the lag of a period due to the planning process and the lag of production. Additionally, it is assumed that wealth is not affected contemporaneously by consumption. Finally, we make the assumption that the Central Bank's goal is price level and real variables, not the value of assets[17]. When assuming these hypotheses, the structural VAR is identified as follows:

$$B_0 = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ \beta_{21} & 1 & 0 & 0 & 0 \\ \beta_{31} & \beta_{32} & 1 & \beta_{34} & 0 \\ \beta_{41} & \beta_{42} & 0 & 1 & \beta_{45} \\ \beta_{51} & \beta_{52} & \beta_{53} & 0 & 1 \end{matrix} \tag{2}$$

Through this methodology it is possible to breakdown the transmission of monetary policy on consumption so as to isolate the wealth effect. To assess the transmission in the absence of the wealth channel, the model needs to be re-specified. In fact, consumption does not depend on wealth, as well as its lags. In this way, to promote a counterfactual exercise, the model will be specified setting $\beta_{34} = 0$. By comparing the main and counterfactual arguments, it is possible to size whether the magnitude of the wealth effect changes and whether such effects are statistically different. Thus, if the diffusion of the interest rate shock on the consumption of the main argument is statistically different from that of the counterfactual, it can be said that the wealth effect is significant.

The decomposition exercise will be replicated for each type of wealth. The evaluation of the effects can be divided into two groups, the first being the Internal Federal Domestic Public Debt (DPMFi) and the second being real estate and equity. In the case of DPMFi, in order to measure the impact of the withdrawal of the indexation instrument on the wealth effect we first estimate the wealth effect of the consolidated stock of DPMFi, then we perform the estimation with the stock of DPMFi without LFTs. Finally, the DPMFi stock is evaluated in a consolidated manner with the REPO operations. The specifications are used to analyze whether the indexation, through LFTs or through REPO operations, compromises the transmission of monetary policy.

Unlike Ludvigson, Steindel and Lettau (2002), we estimate a structural BVAR instead of a traditional VAR using the Minnesota prior to estimate the model. As Robertson and Tallman (1999) demonstrated, BVARs give greater accuracy and better forecasting power than Autoregressive Integrated Moving Average (ARIMA) models and traditional multivariate simultaneous equations. Moreover, Canova (2007) argued that BVARs models reduce the dimensionality of the problem imposing probability distributions on the coefficients of the VAR[18]. The Ludvigson, Steindel and Lettau (2002) approach was built through a Cholesky factorization. We replace the Cholesky factorization by a sign restriction framework[19]. In the sign restriction approach, we chose to control a positive interest rate shock, so that it causes a decline in inflation, labor income, and wealth for four quarters. According to the theory, it is expected that an interest rate hike causes a fall on inflation, labor income, consumption and

[17] For more details on the identification scheme, see Ludvigson, Steindel and Lettau (2002).

[18] For more discussion on the estimation of the BVAR and its advantages see Litterman (1986), Dieppe et al (2016), and Marimon and Scott (2001)

[19] Migliardo (2010) studied the transmission of monetary policy by comparing a BVAR with Cholesky decomposition with a BVAR with sign restrictions. See Dieppe et al (2016) and Arias et al (2014) for more details on the sign restriction approach.

wealth. As we are not controlling the consumption response to an interest rate shock, we aim to test if the consumption impulse response function is statistically less than zero[20].

4. Empirical results

4.1 Public Debt and the Wealth effect

It should be noted that the valuation of the public debt as a stock of wealth can take place by marking prices at the curve or by marking to market value. Pires and Andrade (2009), for example, evaluated the wealth effect of public debt composition through data from the stock of government bonds marked on the curve. Under this method, the securities are priced according to the respective issuance Internal Rate of Return (IRR). Thus, according to this methodology, the stock becomes less sensitive to the interest rate oscillations, since the change in the interest rate only modifies the prices of the new bonds in issue, not affecting the prices of the old bonds - those that were issued prior to said change. In contrast, in the marked-to-market securities, the securities are priced based on the market rate, which is calculated daily by ANBIMA. As a result, the stock tends to be more sensitive to changes in the interest rate, since the price of all the securities that belong to the stock are changed. In this sense, we used the concept of market rates.

The DPMFi is a proxy to the wealth variable. We are interested in understanding the reaction of consumption to a shock in the interest rate. As the consumption response is not statistically different from zero, we haven't found any evidence that the DPMFi plays an important role in the transmission of the monetary policy through the wealth channel as an interest rate shock has a statistically significant impact on wealth. A BVAR with one lag was used[21]. Figure 1 displays that the fall in the wealth has no impact on consumption, rejecting the relevance of the wealth effect through the DPMFi. According to the theory, the wealth effect occurs when an increase in the interest rate causes the reduction in the market value of the wealth stock. Thus, this wealth contraction is the transmission vessel that causes the reduction on consumption. Nonetheless, as the impulse response in Figure 1 shows, the interest rate hike causes a fall in the wealth stock, yet it is not translated in a fall in consumption.

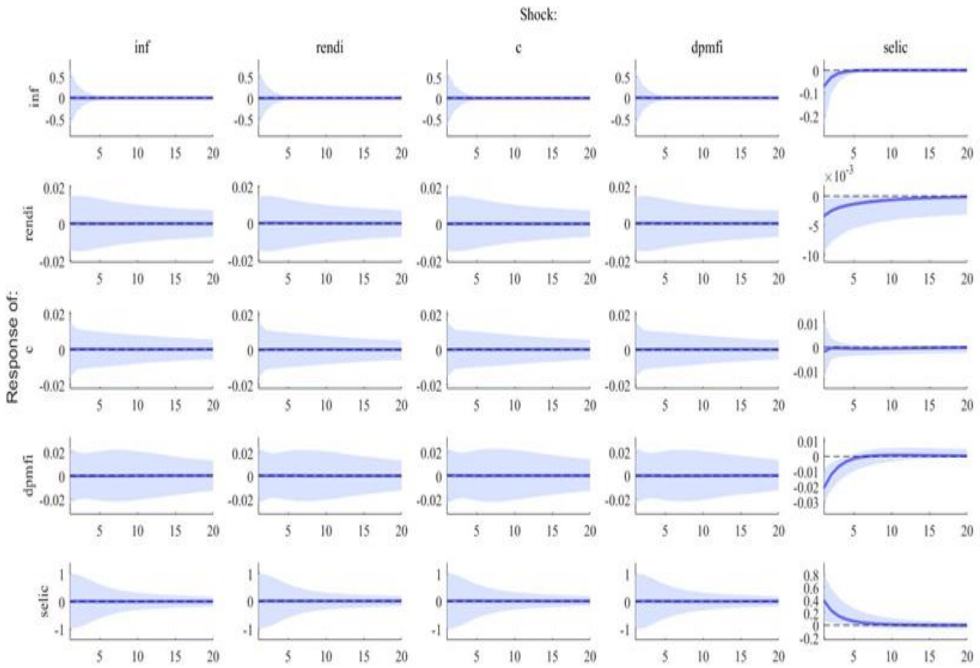
We discovered that public debt has a neutral effect on consumption, using the total stock of DPMFi as our proxy for wealth, which is in line with Ricardian equivalence[22]. If the Ricardian Equivalence is valid, the role played by public debt composition becomes irrelevant. In a Ricardian environment, Goldfajn and de Paula (1999) argued that the impact of debt composition is limited to minimizing the expected cost of debt service and signaling credibility, minimizing budget volatility, and increasing liquidity or information available in the market.

[20] The results for the Cholesky identification scheme with the exception for the case of real estate prices are not shown in order to save space since they do not bring significant differences, but they are available upon request. Similarly, the robustness test proposed by Ludvigson, Steindel and Lettau (2002) was run by including the commodity index in the BVAR. The results of this robustness test confirmed the results found and they can also be made available upon request. One example is included in the annex using both the Cholesky decomposition and including the commodity index.

[21] The lags of the BVARs estimated in this study were selected using the Schwarz (SC) criterion. The choice of this criterion is more conservative, as it is not affected by the number of lags to be tested *ex-ante*.

[22] There are three conditions needed for the Ricardian Equivalence to be supported: (1) Agents must have an infinite horizon of planning; (2) Existence of complete markets and (3) Existence of non-distorting taxes. The discussion about the importance of active management of Public Debt and how it should be carried out is based on the loosening of these hypotheses. For a detailed discussion, see Barro (1974).

Figure 1: BVAR impulse response functions taking into account the DPMFi as the wealth variable. Sign Restriction

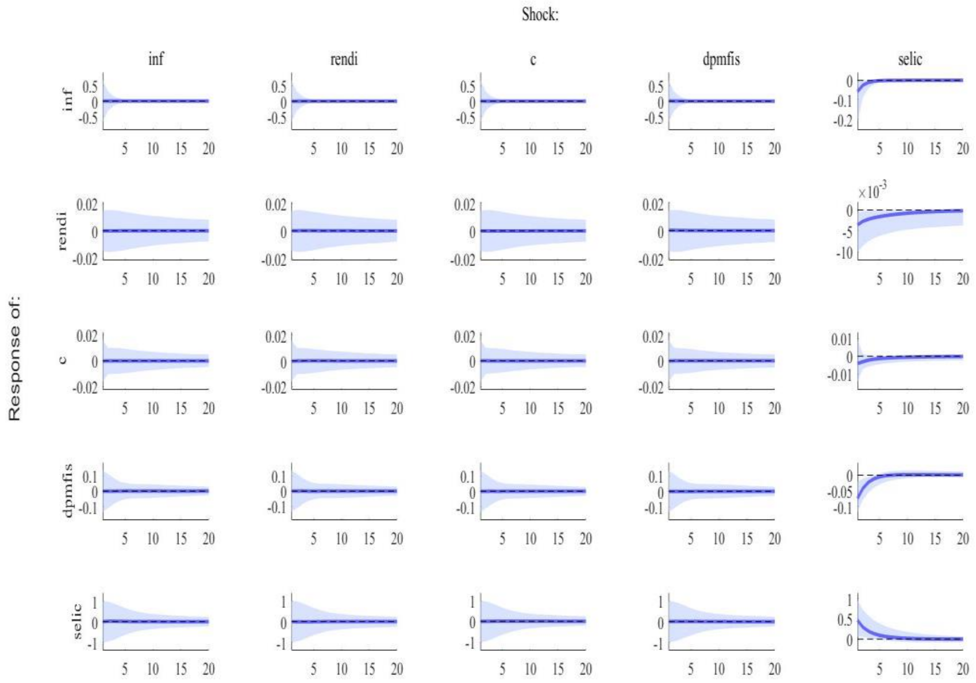


Source: elaborated by the authors

As discussed in the previous section, in Brazil the debate is whether interest rate indexed bonds (LFTs) have an impact on the monetary policy transmission. One view is that, given the importance of the LFTs in the stock of public debt, an increase in the short-term interest rate would not affect the wealth of the individuals since the price of the LFT is not sensitive to changes in the interest rate. Assuming that consumption depends on the stock of wealth, raising the interest rate will not have the desired effect of decreasing consumption, since the stock of wealth will not be affected.

It is worth performing a counter-factual exercise in order to test the LFTs' role on monetary policy transmission. It might be the case that the insignificant impact of the wealth changes in the consumption is because of the debt composition. It may be the case that the presence of bonds indexed to the short-term interest rate - LFTs - blocks the wealth effect; therefore, it is expected that with the withdrawal of this type of bond there will be a boost in the wealth effect. In order to measure how interest rate indexation through the LFTs affects the transmission of monetary policy on consumption we estimated a model in which the wealth corresponds to DPMFI with the subtraction of the stock of LFTs. This exclusion was made to gauge the role of the LFT in the impact of the monetary policy over consumption.

Figure 2: BVAR impulse response functions taking into account the DPMFi excluding the LFTs as the wealth variable. Sign Restriction



Source: elaborated by the authors

The wealth effect seems to be irrelevant as the response of consumption to an interest rate shock continues to be statistically equal to zero even after the exclusion of the LFTs. The impulse response in figure 2 indicates that the exclusion of the LFTs does not broaden the power of monetary policy over consumption. Even with the exclusion of LFTs, the wealth effect of the DPMFi is statistically zero. Under this exercise, unlike Pires and Andrade (2009), it is not possible to conclude that the LFTs are responsible for blocking the wealth effect of the DPMFi. Besides, this outcome sheds some light on the work done by Pastore (2006). He concluded that it is only possible to assert with certainty that LFTs do not cause wealth effect, and it cannot be said that they increase consumption by raising available income.

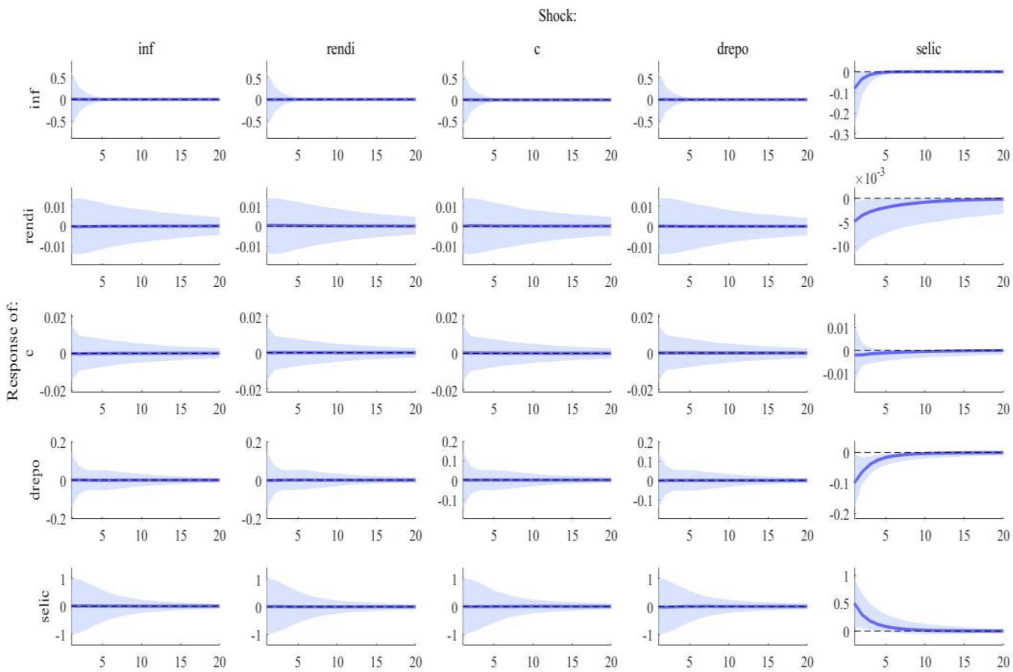
It is also relevant to look at the interplay between LFTs and REPOs (*compromissadas*). In previous sections we also discussed that the stock of REPOs may play a role in the significance of the wealth effect and, hence, in the transmission mechanism of monetary policy. LFTs and REPOs are substitute securities, because, like LTFs, *compromissadas* are remunerated by SELIC in the same way as LFTs[23]. REPOs' balances are significant, so that, as of November 2018, its stock equals to 22.5 percent of the General Government Gross Debt according to the Central Bank of Brazil. Therefore, we estimated an additional specification in which the wealth is represented by the sum of the stocks of REPOs and DPMFi.

REPOs as a part of public debt. By analyzing the response of consumption to a shock in interest rate (Figure 3), it is possible to note that the consumption continues to be insensitive to monetary policy decisions even with a fall in the wealth. So, we can conclude that the wealth effect continues to be

[23] Strictly speaking, LFTs are not a perfect substitute for reverse repo, as the former has average maturity of five years and the latter has an average maturity of less than six months. Reverse repos also enable the investor to carry out directional trades, such as taking a short position in the bond received as collateral.

statistically equal to zero. This result reinforces public debt neutrality on consumption shown in Figure 1 as, even considering a broad debt definition, we have not found evidences of the wealth effect.

Figure 3: BVAR with sign restrictions impulse response functions taking into account the DPMFi plus REPOs as the wealth variable.



Source: elaborated by the authors

4.2 Housing, stock market, and the Wealth effect

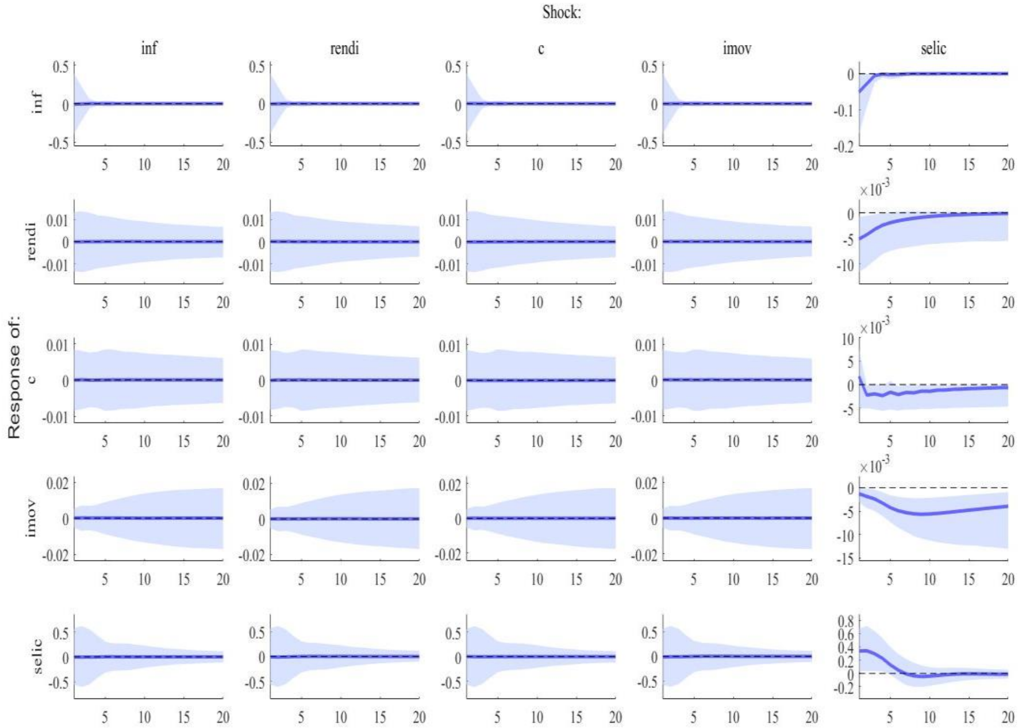
Moving forward, it is crucial to recall that the household wealth stock is not only composed by government debt securities. Hence, it is important to measure the impact, in terms of wealth effect, of assets that traditionally have not been contemplated by empirical studies in Brazil. Thus, due to the relevant participation in the stock of wealth, as measured by the RFB, real estate and equity (stock market) also became a target of this study.

According to RFB data, real estate is the main component of the wealth stock of Brazilians. Thus, the fluctuations in real estate prices due to interest rate shocks are expected to be an effective channel for the transmission of monetary policy over consumption. Thus, the initial hypothesis is that the wealth effect is positive.

To test this hypothesis, we constructed a BVAR with four lags in which the wealth variable is priced according to the variations of the real estate price index[24] calculated by the BACEN. Figure 4 shows that the wealth effect is statistically different from zero in this case. Figure 4 shows that an increase in the interest rate provokes the reduction in the market value of the wealth stock (real state). This wealth contraction is the transmission mechanism that leads to a reduction on consumption. Thus, as Figure 7 shows, the interest rate shock causes a decrease in the wealth stock, which is gauged by the real estate price index.

[24] This is a proxy to gauge the real estate wealth, since we are unable to measure the real estate wealth as a quantum time's price variable.

Figure 4: BVAR with sign restrictions impulse response functions taking into account the real estate price index as the wealth variable.

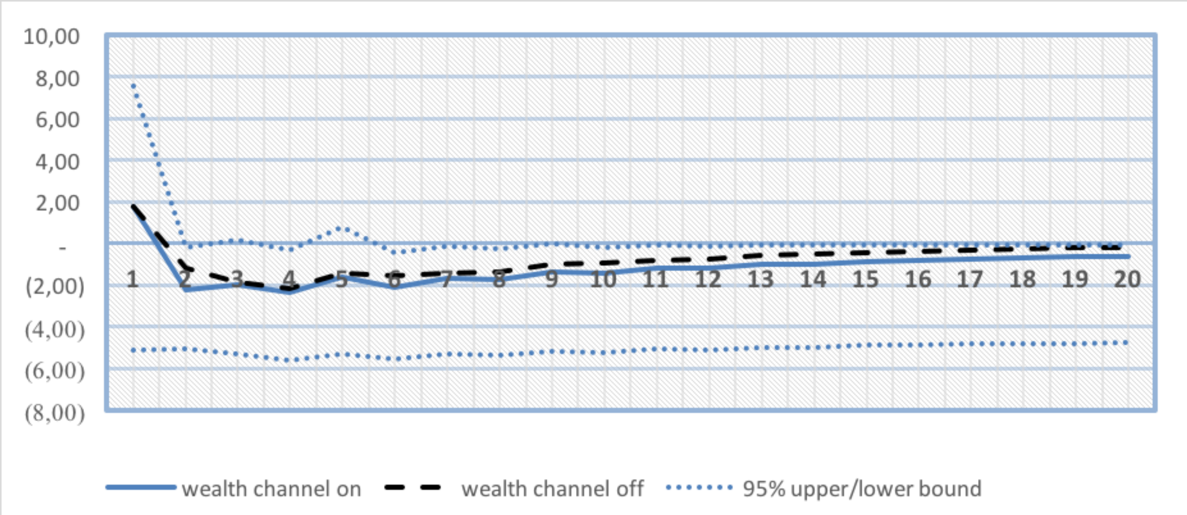


Source: elaborated by the authors

Figure 5 confirms the relevance of the wealth effect on consumption through real estate prices. The wealth effect leads to a further fall in the consumption when compared to when the wealth effect is off. It is interesting to note that the fall in consumption is persistent, vanishing only after a long horizon. This result is in line with Sousa (2010), who found out that real estate assets are sensible to monetary policy changes, and housing wealth effects are also persistent. Moreover, our findings agree with Aoki, Proudman and Vlieghe (2004). The authors analyze how real estate plays an important role via the credit channel. To test that, they used a variant of the financial accelerator model calibrated to UK data, to assess the impact of monetary policy on the real economy through its effect on housing prices. The model indicates that policy-induced changes in house prices have in fact played a significant role in the transmission of monetary policy in the UK.

Nonetheless, one should read this result considering that Brazilian households' financial structure has changed intensely over the last years. Gaber el al (2018) argue that these changes were chiefly driven by a sharp expansion in household indebtedness and stimulative government public policies. The authors point out that there was a boom of Brazilian housing market from 2011 to 2014. The credit escalation was driven by massive government policies aiming lower/medium-income household, such as Bolsa Familia, providing credit below market rates.

Figure 5: BVAR with sign restriction using the real, state proxy as the wealth variable.



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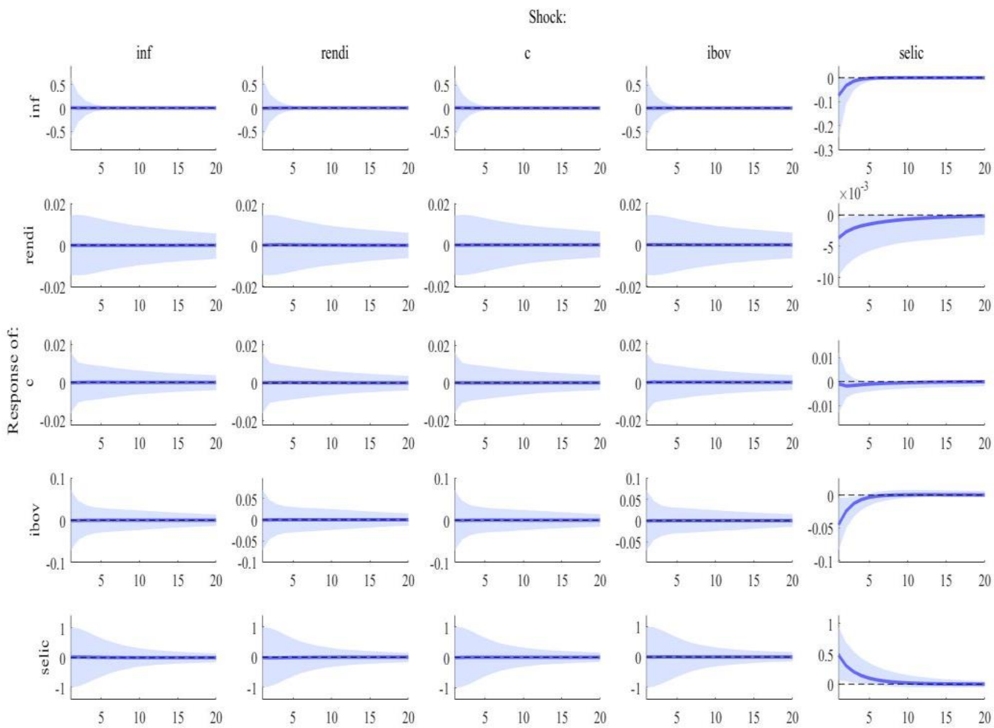
Finally, as reported by the RFB, the equity holdings have the third largest participation in the quasi-financial assets held by Brazilian families. In addition, Ludvigson, Steindel and Lettau (2002) found evidence that this type of asset produces a greater wealth effect than other investment classes. To verify the role of equity holdings of listed firms, we constructed a BVAR with one using the Ibovespa index as the wealth variable. By looking at the results on figure 6, it is not possible to reject the hypothesis that the wealth effect is equal to zero.

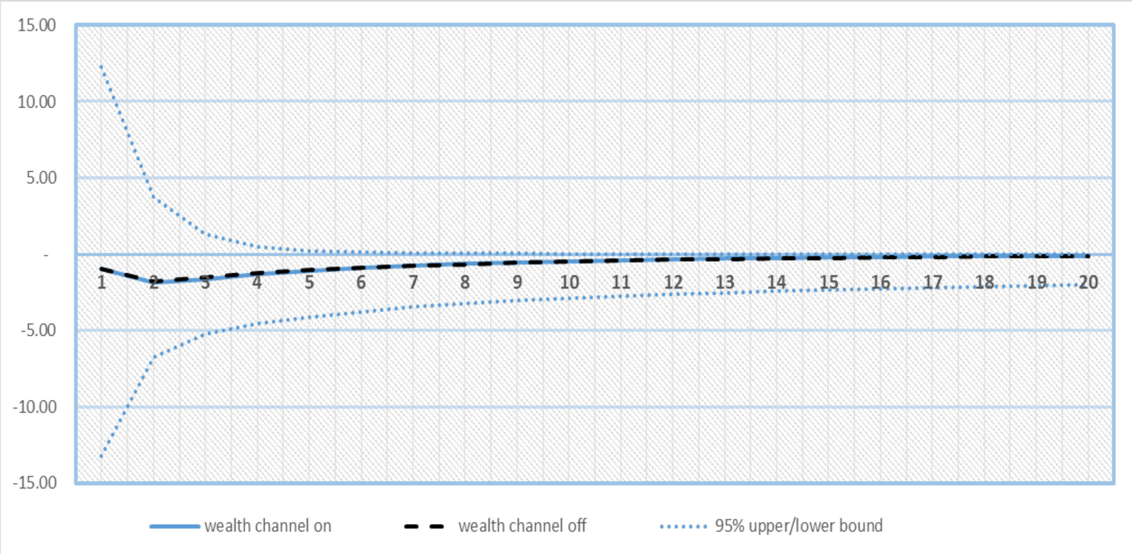
Figure 6: BVAR with sign restrictions impulse response functions taking into account the Ibovespa index as the wealth variable



Source: elaborated by the authors

The results in figure 7 confirm that the wealth effect brought by changes in the equity prices after shocks in the interest rate does not have a statistically significant impact on consumption. The stock market's weak wealth effect could be interpreted in the light of the theory of life cycle and permanent income as equity prices shocks have a short duration and, thus, do not impact consumption. The fact is that consumption only responds strongly to variations in wealth when such variations are permanent[25]. Furthermore, Brazilian stock market results are aligned with other empirical studies[26], in which the equity elasticity of consumption is close to zero.

Figure 7: BVAR with sign restriction, using the equity proxy as the wealth variable



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4.3 Robustness

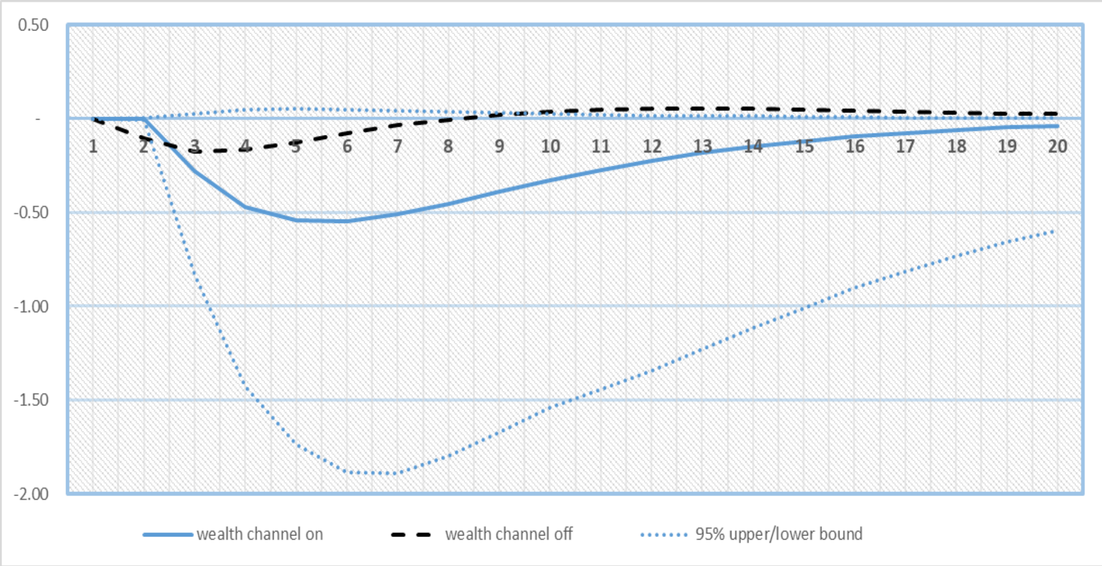
To check the robustness of our findings, we estimate the previous impulse-response functions under the traditional Cholesky factorization and replicate the commodity robustness exercise proposed by Ludvigson, Steindel, and Lettau (2002).

We build a BVAR framework so that the transmission of the monetary policy to the economy follows, by design, the wealth effect theory, implying that when an interest rate hike causes the reduction in the market value of the wealth stock, this reduction is the channel through which consumption is affected. Even though Cholesky factorization does not guarantee these features, the impulse response functions also follow the structural specification detailed in equation (2) and provide a more data-driven reaction of consumption to an interest rate shock. The results in figure 8 reinforces the neutrality of public debt on consumption as its response continued to be statistically insignificant.

[25] Lettau and Ludvigson (2001) show that consumption responds unequally to changes in consumer wealth, depending on whether such variations are transient or permanent. While transient variations have a low effect on consumption, permanent variations have a strong effect. It is worth to note, however, that the study did not map out whether the effects of monetary policy are transient or permanent.

[26] See Ludwig and Sløk (2004) and Bertaut (2002)

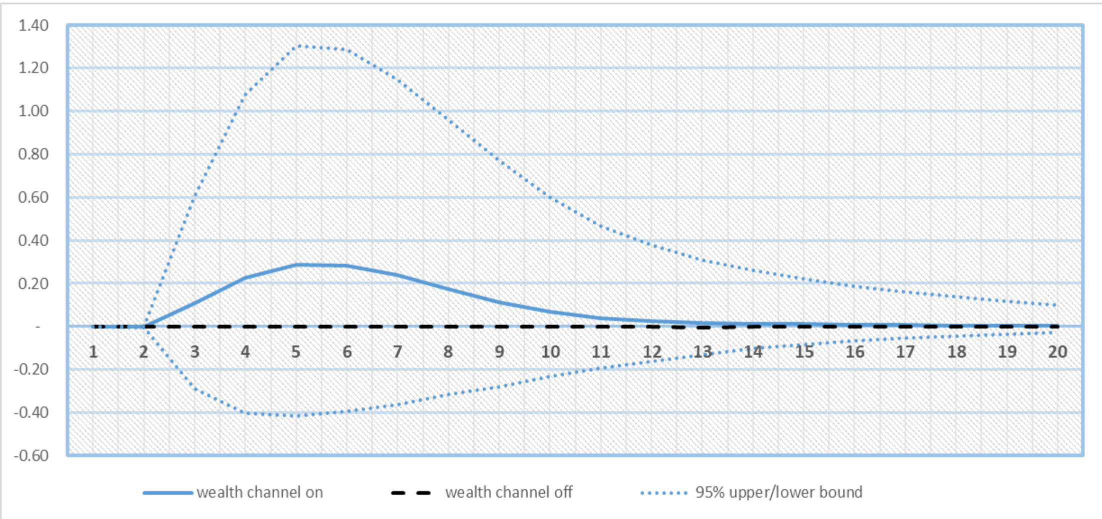
Figure 8: VAR with Cholesky factorization, using the DPMFi as the wealth variable.



Source: elaborated by the authors

Next, we can assess LFTs' role on monetary policy transmission. Figure 9 confirms that the wealth effect is irrelevant as the path of consumption is almost identical when we consider the wealth channel on and when we turn it off. Changes in the interest rate have no statistically significant impact on consumption in both cases. It is worth to highlight that LFTs' exclusion worsens DPMFi's wealth effect, strengthening the conclusion that these securities do not deteriorate monetary policy propagation.

Figure 9: VAR with Cholesky factorization, using the DPMFi excluding the LFTs as the wealth variable.



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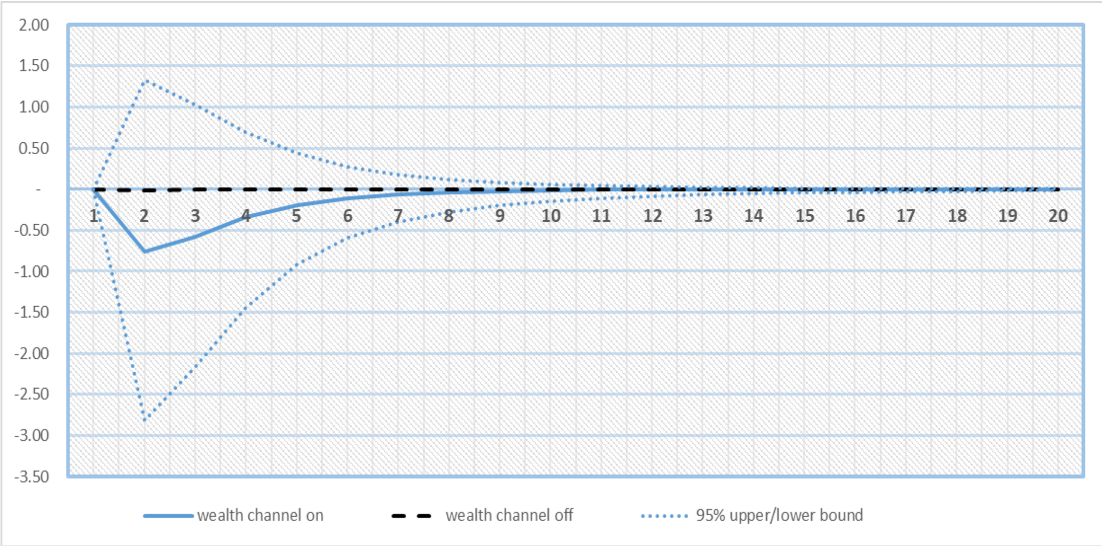
We can also test public debt neutrality under a broader debt definition. In line with the previous results, Figure 10 shows that the consumption is insensitive to an interest rate shock, even taking into account an extensive debt definition computed by the DPMFi and REPOs.

Figure 10: VAR with Cholesky factorization, using the DPMFi plus REPOs as the wealth variable.



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An interesting result is that housing prices are a key transmission mechanism of the wealth effect. Figure 11 indicates that the result is not being driven by the identification of the shocks. The consumption reaction is also statistically different from zero. An increase in the interest rate leads to a fall in wealth and consumption. Note that in this case the inflation does not react to interest rate shocks even considering the wealth effect on consumption. It might be the case that another factor is clogging the transmission mechanism that is not the wealth effect.

Figure 11: VAR with Cholesky impulse response functions taking into account the real estate price index as the wealth variable.

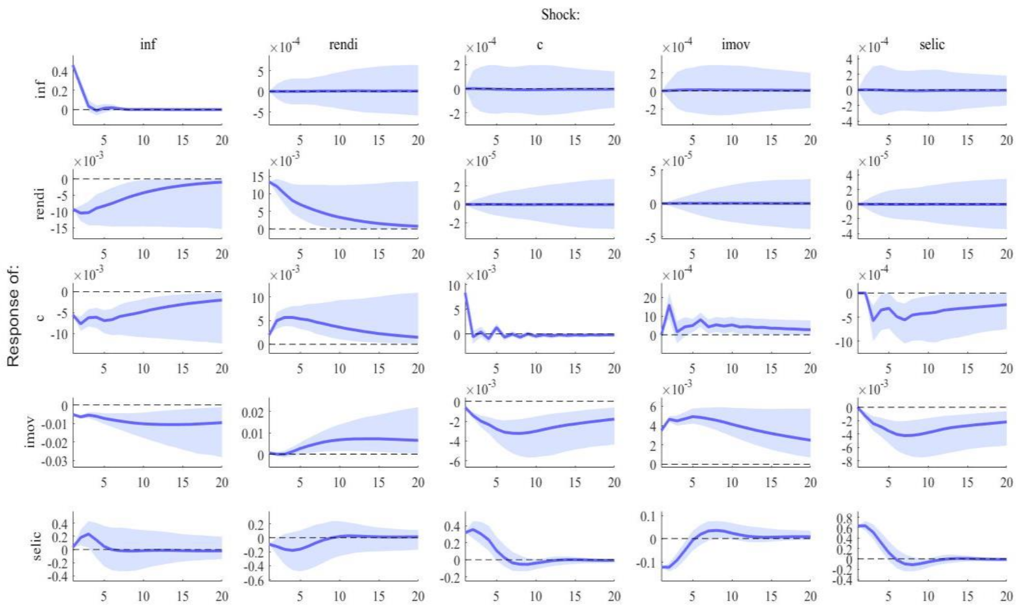

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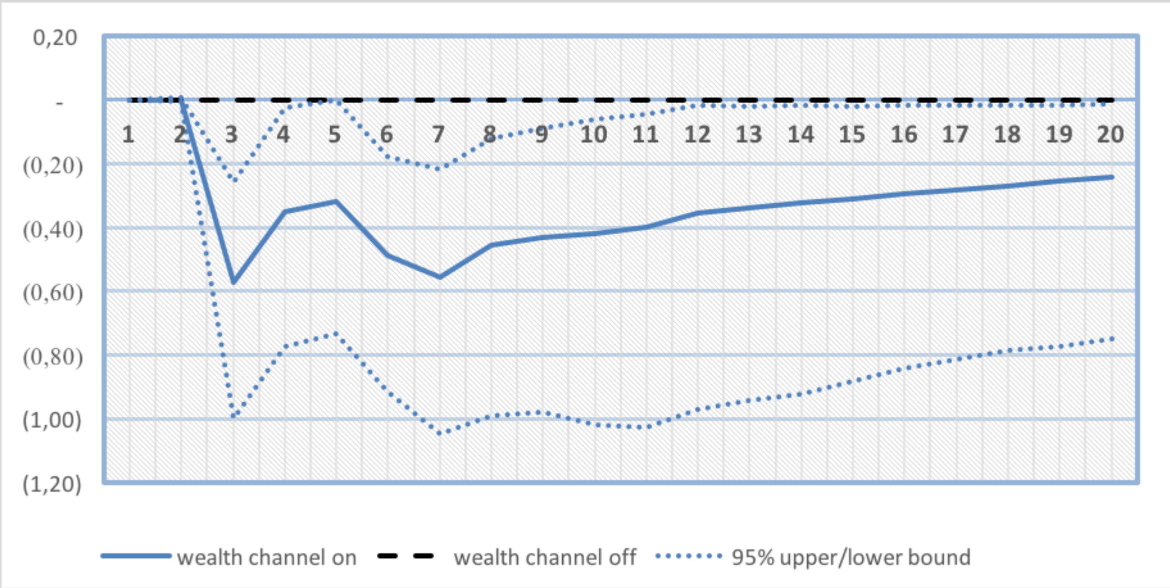
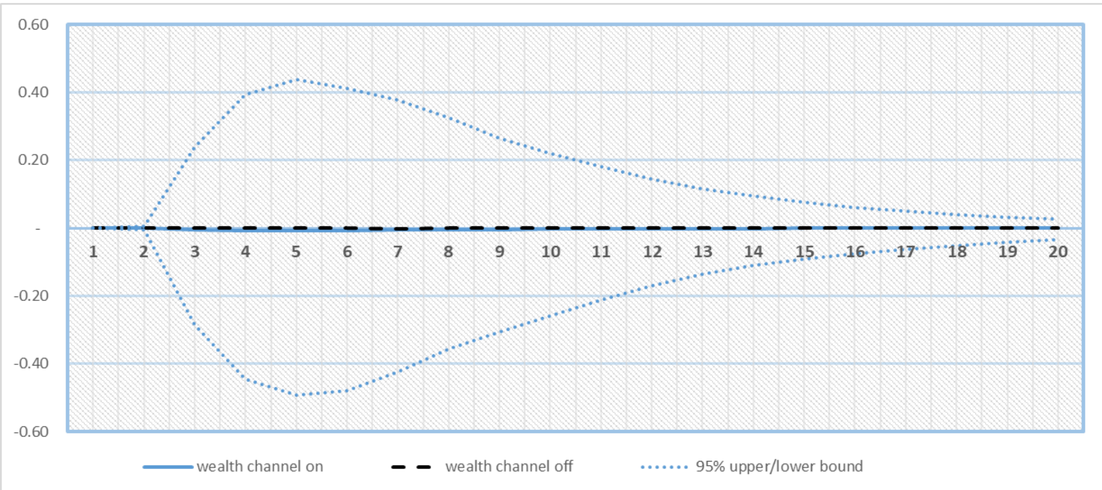
Figure 12: VAR with Cholesky factorization, using the real state proxy as the wealth variable.



Source: elaborated by the authors

Another interesting feature is consumption's insensibility to stock market changes. The results in figure 13 confirm that the wealth effect brought by changes in the equity prices after shocks in the interest rate does not have a statistically significant impact on consumption.

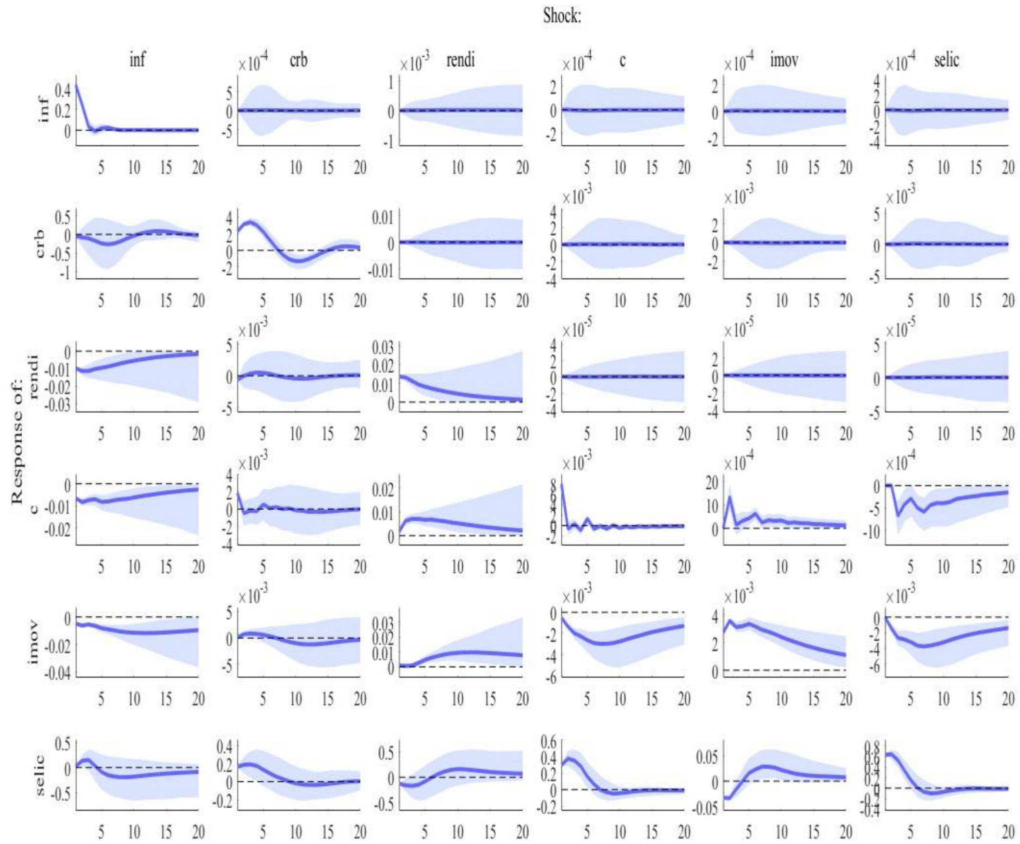
Figure 13: VAR with Cholesky factorization, using the equity prices as the wealth variable.



Source: elaborated by the authors

Finally, we present the commodity robustness exercise proposed by Ludvigson, Steindel, and Lettau (2002). According to the authors, it is important to include a commodity index as it can capture information almost contemporaneously with inflationary shocks about to take place. By comparing the impulse response functions with and without a commodities index in Figure 14, one can easily see that magnitude and significance of the real estate wealth effect were confirmed.

Figure 14: Real estate commodity robustness test.



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5. Conclusions

The paper studies the role of the wealth channel in the transmission of monetary policy in Brazil. Following the recent literature, we separate the wealth into different components: public debt, equity, and real estate. To address these issues, we follow Ludvigson, Steindel and Lettau (2002) in testing the role of the different type of assets, yet we estimate a BVAR and we perform different robustness tests.

The results indicate that the stock of public debt does not play a role in the transmission mechanism of monetary policy through the wealth effect. Under different specifications, although a shock in the interest rate exerted an impact on the stock of wealth composed by government bonds, it did not propagate to consumption, implying that the wealth effect of this stock of wealth is statistically insignificant. It is important to note that this result holds even after taking into account the composition of debt. Differently from what is argued by some authors, the existence of debt indexed to the short-term policy rate does not reduce the power of monetary policy. Even after the indexation is considered, the wealth effect continues to be irrelevant.

The paper shows that the debate about the role of the wealth effect in the transmission of monetary policy is misled, focusing only on the impact of the government bonds. We find that the wealth effect works in Brazil only through the evolution of real estate prices. The paper shows that a shock to the interest rate leads to a fall in real estate prices and in consumption. Our work also indicates that this effect is not only significant, but it persists for a long period. In addition, there is also an indication that changes in the stock market wealth do not have a significant impact on consumption.

The results are in line with the idea that only persistent shocks in wealth would have a sizeable effect on consumption and that consumption responds unevenly to changes in consumer wealth, depending on whether such variations are transient or permanent. The paper shows that the impact on consumption depends on the type of wealth and in the case of Brazil, only real estate wealth has a significant impact on consumption.

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Variable Rate Debt to Ensure the Government Budget against Macroeconomic Shocks

Gerhard Fenz[1] and Johannes Holler[2]

Abstract

Inspired by the fiscal insurance theory of public debt management we focus on the role of debt management in insuring the government budget against business cycle fluctuations. In particular, we analyze the potential of inflation-indexed and short-term interest-rate-linked debt to hedge government budgets against macroeconomic demand, supply and monetary policy shocks. We employ a multi-country BVAR model for selected euro area countries and the euro area aggregate over the period 1999 to 2018. The obtained results show that short-term interest-rate-linked debt is able to hedge a substantial part of cyclical budget balance dynamics for all considered countries while inflation-indexed debt can only be used by selected euro area countries to stabilize the budget balance. The reasoning for the mixed results is based on the variation of the hedging potential of both instruments for specific drivers of business cycle fluctuations. In case of demand shocks both instruments have the potential to insure the government budget, while in case of supply shocks this is only true for interest-rate-linked debt. In case of monetary policy shocks, only inflation-indexed debt can be used to smooth the budget balance. The composition of the aggregate shock decides about the overall hedging potential of variable-rate debt instruments.

JEL Classification: H63, E62, E44

Keywords: Public finance, debt management, variable rate debt

1. Introduction

Over the last decades, sovereign debt management in OECD countries has shifted from operational bodies within finance ministries or central banks to partly or fully independent entities. This operational transformation has been accompanied by a change of debt management objectives from macroeconomic stabilization to expected cost minimization (Hoogduin et al., 2011). Our work tries to counteract this development by raising awareness about the potential of debt management as a vital tool of fiscal stabilization policy. Inspired by the fiscal insurance theory of public debt management (Faraglia et al., 2008) we focus on the role of debt management in insuring government finances against macroeconomic shocks.

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Disclaimer: This paper does not necessarily express the views of the Oesterreichische Nationalbank or the Austrian Fiscal Advisory Council.

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In the traditional optimal taxation literature setting (Lucas and Stokey, 1983) fiscal insurance addresses the potential of debt management strategies to smooth taxes over time. Our approach focuses on the potential of debt management to create pro-cyclical interest payment reactions (i.e. decreasing interest payments in a recession and increasing payments in a boom) in order to smooth the budget balance over time creating fiscal space for automatic stabilizers to move freely and to reduce the need for pro-cyclical policies like spending cuts during recessions. Similar motives of public debt management that indirectly stress the situation of a fiscal rule environment can be found in Quah et al. (1997), Giavazzi and Missale (2004), Borensztein et al. (2004), Goldfajn (1998), Lloyd-Ellis and Zhu (2001) and Missale (2012). In theoretical terms, our setting implies that public debt management tries to minimize the conditional variance of the budget balance ratio, i.e. to minimize the cash flow risk of the budget, which corresponds to a smoothing of the budget balance ratio over time. Alternative risk measures relevant for public debt management like rollover risk, liquidity risk, interest rate risk and reputation risk stay undiscussed.[3]

Deviating from the cited literature, we do not consider the price of government bonds (market value of debt) to be of specific relevance for the governmental inter-temporal budget constraint (fiscal policy/public debt management). This assumption replicates real-life debt management behavior in many countries, where government debt is to a large extent held to maturity and debt management only occasionally makes use of buy-backs or equivalent derivative operations. This assumption is further backed by the findings of Faraglia et al. (2014) and Faraglia et al. (2016) that held to maturity portfolios are needed to replicate real life optimal portfolio decisions observed for the US, where a large share of total debt is issued in short-term securities.

The first part of the paper presents a theoretical framework for identifying the key elements determining the hedging/insurance properties of debt management instruments. We show that in a simple static framework the optimal debt portfolio hedge against the effect of macroeconomic shocks on the government budget is realized if the reaction of interest payments is equivalent to the reaction of the primary budget balance ratio and budget balance becomes completely immune to macroeconomic shocks. GDP-indexed bonds, an idea first discussed following the debt crisis of the 1980's (Krugman, 1988, Froot et al., 1989 and Shiller, 1998) are a natural first best candidate to replicate government budgets that are immune to the economic cycle.[4] Unfortunately, until today liquid markets for GDP-indexed bonds do not exist. The instrument should therefore be seen as an intellectually promising mind experiment, that has only found application during historic debt restructurings (Mexico 1981: oil price-indexed bonds, Bulgaria (1994), Argentina (2005), Greece (2012) and Ukraine (2015): GDP-indexed bonds). Reflecting this fact, we try to replicate the features of GDP-indexed bonds using established variable rate debt instruments. By considering stylized textbook monetary policy and macroeconomic demand and supply shocks we analyze the hedging potential of debt instruments with coupon payments linked to short-term interest rates (floating rate bonds) and inflation rates (inflation- indexed-bonds). We use a standard theoretical model to show that floating rate bonds can be used to insure the government budget against demand shocks while in the case of supply shocks their hedging potential crucially depends on the theoretically indeterminate shock reaction of interest rates. Only in the case of monetary policy shocks the theoretical framework clearly identifies an increase of the variance of the budget balance using floating rate instruments. In contrast, inflation-indexed debt reduces budget cash flow risk in the case of demand shocks and monetary policy shocks while it increases the variance of the budget balance in the case of supply shocks.

[3] For a thorough discussion of these risk measures in the context of public debt management see Holler (2013).
[4] For a recent discussion on the merits of GDP-indexed bonds see Blanchard et al. (2016).

The theoretical analysis is followed by an empirical evaluation of the potential historical performance of variable rate debt instruments to insure the government budget of Austria, Belgium, Germany, France, Italy and Spain against national and international macroeconomic shocks over the period 2006 to 2018. Specifically, we use a multi-country structural Bayesian VAR model to identify the joint reaction of macroeconomic variables to national and euro area supply, demand and monetary policy shocks. This analysis supports the results drawn from the simple theoretical framework and further highlights that the theoretically ambiguous hedging potential of floating rate bonds against supply shocks is clearly positive for all considered countries. We identify the potential of short-term interest-rate-linked debt to insure the government budget against aggregate macroeconomic shocks observed over the period 2006 to 2018 and discuss the mixed results on the aggregate hedging potential of inflation-indexed debt.

2. Analytical framework

In our framework the objective of debt management solely lies in smoothing the budget balance in terms of GDP over time. Mathematically this implies that debt management is trying to minimize the conditional variance of the budget balance ratio $minE_t(BB_{t+1} - E_t BB_{t+1})^2$, where BB_t is the budget balance ratio in period t. We assume that debt is issued at face value (par) and held until maturity. The contemporaneous government budget constraint is given by:

$$BB_{t+1} = PB_{t+1} - i^a_{t+1} D_t \qquad (2.1)$$

where PB_{t+1} is the primary balance ratio and i^a_{t+1} is the average growth-adjusted benchmark interest rate in period $t+1$ $\left(i^{\tilde{a}}_{t+1} Y_t / Y_{t+1}\right)$ and D_t is the debt ratio in period t. The impact of an unexpected macroeconomic shock ϵ_{t+1} on the balance budget ratio is given by[5]:

$$\frac{\partial BB_{t+1}}{\partial \varepsilon_{t+1}} = \frac{\partial PB_{t+1}}{\partial \varepsilon_{t+1}} - \frac{\partial i^a_{t+1}}{\partial \varepsilon_{t+1}} D_t \qquad (2.2)$$

A perfect budget balance hedge against the macroeconomic shock implies that the reaction of

the primary balance ratio is offset by the reaction of interest payments $(i^a_{t+1} D_t)$:

$$\frac{\partial PB_{t+1}}{\partial \varepsilon_{t+1}} = \frac{\partial i^a_{t+1}}{\partial \varepsilon_{t+1}} D_t \qquad (2.3)$$

The reaction of the primary balance to a macroeconomic shock (left-hand side of equation) is crucially dependent on the fiscal policy (transfer and taxation system) of a country that determines the size of automatic stabilizers. To understand the reaction of interest payments (right-hand side of equation) we consider a simple two-period framework with fixed and variable interest rate debt to split the average growth-adjusted interest rate into its components:

$$i^a_{t+1} D_t = i_t D_t (1 - \Psi) + i_{t+1} D_t \Psi \qquad (2.4)$$

where $\Psi \in 0, 1$ is the share of variable rate debt and $(1 - \Psi)$ is the share of fixed rate debt.

$$\frac{\partial i^a_{t+1}}{\partial \varepsilon_{t+1}} D_t = \frac{\partial i_{t+1}}{\partial \varepsilon_{t+1}} D_t \Psi \qquad (2.5)$$

[5] For the sake of clarity, we assume that the second order effect of macroeconomic shocks on the growth-adjustment factor Y_t / Y_{t+1} in equation 2.2 is negligible.

Equation (2.5) highlights that the reaction of interest payments is determined by the reaction of the benchmark interest rate to the macroeconomic shock, the size of public debt and the debt portfolio structure chosen by the public debt management authority. In a traditional set of public debt management instruments, the variable-rate-ratio[6] represented by Ψ, steers the influence of benchmark interest rate changes on overall interest payments. The general question of our analysis is whether Ψ can be used to smooth the government budget against the budget balance effect of macroeconomic shocks. Specifically, we try to identify the variable-rate-ratio that minimizes the variance of the budget balance by considering two types of variable rate instruments, namely inflation-indexed debt and floating rate debt linked to the 3-month Euribor. With respect to the macroeconomic shocks (ε) we differentiate between macroeconomic supply, demand and monetary policy shocks. We draw from textbook economic theory that inflation-indexed debt has the potential to smooth the government budget in the case of demand and monetary policy shocks while the opposite is true in the case of macroeconomic supply shocks. The smoothing potential of floating rate debt is less clear-cut. While floating rate debt smooths the budget balance in the case of demand shocks, it increases the variance of the budget deficit in case of monetary policy shocks. Its reaction to supply shocks is ambiguous. In a Taylor-rule-like monetary policy framework short term interest rates are determined by an inflation term and by an output term. If the output reaction to a supply shock is strong enough compared to the inflation reaction and if the monetary policy rule puts enough weight on the output term, floating rate debt offers a budget hedge against supply shocks. The opposite is true for a strong reaction of inflation to the supply shock and large weight of the inflation term in the monetary policy rule. This highlights that the size and type of observed economic shocks and the monetary policy rule in place determine the hedging or smoothing potential of the considered variable debt instruments. In order to draw general conclusions about the hedging potential of variable rate instruments the next section of the paper empirically evaluates their potential historical performance over the period 1999 to 2016 for Austria, Belgium, Germany, France, Italy and Spain.

3. Identification of macroeconomic shocks driving business cycle fluctuationes

This part focuses on the identification and quantification of structural economic shocks hitting the analyzed economies between 2000 and 2018. With respect to our theoretical framework we try to identify the macroeconomic shock variable ε and its impact on economic output, inflation and interest rates. Economic shocks driving business cycle fluctuations are analyzed within a Bayesian VAR model using sign and zero restrictions. The identification of euro area and country specific shocks is analyzed in a two-country/region model including the euro area and the respective national economy (see Canova (2005), Fenz and Schneider (2006) and Fenz and Schneider (2007)).

3.1 The BVAR model

The BVAR model consists of three variables for the euro area: real GDP as a measure of real activity, the HICP and the 3-month Euribor as measures of inflation and short-term interest rates. Since all considered countries are European monetary union (EMU) member states the country block reduces to two variables only: real GDP and HICP. Given the small size of the Austrian and Belgian economy relative to the euro area, we assume that there are no feedbacks from Austrian and Belgian variables to euro area variables. In contrast, Germany, France, Italy and Spain are modeled as euro area member countries with potential effects of their economy on euro area aggregates. Since the focus of the paper is on short- to medium-term effects of idiosyncratic economic shocks only stationary variables enter

[6] Variable rate debt as a percentage of total debt.

the BVAR. The possible loss of information concerning long-run relations by not using levels in the BVAR is more than offset by the reduced risk of spurious regressions. Since statistical tests indicate that most variables are integrated of order 1, I(1), we decided to use annual growth rates for output and price index. Short-term nominal interest rates enter in levels.[7] The corresponding reduced form two-country model is given by:

$$\begin{pmatrix} x_t^{EA} \\ x_t^i \end{pmatrix} = \begin{pmatrix} A_{11}(L) & A_{12}(L) \\ A_{21}(L) & A_{22}(L) \end{pmatrix} \begin{pmatrix} x_{t+1}^{EA} \\ x_{t+1}^i \end{pmatrix} + \begin{pmatrix} \varepsilon_t^{EA} \\ \varepsilon_t^i \end{pmatrix} \qquad (3.1)$$

where $A_{12}(L)$ is 0 for countries *i* = Austria and Belgium and $\left(\varepsilon_t^{EA}, \varepsilon_t^i\right)' \sim (0, \Sigma)$, $\Sigma = blockdiag\left(\Sigma_{\varepsilon^{EA}, \varepsilon^i}\right)$. x_t^{EA} represents the set of euro area variables, x^i the set of country specific variables. According to the Akaike information criteria, a lag length of two was selected.

3.2 Identification scheme

We use the identification scheme of Canova (2005) to derive structural shocks from the BVAR innovations. The basic idea behind that approach is to use sign restrictions on the cross-correlation of the impulse responses to identify economically interpretable shocks. Instead of imposing restrictions on the contemporaneous relations between the innovations, we search randomly among all possible decompositions of the BVAR innovations and choose those which are in line with our restrictions on the impulse responses.[8] The search is continued until 10,000 admissible decompositions are found. Among all admissible decompositions, we choose the one that according to the historical decomposition has the minimal distance over all shocks to the median historical decomposition. These sign restrictions are derived from standard economic theory. We aim to identify three different structural shocks - a demand shock, a supply shock and a monetary policy shock - for the euro area and two different structural shocks - a demand shock and a supply shock - for single countries. Standard macroeconomic theory provides us signs for the theoretical co-movement of the variables of the euro area and the country block in the BVAR in response to the structural shocks. A positive demand shock will generate a positive response of output and a rise in inflation. Monetary authorities will increase interest rates, thereby generating a positive co-movement between all three variables. In contrast, a positive supply shock will increase output but decrease prices, while the effect on short-term interest rates remains ambiguous. Finally, a positive monetary policy shock is associated with lower short-term interest rates. The expansionary impulse will cause output and inflation to increase simultaneously. Thus, the three structural shocks are characterized by co-movements between output, inflation and short-term interest rates with different signs. These sign restrictions can be derived from a large set of theoretical models. They are consistent with the standard textbook aggregate-demand aggregate-supply framework as well as with more advanced models like DSGE models in the line of Smets and Wouters (2003):

[7] To render the interest rate series stationary in levels we corrected for the negative trend over the observation period.

[8] Compared to alternative identification schemes (Cholesky decomposition, short-run restrictions (Sims (1980)), long-rung restrictions (Blanchard and Quah (1988)) and the generalized impulse response function (Pesaran and Shin (1998)) the one proposed by Canova (2005) has two main advantages. First, the statistical problem of orthogonalization is strictly separated from identification, which helps to make all assumptions needed for identification very explicit. Second, no zero restrictions on either the short-run or the long-run impulse responses are needed. These are often inconsistent with a large class of theoretical models (Canova and Pina (1999)).

Table 3.1: Sign restrictions

	GDP^{EA}	π^{EA}	i^{EA}	GDP^{AT}	π^{AT}
EA demand shock	1	1	1	?	?
EA supply shock	1	−1	?	?	?
EA monetary policy shock	1	1	−1	?	?
country i demand shock	A	A	A	1	1
country i supply shock	A	A	A	1	−1

where A = 0 for *j* = Austria and Belgium and A = ? for *j* = Germany, Frances, Italy and Spain. GDP^j indicates the year on year growth rate of real GDP of country j, π^j the year on year inflation rate of country *j* and i^{EA} the short-term interest rate of the euro area. For each admissible decomposition, the impulse responses for the euro area and country specific variables must fulfill the theoretical restrictions outlined in table 3.1. A positive co movement is indicated by (1) in table 3.1, a negative co-movement by (-1), a zero restriction by (0) and no restriction by (?). For the single countries analyzed, a distinct monetary policy shock cannot be identified as all of them are EMU-member states; thus, the country blocks consist of only two variables, GDP growth and inflation, respectively. The estimation method used follows Rubio- Ramirez et al. (2014). It allows simultaneously for sign restrictions and zero restrictions in a time varying BVAR model with stochastic volatility. As can be seen from table 3.1 the response of output growth and inflation of individual countries to euro area shocks has not been restricted a priori. Nevertheless, given the tight economic linkages one would expect the individual country variables to move in the same direction as the euro area variables. All data are taken from Eurostat's New Cronos database. The estimation period starts in the first quarter of 1999 (start of EMU) and ends with the fourth quarter of 2018. The analysis of the structural shocks that hit the individual countries draws on results for impulse response functions and historical decomposition.

3.3 Impulse response functions

The first step in the analysis of business cycle shocks in the euro area and individual countries is to consider the impulse response functions of the BVAR model. All shocks show the expected textbook dynamics. While this holds per definition for euro area and individual country shocks within each region, also the transmission pattern of euro area shocks to the individual countries – a case where no restrictions have been imposed – is in line with expectations. All three structural euro area shocks – supply, demand and monetary policy shocks – cause GDP and prices in the individual countries to move in the same direction as in the euro area. Moreover, euro area supply shocks trigger a positive co-movement between the short-term interest rate and GDP. Thus, in the implicitly estimated Taylor-rules of the BVAR model, changes in output dominate changes in inflation in case of a standard supply shock. The use of short-term interest-rate-linked debt therefore reduces the variance of the government budget balance not only in the case of euro area demand shocks but also for euro area supply shocks. Only monetary policy shocks cause short-term interest rates and GDP growth to move in opposite directions.

To summarize, the estimated impulse response functions clearly identify a hedging potential for short-term interest-rate-linked debt in case of euro area demand and supply shocks and for inflation-linked debt in case of demand and monetary policy shocks.

3.4 Historical decomposition

Figure 5.1 shows the historical decomposition of GDP growth for each considered country into euro area and country specific structural shocks. The contribution of a shock at time *t* comprises the contemporaneous influence at time t as well as the delayed influence of the shock in all previous periods. Thus, although the model was estimated over the full sample it takes some time at the beginning of the sample period until past shocks can explain business cycle fluctuations completely. The length of this phase-in period depends crucially on the persistence of shocks as shown in the impulse response functions. The unexplained part of business cycle fluctuations at the beginning of the sample is captured by the blue bars called ”exogenous” in figure 5.1. After approximately 5 years the unexplained part of business cycle fluctuations becomes negligible. The global character of the financial and economic crisis with its climax in 2009 is reflected in the historical decomposition by large negative contributions from international (euro area) shocks – mainly demand shocks – to output growth. But the downturn was also reinforced by country specific shocks.

4. Hedging properties of variable rate debt instruments

After the identification of the reaction of national and international macroeconomic variables to macroeconomic shocks we now focus on the last unexplained element of equation 2.3, the shock-induced reaction of the primary balance. Due to the fact that the primary balance is crucially influenced by a variety of variables outside the scope of the BVAR we did not directly include it in the BVAR analysis. Instead, we simply assume that the shock-induced change of the primary balance is determined by the size of the shock weighted with the semi-elasticity of the budget balance taken from Mourre et al. (2014).[9] Since the semi-elasticity of the budget balance, which measures the reaction of the budget balance as a ratio of GDP to a change in the country specific output gap, considers interest payments to be acyclic, the semi-elasticity of the budget balance is identical to the semi-elasticity of the primary balance. Throughout our analysis we assume that potential output stays constant over time. Therefore, the semi- elasticity of the primary balance is equivalent to the reaction of the primary balance to a change in economic growth rates, which corresponds to the measure of economic shocks presented in the previous section. We now have all the necessary tools to evaluate equation 2.3, which corresponds to the hedging potential of variable rate debt instruments. Due to our assumption that Austrian and Belgian shocks do not influence macroeconomic variables at the euro area level the only instrument which potentially can insure their government budgets against country specific shocks is debt linked to the respective domestic HICP. Contrary, our assumptions imply that euro area interest-rate-linked debt has the potential to insure the government budget of France, Germany, Italy and Spain against country specific shocks. Reflecting the results from the historical shock decomposition (subsection 3.4) we calculate the hedging potential of debt linked to the 3M-Euribor rate and debt linked to domestic HICP rates for country specific and euro area demand, supply and monetary policy shocks.

4.1 Demand shocks

Figure 5.2 presents the reaction of primary balance $(\partial PB/\partial \varepsilon)$, interest payments connected to inflation-indexed debt $(\partial IP\ HICP-linked/\partial \varepsilon)$ and interest payments connected to interest- rate-linked

[9] This assumption implies that inflation rate dynamics do not influence the budget balance. While this assumption must not hold in reality, the influence of inflation rate changes on the budget balance is not clear-cut (see for example Attinasi et al. (2015) or Prammer and Reiss (2015)).

debt (∂IP 3M−Euribor/∂ε) to country specific and euro area demand shocks.[10] In the case of demand shocks, for all analyzed countries over the period 2006 to 2018 interest payments connected to HICP-linked debt and primary balance dynamics generate a pattern that reflects the idea of textbook economic theory of positively correlated inflation rates and GDP growth rates. This holds for country specific and euro area demand shocks. Therefore, our results show that HICP-linked interest payments can partially insure the government budget against macroeconomic demand shocks. The results further highlight that also debt linked to the 3M-Euribor rate can be used to hedge the government budget against demand shocks. Again, this is true for country specific and euro area wide shocks. Only in the case of Austria and Belgium 3M-Euribor rates do not react to country specific shocks and Euribor-linked debt instruments can therefore not be used to insure against domestic shocks.

In order to derive a metric to measure the smoothing potential of variable rate debt we calculate the ratio of the variance of the budget balance ($\sigma^{2,BB}$) and the variance of primary balance ($\sigma^{2,pB}$) for the whole set of viable variable-rate-ratios (φ). Values below unity represent a positive hedging potential of debt instruments while the opposite is true for values above unity. Figure 5.3 shows that HICP- and 3M-Euribor-linked debt has the potential to smooth the government budget of all considered states against demand shocks. For Germany the level of smoothing steadily increases in the share of variable-rate debt. A German debt portfolio consisting of 100% inflation-indexed debt for example would have reduced the variance of the budget balance due to domestic demand shocks by close to 60%. For other countries we observe that the level of smoothing is maximized at a certain variable-rate-ratio below 100%. This implies that for a large share of variable-rate- debt beyond a certain threshold induced changes in interest rate payments to become larger than changes in the primary balance. In all cases except for domestic demand shocks in Spain 3M-Euribor-linked debt has a larger potential to smooth government balances than HICP-indexed debt.

4.2 Supply shocks

The impact of domestic and euro area supply shocks on primary balance and interest payments is presented in figure 5.4. Corresponding to standard economic theory our results show, that HICP and GDP growth dynamics show a strong negative correlation in the case of supply shocks. Therefore inflation-indexed debt amplifies the variance of the budget balance for all variable-rate-ratios. This is true irrespective of whether the shock hitting the economy is of domestic or euro area origin (figure 5.5). Contrary, we calculate positive correlations between GDP shocks and 3M-Euribor rates for all considered countries. This underlines the potential of 3M-Euribor- linked debt to insure the government budget against supply shocks. Our results further highlight a large and for most countries continuously increasing hedging potential for 3M-Euribor-linked debt.

[10] In order to ease the visual interpretation of the graphs we assume that ϕ = 50%. The same is true for all presented figures of potential interest payments throughout the whole article.

4.3 Monetary policy shocks

In our framework, monetary policy shocks imply that euro area GDP growth rates are positively correlated to euro area inflation rates and negatively correlated to changes in euro area interest rates. Our simulations (figure 5.6) show that for most countries monetary policy shock induced country specific GDP changes and country specific HICP are also positively correlated. In these cases, HICP-linked debt reduces the variability of the government budget. Spain and Italy are the only countries where HICP-linked interest payments amplify the variability of the budget balance.[11] Our results further show that for all considered countries shock induced changes of GDP are negatively correlated to 3M-Euribor-rates. Thus, 3M-Euribor-linked debt amplifies the variance of the budget balance in the case of monetary policy shocks.

4.4 Aggregate shocks

Now we turn towards the aggregate GDP growth shock hitting the analyzed economies over the years 2006 to 2018. Clearly, the size of the underlying shocks, as identified in the historical shock decomposition, steers the effect of aggregate shocks. Our simulations show that with the exception of Spain and Italy both considered variable rate instruments have the potential to smooth the budget balance, since the correlation between shock induced changes of GDP and HICP or between GDP and the 3M-Euribor rate are positive (figure 5.7). In Italy and in Spain HICP-indexed debt amplifies the variability of the budget balance for all variable-rate ratios. The hedging potential for HICP-indexed debt in Belgium is positive but rather small. For variable rate debt shares above 36% and 76% respectively, HICP-linked debt amplifies the variability of the budget balance in the case of Belgium and France. Our results further show that in the case of a 3M-Euribor-linked instrument the hedging potential is substantially larger than in the case of an inflation-indexed debt instrument.

5. Conclusions

Our work addresses the potential of variable rate debt to hedge government budgets against business cycle fluctuations. In particular, we analyze the potential of interest payments linked to country specific HICP and 3M-Euribor-rate to counteract shock responses of the primary balance to monetary policy, supply and demand shocks. In the case of supply and demand shocks, we consider country specific as well as euro area shocks.

A simplified theoretical framework is used to show that both variable rate instruments can insure the government budget against demand shocks. In the case of supply shocks, inflation-indexed debt unambiguously amplifies shock-induced budget developments, while the hedging properties of 3M-Euribor-linked debt depends on the relative importance of GDP and inflation dynamics to determine interest rates. The theoretical framework further highlights that in the case of monetary policy shocks only inflation-indexed debt can be used to smooth the budget balance.

To empirically evaluate the hedging potential of variable rate debt for Austria, we employ a multi-country BVAR model to identify country specific and international (euro-area) macroeconomic shocks hitting the Austrian, Belgian, German, French, Italian and Spanish economy over the period 2006 to 2018. Our empirical findings support all theoretically obtained results. Moreover, we find that 3M-Euribor-linked debt can be used to smooth the government budget against macroeconomic supply shocks, indicating that empirically the shock reaction of interest rates is strongly linked to GDP

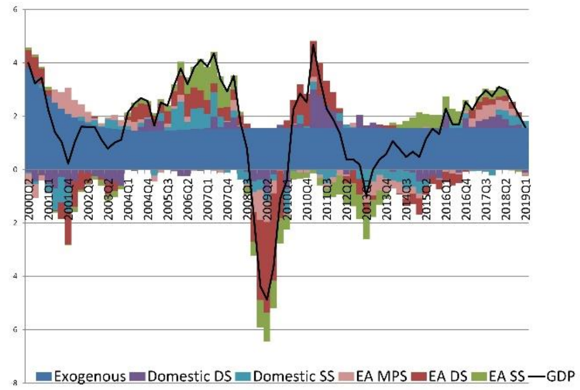
[11] Note that for large shares of variable rate debt, HICP-linked debt also amplifies the variability of the budget balance for Belgium and France.

dynamics. Reflecting the aggregate hedging properties for considered country specific and euro area shocks, we show that in the case of Austria, Belgium, Germany and France both variable rate instruments would have had a substantial potential to insure the budget balance against aggregate macroeconomic shocks. For Italy and Spain HICP-linked debt would have amplified the shock-induced reaction of the government budget, reflecting the rather weak hedging potential of HICP-linked debt in the case of demand shocks and the rather strong shock amplifying effect of HICP-linked debt in the case of supply shocks. In addition, we show that 3M-Euribor-linked debt has the potential to substantially smooth the government budget for all considered countries. Thus, the use of variable rate instruments can create substantial additional room for automatic stabilizers to act freely, enabling welfare increasing macroeconomic stabilization.

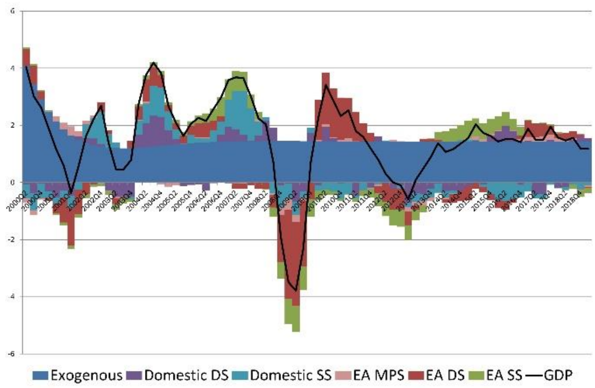
While our work convincingly highlights the potential of variable rate debt in insuring the government budget against macroeconomic shocks, we do not produce results for the optimal portfolio choice regarding the use of variable rate instruments. An optimal portfolio decision about the type and share of variable rate debt would have to reflect all potential alternative candidates of the government objective function (e.g. minimization of expected costs) subject to adequate weighting coefficients. In addition, existing constraints regarding interest payments (e.g. ceiling at a certain percentage of GDP) and alternative risk metrics (e.g. liquidity risk) would have to be considered in the optimization problem.

Figures

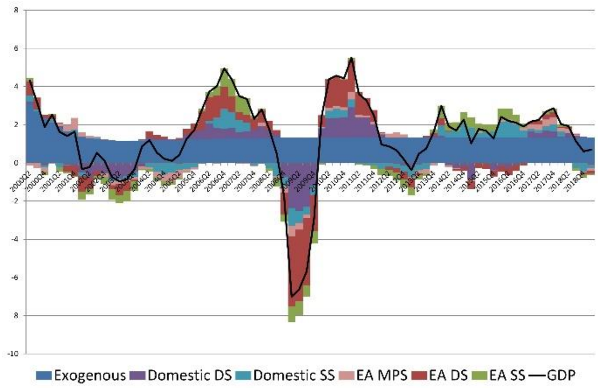
Figure 5.1: Historical decomposition of real GDP growth rates (year-on-year growth rates)



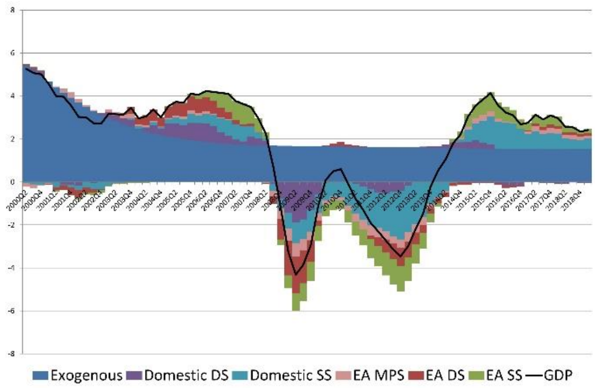
(a) Austria



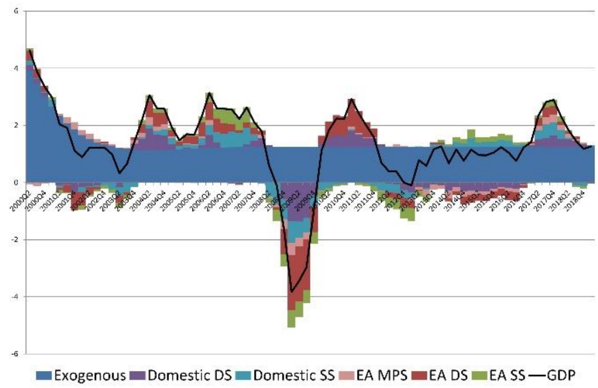
(b) Belgium



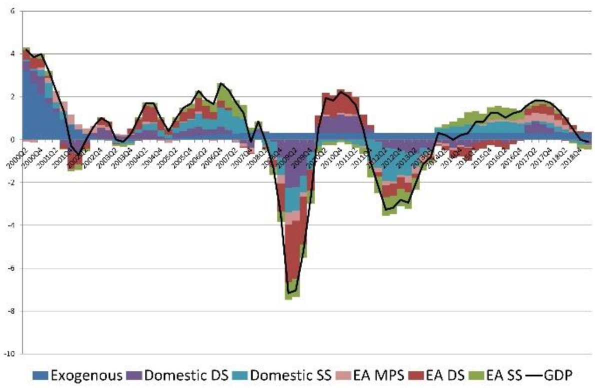
(c) Germany



(d) Spain



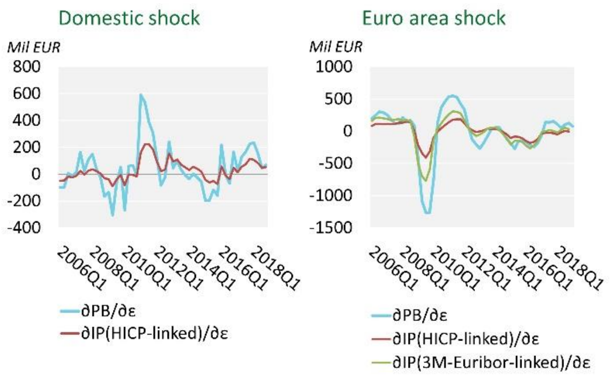
(e) France



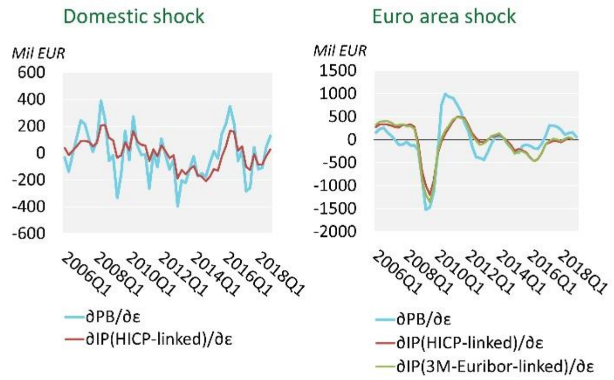
(f) Italy

SS = supply shock, DS = demand shock, EA = Euro Area; Source: own calculations.

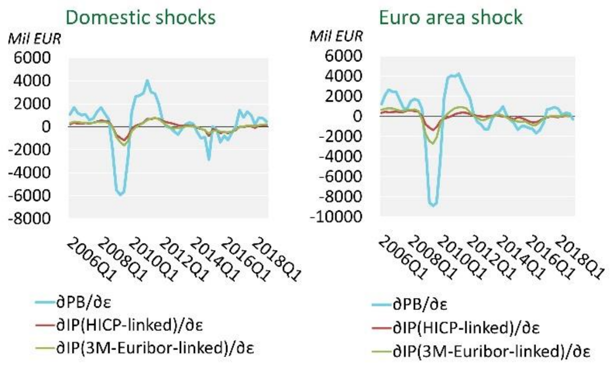
Figure 5.2: Demand shock-induced reaction of primary balance and interest payments



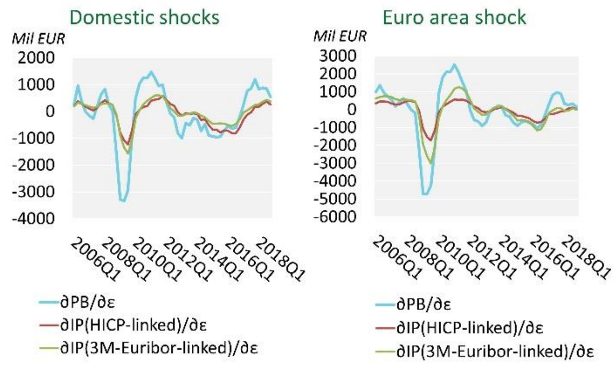
(a) Austria



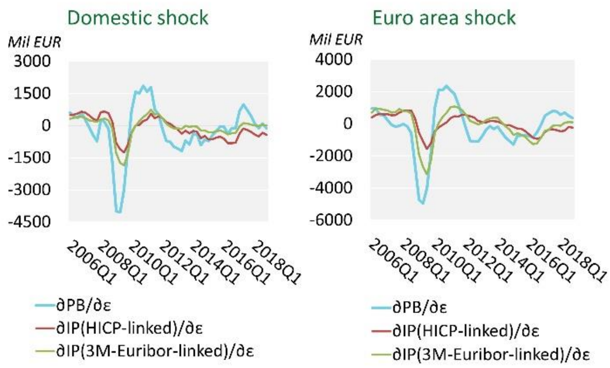
(b) Belgium



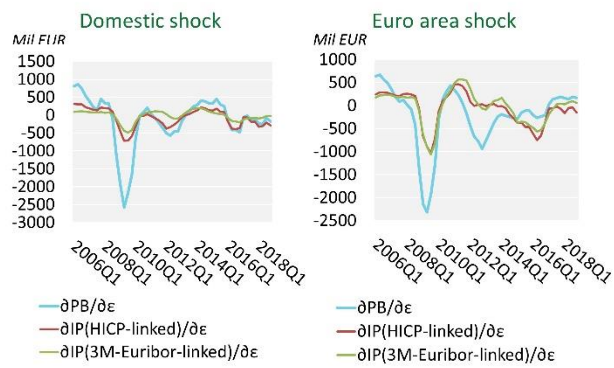
(c) Germany



(d) France



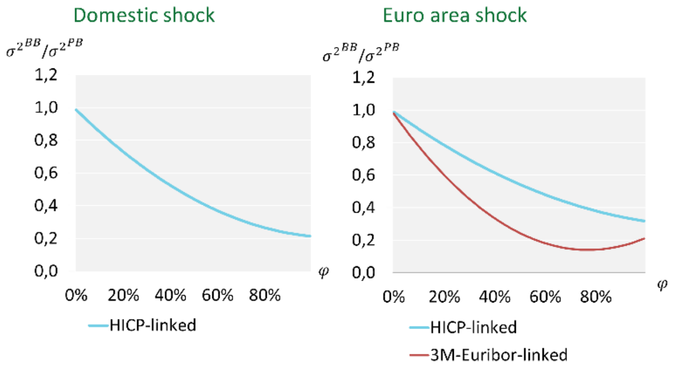
(e) Italy



(f) Spain

Source: own calculations.

Figure 5.3: Demand shock-induced variance of the budget balance



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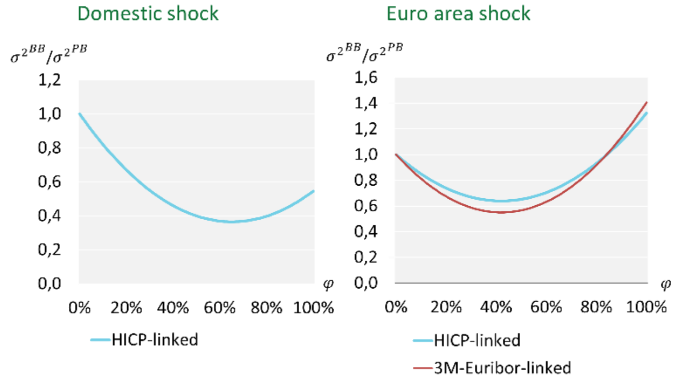

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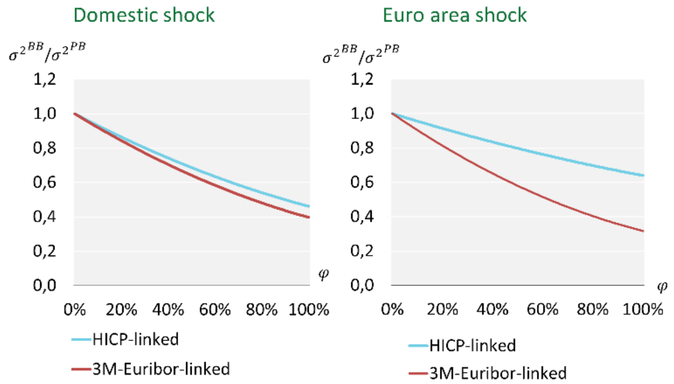
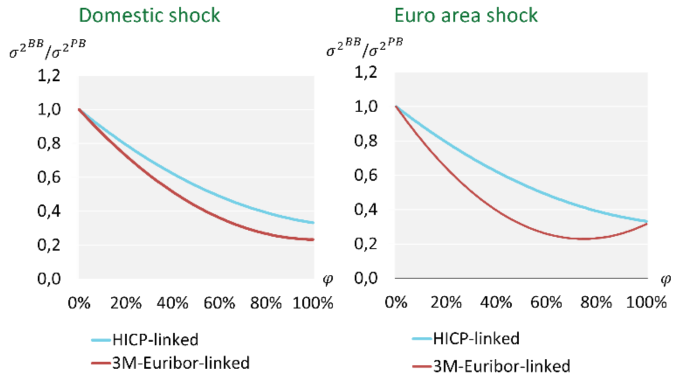


(c) Germany



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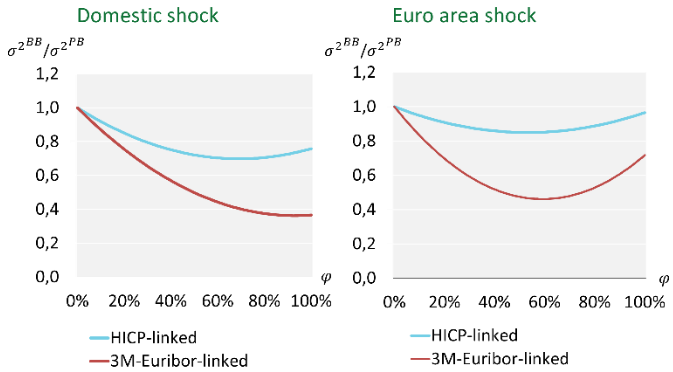

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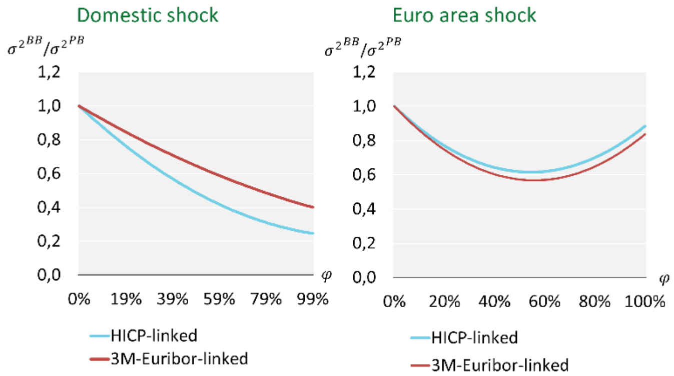
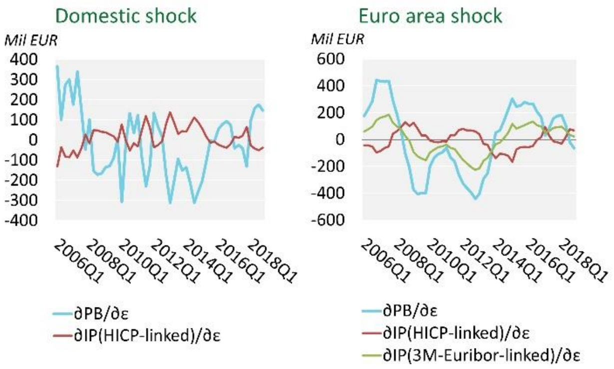


(f) Spain

Source: own calculations.

Figure 5.4: Supply shock-induced reaction of primary balance and interest payments



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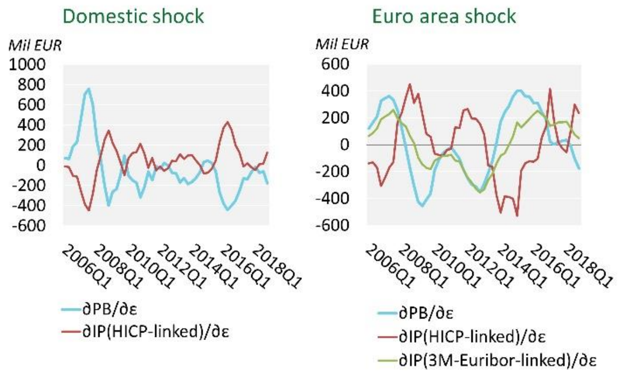

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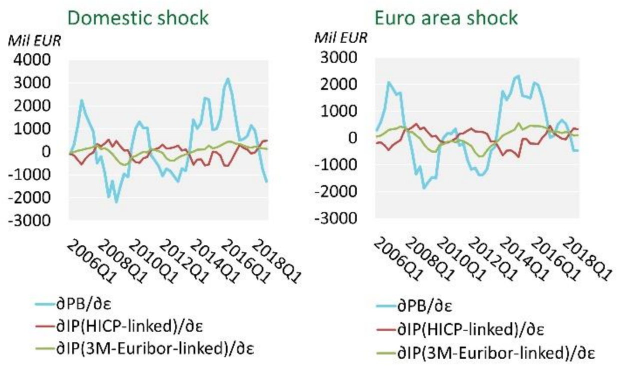

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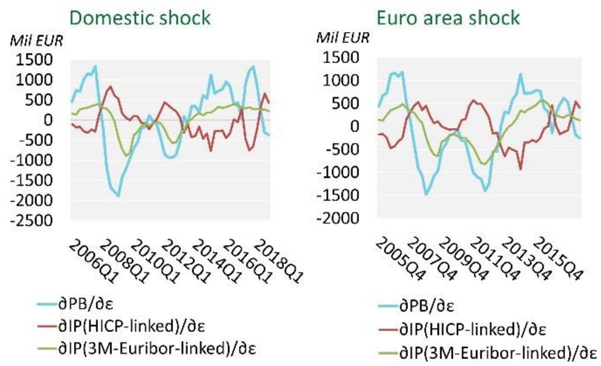

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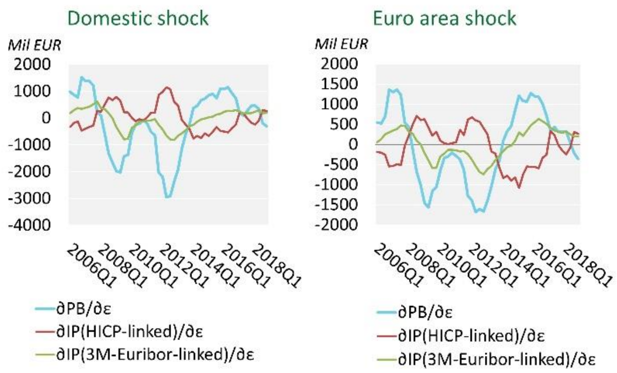

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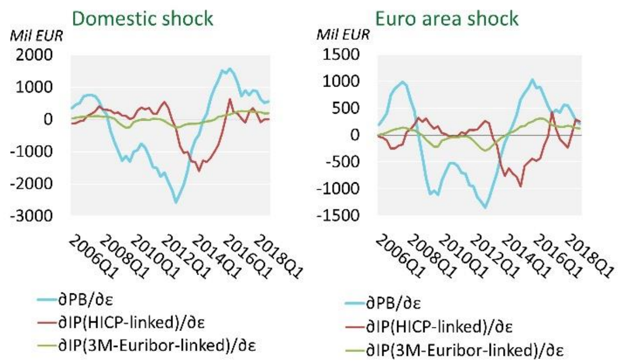
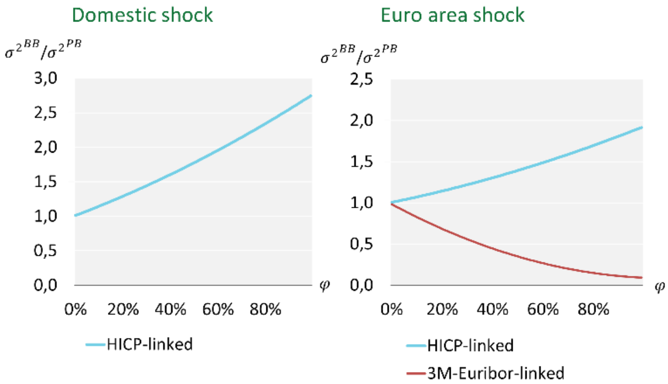


(f) Spain

Source: own calculations.

Figure 5.5: Supply shock-induced variance of the budget balance



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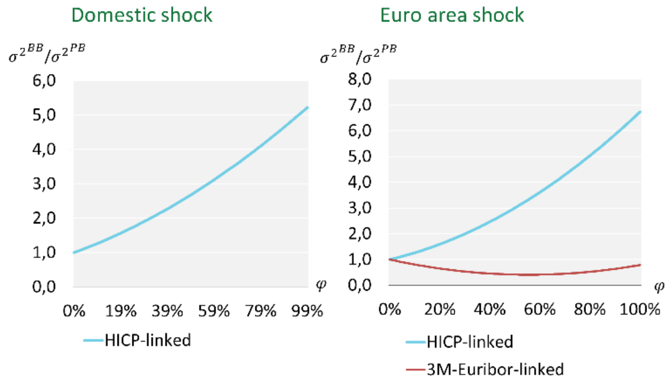

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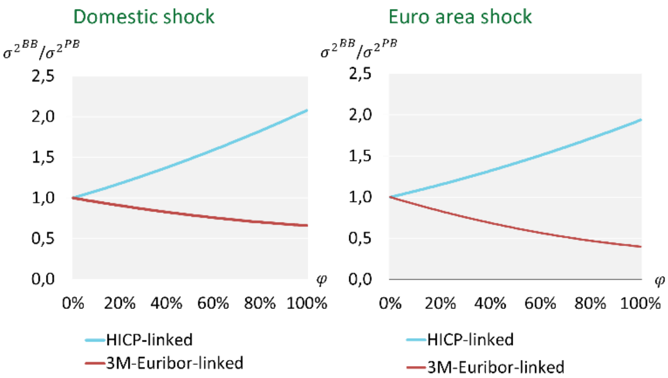

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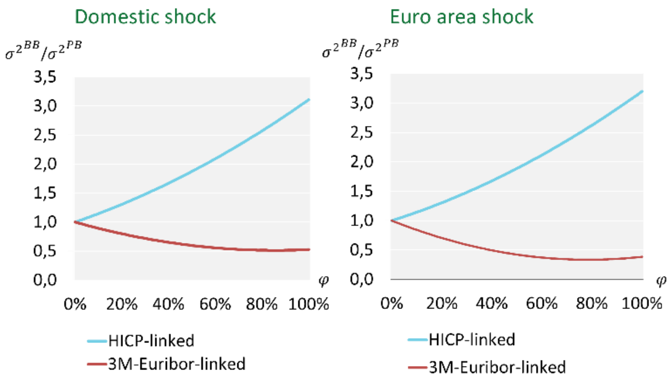

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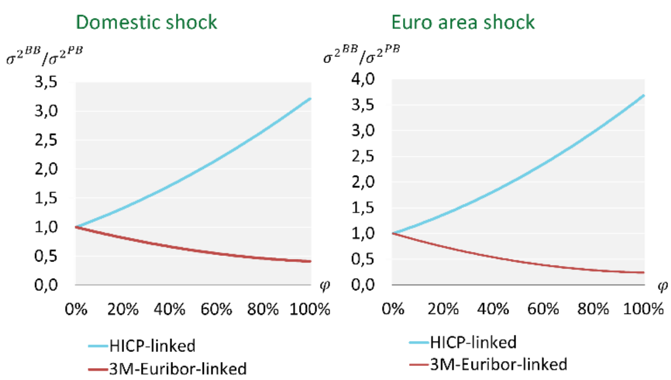

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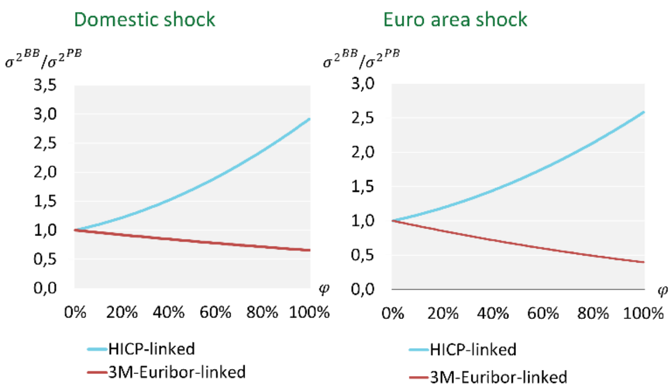
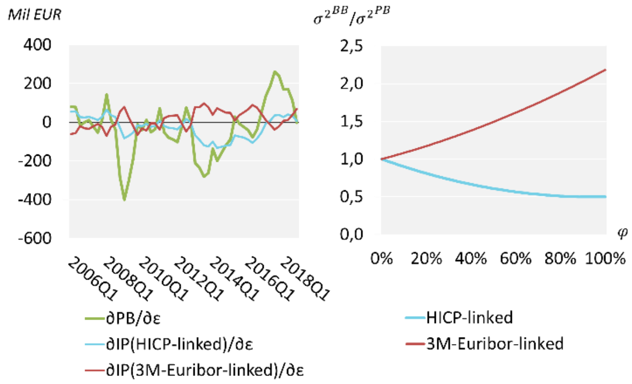


(f) Spain

Source: own calculations.

Figure 5.6: Primary balance, interest payments and variance of the budget balance induced by monetary policy shocks



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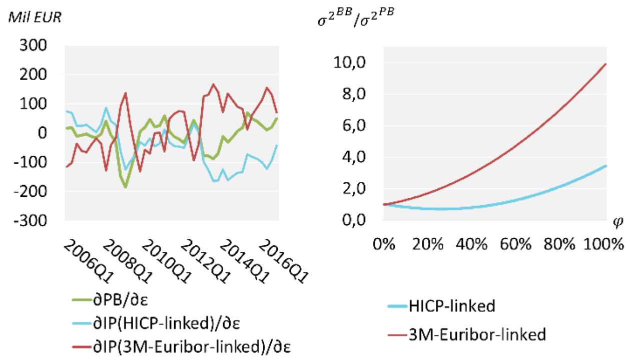

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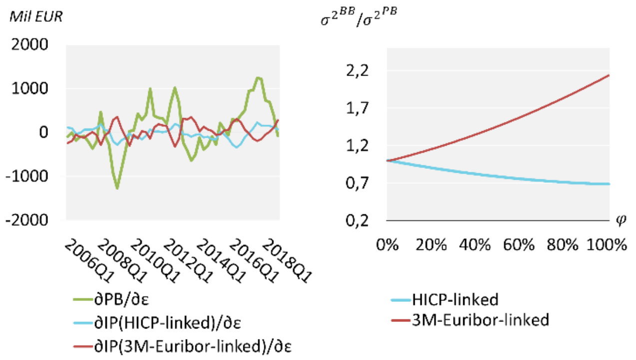

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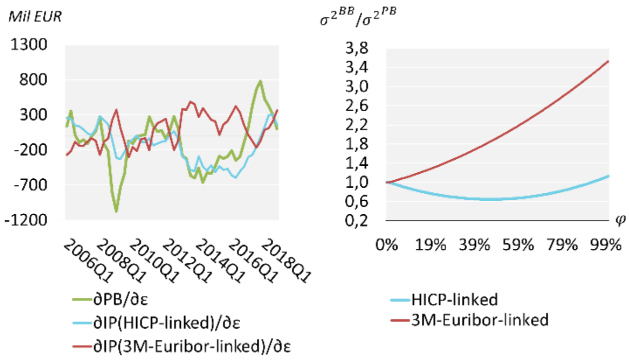

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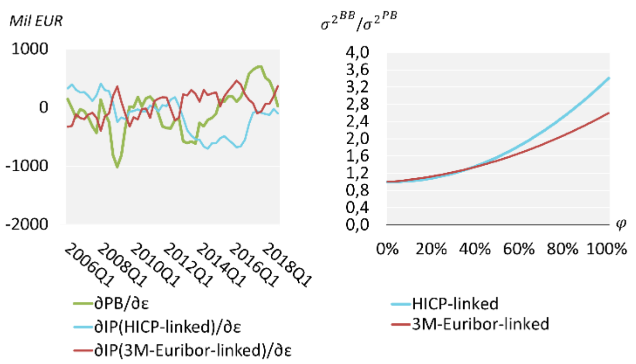

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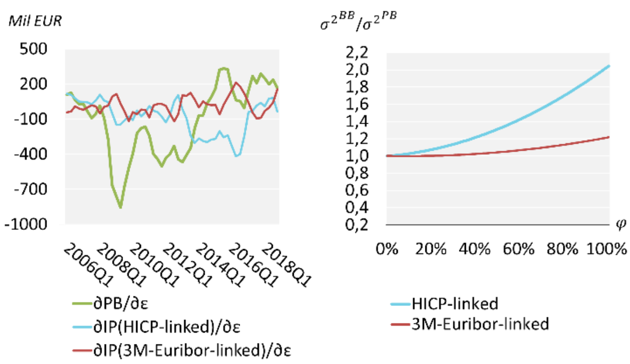
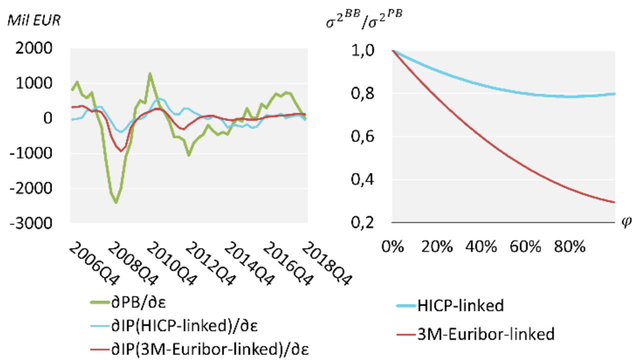


(f) Spain

Source: own calculations.

Figure 5.7: Primary balance, interest payments and variance of the budget balance induced by aggregate shocks



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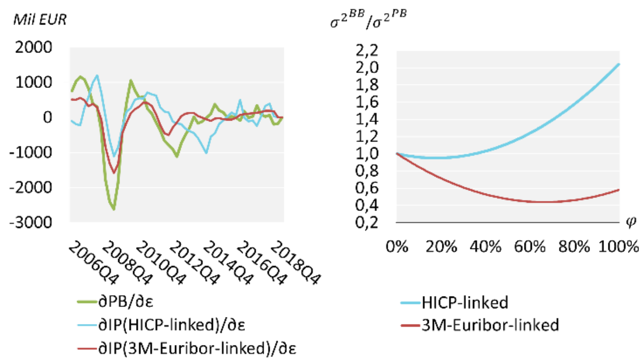

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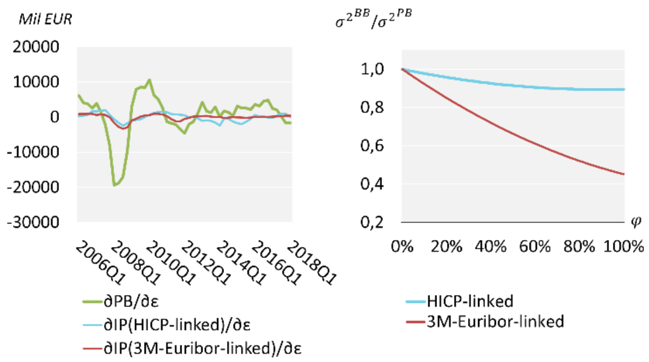

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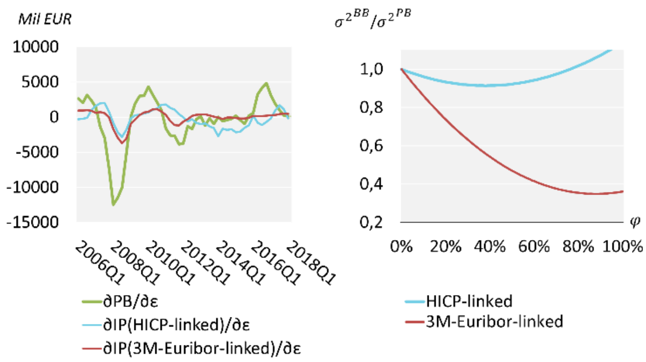

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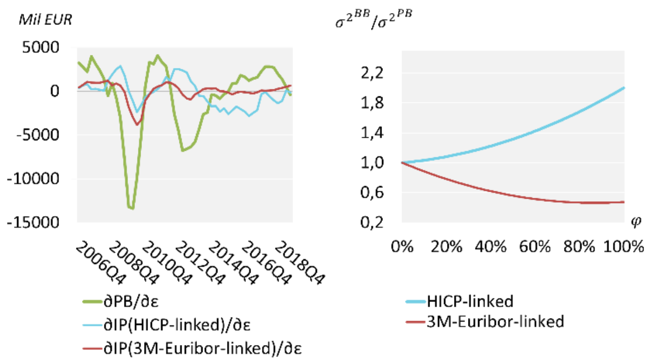

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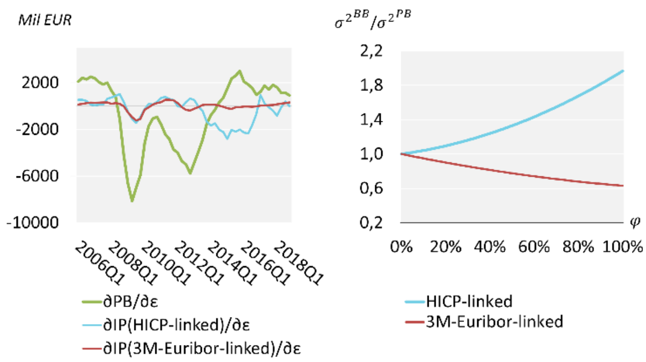

(f) Spain

Source: own calculations.

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How Should Public Debt Management Institutions Develop Medium-Term Issuance Strategies?

An optimal debt portfolio model

Dávid Tran[1] and András Bebes[2]

Abstract

Public debt management institutions face challenges in developing medium-term debt management strategies. The main objective of public debt management is the funding of government borrowing needs, with two goals in mind: minimizing costs while keeping risks at an acceptable level. However, these two goals are contradictory as lower costs can usually be achieved only by taking higher risks. Therefore, formalizing a comprehensive public debt management strategy and analyzing its effects is crucial. Our purpose is to find Pareto-optimal composition of borrowing that satisfy these goals with the help of stochastic financial modeling. We propose an optimal portfolio model, where we apply a multi-objective optimization scheme to construct composition of borrowing that can be considered by the debt manager as feasible alternatives. We apply our model on the Hungarian government debt portfolio, which is relatively complex by having a significant share of foreign currency debt and special retail debt securities as well. Results show that our model is capable of providing a complex analysis of desired issuance strategies and borrowing compositions based on the debt manager's preferences regarding all important aspects of debt management, especially risk management. The model can be modified to satisfy the unique needs of different DMOs in creating medium-term debt management strategies.

JEL Classification: C32, C53, C61, C63, G11, G17, H63

Keywords: Public Debt Management, State Space Models, Yield Curve Modeling, Macroeconometric Forecasting, Financial Econometrics, Portfolio Optimization

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Disclaimer: In this paper „we" (our, ours, etc.) refers to the authors as employees being responsible for the support of decision-making in the course of the development of the debt management strategy of the Hungarian Government Debt Management Agency Pte. Ltd. Therefore, this paper should be construed as how they implement the respective policies of the Government Debt Management Agency Pte. Ltd. and, for the purposes of this paper, how they demonstrate the modelling thereof. All data and formulas contained in this paper are provided solely for the purpose of illustrating the modelling framework for projecting possible outcomes under different economic scenarios. The data contained in this paper is a computer-generated output from respective mathematical models using available statistical and economic data and the output of the models should not be regarded as representative of any current data or forecasts, furthermore, must not be relied upon as an accurate prediction of current or future market performance, etc.

Results published in this paper, including but not limited to macroeconomic forecasts and the composition of the Hungarian government debt, do not represent the official views of the Government Debt Management Agency Pte. Ltd. regarding debt financing. The only purpose of disclosing such results is to illustrate the features and possibilities of the optimal debt portfolio model. The authors give no warranty and make no representation as to the accuracy, reliability, timeliness or other features of any data contained in this paper or data obtained from using the model. All models must be scientifically validated by the user for the strategy for which it is to be used, and for the most appropriate and safe application of models, scientific and expert interpretation and adequate advice is required.

1. Introduction

In this paper, we demonstrate the construction of an optimal debt portfolio model with the purpose of supporting the development of a medium-term issuance strategy for the Government Debt Management Agency Pte. Ltd. being the Hungarian DMO. Public debt management institutions face the challenge of funding government borrowing needs at a minimal cost subject to an acceptable risk level. These two goals are in most cases contradictory as lower costs can usually be achieved only by taking higher risks. The constraint of keeping risk levels “acceptable” is also subject to interpretation. Therefore, formalizing a comprehensive strategy and analyzing its effects is crucial. The purpose of the model is to find Pareto-optimal composition of borrowing that satisfy these goals with the help of stochastic financial modeling.

An optimal debt portfolio model can help the Hungarian Government Debt Management Agency Pte. Ltd. in creating a medium term (5-year) debt management strategy. Several countries have developed stochastic optimal portfolio models for debt management purposes. Notable examples include Canada (Bolder and Deeley 2011), Italy (Adamo et al. 2004; Consiglio and Staino 2012), Sweden (Bergström, Holmlund and Lindberg 2002), Turkey (Balibek and Memis 2012) and the United Kingdom (Pick and Anthony 2006).

Compared to other countries, we face relatively unique challenges concerning the attributes of the Hungarian government debt portfolio. It is relatively complex, containing both fixed and floating rate debt, significant foreign currency (FX) debt denominated in multiple currencies (but swapped to Euros), and a sizeable (and growing) share of retail debt, including inflation-linked securities.

This paper is a combination and extension of two of our previous papers. One of them (Bebes, Tran and Bebesi 2018b) focuses on forecasting, while the other (Bebes, Tran and Bebesi 2018a) focuses on optimization. This standalone study gives a complete picture of the Hungarian optimal debt portfolio model and goes beyond the scope of our previous papers in several ways.

First, we treat the sizeable Hungarian retail debt as an external factor regarding optimization. This is closer to reality, as the Government Debt Management Agency cannot refuse retail buyers. However, we use a more complex estimation of retail demand than before, incorporating it into the forecasting model similar to macro variables. Next, the issuance algorithm is overhauled to include the balance of the Treasury Single Account as an important issue. The calculation of liquidity costs is also changed to allow excess issuances to have temporal spillover effects by elevating future yields. Furthermore, this paper includes discussion on determining the optimal resource allocation for the optimization algorithm. Finally, we updated all results to reflect these changes, and the forecasting horizon has been changed to December 2019-December 2024.

The structure of this paper is as follows: Section 2 gives an overview of the optimal debt portfolio model. Section 3 introduces the data used for the model. Section 4 deals with the specification of the used Markov regime switching state-space model and gives an overview of the process of parameter estimation. Section 5 deals with issues regarding the estimation of costs and risks. Section 6 discusses the optimization and simulation process. Section 7 analyzes the results of the optimization. Section 8 concludes.

2. Overview of the model

In this section, we give an overview of the various phases and steps of the Hungarian optimal debt portfolio model. We also explain the modeling terms we use in later sections of the paper.

The first phase of the model is the construction of a Markov regime switching state-space model. We use this model to simultaneously forecast the Hungarian and the Euro area term structures of interest rates as well as some macroeconomic and financial factors, namely the Hungarian inflation (CPI) rates, the Hungarian credit default swap (CDS) curve, the EUR/HUF exchange rate and the demand for Hungarian retail debt instruments. The two yield curves and the macro factors are adequate for modeling the future cash-flows of both the outstanding government debt securities and the instruments to be issued in the future by the Hungarian state.

Modeling and forecasting the term structure of interest rates (yield curve) is a well-researched topic. The most popular class of models used in empirical applications are variants of the Nelson-Siegel (1987) model. A dynamic extension of the original static model was proposed by Diebold and Rudebusch (2013). We model the yield curve using a rotated dynamic Nelson-Siegel Model following the work of Nyholm (2015).

State-space models are useful for modeling dynamic linear systems driven by unobservable parameters. These parameters can be estimated using the Kalman filter (1960). In practice, however, economic applications often exhibit non-linearity. Hamilton (1989) was the first to apply Markov regime switching models to economic problems with the purpose of dealing with time varying parameters. The unobservable parameters of Markov regime switching models can be estimated using an extension of the Kalman filter by Kim (1994). Our work follows Kim and Nelson (1999) in using Gibbs sampling for parameter estimation and the Kim filter for determining the factor values.

Using a regime switching model is easily justified by economic considerations. Economic cycles are prevalent and can be separated into longer periods of growth (expansion) and shorter crisis periods of contraction (recession). These two distinct empirical situations allow for a meaningful application of time varying parameters. The steady state values (long-run expectations) determining the factors, the transition matrix and the error terms are all different based on the given regime. The heteroscedasticity of the error terms of the transition equation driving the factors can be handled using a different covariance matrix for every state.

Using a two-economy model with additional macro factors is also necessary as the Hungarian debt portfolio includes foreign currency denominated bonds as well as inflation-linked securities. Although the portfolio includes securities denominated in several currencies, the entire foreign currency exposure is only Euro denominated due to cross-currency swaps.

We can also model the dynamics between a small open economy (Hungary) and a large economy (the Euro area). Our model allows factor dynamics to be specified in a way that the Euro area factors can influence the Hungarian factors but not vice versa.

In the second phase of the model we generate a series of random numbers based on the estimated stochastic distributions. We define a *trajectory* as the realized time series of model factors. Usually, we simulate $1{,}000$ trajectories.

The third phase of the model is optimization. In this phase, we search for Pareto-optimal borrowing compositions. *A borrowing composition* is a weighting of the model instruments, summing to 1, while aiming for the theoretical composition of the portfolio, as time $t \to \infty$. Model instruments include

Hungarian Government Bonds and Treasury Bills as well as retail instruments and foreign currency bonds, as described in Section 6.1.

Starting from a random array of borrowing compositions, the optimization algorithm (Sun, Zhu and Cai 2017) improves and refines through several *iterations*, finding the corner compositions first and filling the optimization space afterwards. *The issuance algorithm* runs for every trajectory, borrowing composition and iteration with a monthly frequency. The cost and risk metrics are calculated based on the simulated issuances. We generally use 25,000 borrowing compositions and 200 iterations. The rationale for this ratio is discussed in Section 6.4. With a simulation horizon of over 60 months, the issuance algorithm runs over 300 billion times[3].

3. Data

In this section, we give an overview of the macro-financial and yield curve data used for fitting the Markov regime switching model. We also address the challenges regarding the construction of yield curves and introduce our prior assumptions regarding the model. We use data with monthly frequency from October 2008 to December 2019 for a total of $n = 135$ observations for each time series. The limitation is due to the lack of earlier Hungarian CDS data. This gives more than 10 years of historical data and most importantly, includes the 2008 crisis and the following recession period, giving merit to using a regime switching model.

Our data sources include Refinitiv for CDS curve and Euro area yield curve points, the Hungarian Central Statistical Office for Hungarian CPI data and the Hungarian National Bank for EUR/HUF exchange rate time series.

To obtain Hungarian yield curve data, we use the secondary market bid-ask quotes of HUF denominated Hungarian government bonds, as price quotation provided by primary dealers are considered to be actual market prices, the fixing process of which is regulated by the Hungarian Government Debt Management Agency.

We use the Fama-Bliss (1987) method to transform price quotes into yield curve points upon which we can fit the Nelson-Siegel model. This non-parametric method allows us to obtain zero-coupon yield curve points from bond price quotes. Then the Nelson-Siegel model can be fitted on the unsmoothed Fama-Bliss yields.

We impose additional restrictions compared to the original Fama-Bliss (1987) algorithm, using only fixed interest rate bonds with a maturity over 1 year as well as zero-coupon Discount T-bills. Our implementation of the Fama-Bliss (1987) algorithm can be summarized in four steps:

1. We determine whether the Yield-to-Maturity (YTM) of a given security is between the moving average of the previous 3 and the next 3 (based on time to maturity) government securities' yields.
2. We examine the unsmoothed Fama-Bliss forward yields. We exclude a government security from the analysis if the forward rate corresponding to its maturity shows a change greater than 0.2 percentage points in the opposite direction. In this step we calculate the forward rates using only government securities passing step 1.

[3] We use CPU+GPU hybrid computing. The issuance algorithm and the optimization algorithm are calculated by the CPU. Costs and risks are calculated by the GPU parallel to the issuance algorithm. The optimization takes 2-3 hours depending on the number of model instruments on an AMD Ryzen Threadripper 2990WX CPU and an Nvidia 1070Ti GPU.

3. We calculate the forward yield curve once more from the remaining government securities. In the third step we determine whether a previously excluded security can be included in the selection set. The inclusion criteria is similar as in step 1, but instead of YTM the forward yields are calculated. An instrument is to be considered in the analysis if the forward rate corresponding to its maturity is between the two moving averages or the difference from one of them is not larger than 0.2 percentage points.
4. In step 4, step 2 is repeated for the selection set after step 3.

In the end, we get a forward yield curve that fits the two smoothness criteria defined in steps 2 and 3. Then the forward yield curve can be transformed into a zero-coupon yield curve.

Fitting a Markov regime switching model requires us to give an initial estimation of the transition probability matrix (Eq. 5). We set the starting value to: $P_{prior} = \begin{pmatrix} 0.98 & 0.02 \\ 0.18 & 0.80 \end{pmatrix}$. This means that the probability of going from the first regime to the second would be 2%, while exiting from the second regime would be 18%. Thus, the first regime is expected to last 4.2 years, whereas the expected duration of the second regime is less than half a year. The prior steady state values of the factors were determined using P_{prior} and incorporate the effects of the current historically low interest rate period.

The Hungarian CPI expectation in the first regime is slightly above the inflation target of the Hungarian Central Bank ($cpi_{prior,HUN} = 3.5\%$), and is 0.6 percentage point higher in the second regime. We expect the net retail demand in a month in the first regime to be 75 billion HUF. Regarding the HUF yield curve, we expect at least a 50bp increase in the short rate compared to 2019 December, and a 3.5% level for the long end of the yield curve. Our forecast for the yield curve also includes a flattening slope and a rising level in case of a crisis.

Finally, we expect the EUR/HUF exchange rate to slightly rise during the first regime and rise rapidly during the second regime, meaning a comparatively weaker HUF and stronger Euro in a crisis situation.

4. The markov regime switching state-space model

In this section, we construct a Markov regime switching state-space model that can be used to model the entirety of the Hungarian government debt portfolio and explore the relationship between the examined factors in a coherent and realistic way.

To analyze the cost and risk features arising from issuing different kinds of instruments one needs to assess all the kinds of macro-economic factors driving the prices of these underlying instruments. When measuring these factors one also needs to pay attention to the interactions between them. To do that we propose a Markov regime switching state-space model, where we also include different regimes to account for different economic cycles.

4.1 The model

A 3-factor Nelson-Siegel model is used to estimate the HUF yield curve. We assume that the Hungarian Euro yield curve at a specific maturity τ is the sum of the risk-free Euro yield curve and the Hungarian Credit Default Swap rate at maturity τ. A 3-factor Nelson-Siegel model is used to estimate the risk-free Euro yield curve.

Following Nyholm (2015) we rotate the level and slope factors of the Nelson-Siegel model to get a more transparent structure for our factors. Thus our level parameter reflects the level of the short-term rate, and the slope factor is positive in case of a normal (upward sloping) yield curve.

Let $A = \begin{bmatrix} 1 & 1 \\ 0 & -1 \end{bmatrix}$ be the rotation matrix and $E_t(\tau) = \begin{bmatrix} 1 & \frac{1-e^{-\tau/\lambda_t}}{\tau/\lambda_t} \end{bmatrix}$ be the factor loadings for the level and slope parameters, thus $E_t(\tau)A^{-1} = \begin{bmatrix} 1 & 1 - \frac{1-e^{-\tau/\lambda_t}}{\tau/\lambda_t} \end{bmatrix}$ denotes the factor loadings for the rotated Nelson-Siegel factors.

In accordance with our assumptions the HUF ($y_{t,H}(\tau)$) and the risk-free Euro ($y_{t,E}(\tau)$) yield curve at time t and maturity τ are given by

$$y_{t,H}(\tau) = L_{t,H} + S_{t,H}\left(1 - \frac{1-e^{-\tau/\lambda_{t,H}}}{\tau/\lambda_{t,H}}\right) + C_{t,H}\left(\frac{1-e^{-\tau/\lambda_{t,H}}}{\tau/\lambda_{t,H}} - e^{-\tau/\lambda_{t,H}}\right) + \varepsilon_{\tau,H}, \tag{1}$$

$$y_{t,E}(\tau) = L_{t,E} + S_{t,E}\left(1 - \frac{1-e^{-\tau/\lambda_{t,E}}}{\tau/\lambda_{t,E}}\right) + C_{t,E}\left(\frac{1-e^{-\tau/\lambda_{t,E}}}{\tau/\lambda_{t,E}} - e^{-\tau/\lambda_{t,E}}\right) + \varepsilon_{\tau,E}, \tag{2}$$

where $\varepsilon_{\tau,H} \sim N(0, \sigma_{\tau,H}^2)$ and $\varepsilon_{\tau,E} \sim N(0, \sigma_{\tau,E}^2)$, $t = 1, \dots, n$. One can easily see that $\lim_{\tau \to 0} y_{t,k}(\tau) = L_{t,k}$ and $\lim_{\tau \to \infty} y_{t,k}(\tau) = L_{t,k} + S_{t,k}$ for $k \in \{H, E\}$, where now L denotes the short rate, and S the slope. The curvature factor remains unchanged.

To avoid negative CDS spreads we model the natural logarithm of the CDS curve with a 2-Factor Nelson-Siegel model. Thus, the Hungarian CDS curve ($y_{t,CDS}(\tau)$) at time t and maturity τ is given by

$$\log\left(y_{t,CDS}(\tau)\right) = L_{t,CDS} + S_{t,CDS}\left(\frac{1-e^{-\tau/\lambda_{t,CDS}}}{\tau/\lambda_{t,CDS}}\right) + \varepsilon_{\tau,CDS}, \tag{3}$$

where $\varepsilon_{\tau,CDS} \sim N(0, \sigma_{\tau,CDS}^2)$, $t = 1, \dots, n$.

Given our expectations of the system we also incorporate the Hungarian inflation rate as well as the EUR/HUF exchange rate into our model. The latter is required to enable us to convert forecasted Euro cash-flows to a HUF basis. Furthermore, recent developments in the issuance and pricing policy of the debt management office inspires a growing need to measure the demand for retail instruments among residents. Therefore, we also added the net retail demand as a factor instead of the previously used Eurozone inflation. The decreasing share of inflation-linked EUR denominated debt is no longer a visible issue, therefore dropping the Eurozone inflation rate seems a rational choice.

We observe the macro factors present in our model with measurement error, thus

$$mac_{t,j} = \widehat{mac}_{t,j} + \varepsilon_{mac_j}, \tag{4}$$

where $\varepsilon_{mac_j} \sim N(0, \sigma_{j,mac}^2)$, $j \in \{cpi_{hun}, retail\ demand, eur/huf\}$.

Given equations (1)-(4) we have a total of 11 factors.

Let $Y_t = \left[y_{t,H}(\tau), y_{t,E}(\tau), mac_{t,cpi_{hun}}, \Delta(mac_{t,\text{retail demand}}), \Delta\log(mac_{t,eur/huf}), \log\left(y_{t,CDS}(\tau)\right)\right]'$ be the vector of our observations[4] while $X_t = \left[L_{t,H}, S_{t,H}, C_{t,H}, L_{t,E}, S_{t,E}, C_{t,E}, mac_{t,j}, L_{t,CDS}, S_{t,CDS}\right]'$ is the vector of unobserved state variables i.e. the factors at time t ($t = 1, \dots, n$).

[4] Both $y_{t,H}$ and $y_{t,E}$ contain maturities for $\tau \in \{1M, 2M, 3M, 6M, 9M, 12M, 2Y, 3Y, 4Y, 5Y, 7Y, 10Y, 12Y\}$, while $y_{t,CDS}$ contains maturities for $\tau \in \{6M, 12M, 2Y, 3Y, 4Y, 5Y, 7Y, 10Y\}$.

Let S_t denote an unobserved, discrete-valued 2-state Markov-switching variable ($S_t \in \{1,2\}$) reflecting our prior assumption that the economy switches between two distinct regimes. The first regime ('normal regime') represents economic stability and growth, while the second one ('crisis regime') is connected to a more turbulent crisis situation.

The transition probabilities of the 2-state Markov process are given by

$$P = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix}, \tag{5}$$

where $p_{ij} = Pr(S_t = j|S_t = i)$ and $p_{i1} + p_{i2} = 1$ for all $i \in \{1,2\}$.

The state-space representation of our dynamic linear model at time t can be written as

$$Y_t = H_t X_t + \theta_t, \tag{6}$$

$$X_{t+1} = C_{S_t} + F_{S_t}(X_t - C_{S_t}) + \varepsilon_t, \tag{7}$$

$$\begin{bmatrix} \theta_t \\ \varepsilon_t \end{bmatrix} \sim N\left(0, \begin{pmatrix} R_{S_t} & 0 \\ 0 & Q_{S_t} \end{pmatrix}\right) \tag{8}$$

with $t = 1, \dots, n$. The measurement equation (6) describes the relation between the data and our factors, where Y_t, θ_t are $m \times 1$ vectors, X_t, ε_t are $f_n \times 1$ vectors, m determines the dimension of the measurement variables, while f_n accounts for the number of factors in the model[5]. H_t is an $m \times f_n$ matrix that links the observed variables to the unobserved factors at time t, mainly containing the factor-loadings of equations (1)-(3). H_t does not depend on the Markov variable S_t, it is only dependent on the time-decay parameters, $\lambda_{t,k}$ $k \in \{H, E, CDS\}$.

The transition equation (7) describes the dynamics of the state variables at time t, where F_{S_t} $(f_n \times f_n)$ is the transition matrix describing the evolution of the factors, while C_{S_t} represents the steady state factor values in the transition equation, which can be derived from the usual state-space representation of the transition equation given by

$$X_{t+1} = \mu_{S_t} + F_{S_t} X_t + \varepsilon_t, \tag{9}$$

with μ_{S_t} denoted as the drift component and $C_{S_t} = \mu_{S_t}(I_{fn} - F_{S_t})^{-1}$. Considering that the factors are easy to interpret in econometrics, the steady state values hold valuable information. While an analyst does not necessarily have expectations for a given element of the drift parameter μ, they may have one for the Hungarian CPI. Both C_{S_t} and F_{S_t} are dependent on the Markov-switching variable S_t. R and Q are covariance matrices with appropriate dimensions.

The (i,j)-th element of the parameters dependent on S_t can be described by the equation

$$f^k_{i,j,S_t} = f^k_{i,j,1} S_{1t} + f^k_{i,j,2} S_{2t}, \tag{10}$$

where k denotes the chosen parameter ($k \in \{C, F, R, Q\}$), with $S_{lt} = 1$ if $S_t = l$, and $S_{lt} = 0$ otherwise for $l \in \{1,2\}$.

We have two additional restrictions based on our assumptions. First, R_{S_t} is diagonal, thus at every time t ($t = 1, \dots, n$) the estimation error in our yield curve points and the measurement errors in the macro factors are uncorrelated. Second, we assume that the foreign factors can influence the domestic ones but not vice versa.

[5] The index in f_n is in no connection with the count of the observations; n.

4.2 Parameter estimation

This section deals with the problem of estimating the parameters of the system described in Section 4.1. The entirety of our parameter space is denoted by $\Theta \in \{H_t, F_i, C_i, Q_i, R_i, P, (X_t, S_t)\}$, where $i \in \{1, 2\}$ and $t \in (1, \dots, n)$. To generate the sequence $(X_t, S_t)_{1\le t\le n}$ we turn to the work of Kim (1994). To sample for the parameters F_i, C_i, Q_i and R_i $(i \in \{1, 2\})$ we use the distributions suggested by Villani (2009) and Sugita (2008). The sampling of the transition probabilities P is a draw from a beta distribution based on the generated state-realizations $(S_t)_{1\le t\le n}$ and on the P_{prior} assumption. To estimate the parameter H we use the Random Walk Metropolis Hastings algorithm, as H is only dependent on the time-decay parameters $\lambda_{t,k}$, $k \in \{H, E, CDS\}$, all other parameters are estimated within the framework of a Gibbs sampler.

4.2.1 Kim filter

The Kim filter is an extension of the Kalman filter (1960) which gives a solution to the parameter estimation problem of general dynamic linear models with a Markov-switching parameter in state-space representation form.

Let's suppose that all parameters of the model defined in Section 4.1 excluding the sequence (X, S) are known. Let $\mathcal{F}_t$ be the information available at time t. As defined in the Kalman filter the goal is to forecast X_t based on information available at time $t-1$. Let

$$X_{t|t-1}^{(i,j)} = E(X_t | \mathcal{F}_{t-1}, S_t = j, S_{t-1} = i) \tag{11}$$

be the conditional expectation of X_t based on $\mathcal{F}_{t-1}$ and $S_t = j, S_{t-1} = i$, and

$$P_{t|t-1}^{(i,j)} = E\left(\left(X_t - X_{t|t-1}^{(i,j)}\right)\left(X_t - X_{t|t-1}^{(i,j)}\right)' \middle| \mathcal{F}_{t-1}, S_t = j, S_{t-1} = i\right) \tag{12}$$

the mean squared error of the forecast. Then, conditional on $S_t = j, S_{t-1} = i$ at time t, the following equations define the Kalman filter algorithm for the system defined in equations (6),(9) and (8). Equations (13)-(16) define the phase of prediction, (18) and (19) the phase of updating, while (17) defines the so-called Kalman gain:

$$X_{t|t-1}^{(i,j)} = \mu_j + F_j X_{t-1|t-1}^{(i)}, \tag{13}$$

$$P_{t|t-1}^{(i,j)} = F_j P_{t-1|t-1}^{(i)} F_j' + Q_j, \tag{14}$$

$$\eta_{t|t-1}^{(i,j)} = Y_t - H_t X_{t|t-1}^{(i,j)}, \tag{15}$$

$$f_{t|t-1}^{(i,j)} = H_t P_{t|t-1}^{(i,j)} H_t' + R_j, \tag{16}$$

$$K_t^{(i,j)} = P_{t|t-1}^{(i,j)} H_t' \left(f_{t|t-1}^{(i,j)}\right)^{-1}, \tag{17}$$

$$X_{t|t}^{(i,j)} = X_{t|t-1}^{(i,j)} + K_t^{(i,j)} \eta_{t|t-1}^{(i,j)}, \tag{18}$$

$$P_{t|t}^{(i,j)} = \left(I_{f_n} - K_t^{(i,j)} H_t\right) P_{t|t-1}^{(i,j)}. \tag{19}$$

$X_{t|t}^{(i)} = E(X_t | \mathcal{F}_t, S_t = i)$ is the conditional expectation of X_t based on $\mathcal{F}_t$ and $S_t = i$, while $P_{t|t}^{(i)} = E\left(\left(X_t - X_{t|t}^{(i)}\right)\left(X_t - X_{t|t}^{(i)}\right)' \middle| \mathcal{F}_t, S_t = i\right)$ is the mean squared error of X_t conditional on $\mathcal{F}_t$ and $S_t =$

i. $\eta_{t|t-1}^{(i,j)}$ is the conditional forecast error of Y_t based on $\mathcal{F}_{t-1}$ and $S_{t-1} = i$, $S_t = j$, while $f_{t|t-1}^{(i,j)}$ is the conditional covariance of $\eta_{t|t-1}^{(i,j)}$.

To handle the increase in the number of cases at each iteration caused by the different states, Kim suggests the following equations to collapse the terms $X_{t|t}^{(i,j)}$ and $P_{t|t}^{(i,j)}$ to $X_{t|t}^{(j)}$ and $P_{t|t}^{(j)}$ respectively

$$X_{t|t}^{(j)} = \frac{\sum_{i=1}^{M} \Pr(S_t = j, S_{t-1} = i|\mathcal{F}_t) X_{t|t}^{(i,j)}}{\Pr(S_t = j|\mathcal{F}_t)}, \quad (20)$$

$$P_{t|t}^{(j)} = \frac{\sum_{i=1}^{M} \Pr(S_t = j, S_{t-1} = i|\mathcal{F}_t)\left(P_{t|t}^{(i,j)} + \left(X_{t|t}^{(j)} - X_{t|t}^{(i,j)}\right)\left(X_{t|t}^{(j)} - X_{t|t}^{(i,j)}\right)'\right)}{\Pr(S_t = j|\mathcal{F}_t)}. \quad (21)$$

Using these approximations, the problem becomes feasible. To approximate the probability terms in equations (20) and (21) one can use the Hamilton filter suggested by Kim and Nelson (Kim and Nelson 1999).

The second step of the Kim filter is smoothing, which is a backward recursion for all $t = n, \dots, 1$ with the calculation of the expectation and mean squared error of X_t conditional on $\mathcal{F}_n$.

The final step of the Kim filter is backward sampling from the sequence $(X_t)_{1 \le t \le n}$ step-by-step from the conditional distribution

$$X_t|\mathcal{F}_t, X_{t+1} \sim N\left(X_{t|t,X_{t+1}}, P_{t|t,X_{t+1}}\right), \quad (22)$$

where $X_{n|n} = E(X_n|\mathcal{F}_n)$, $P_{n|n} = Cov(X_n|\mathcal{F}_n)$ while $X_{t|t,X_{t+1}} = E(X_t|\mathcal{F}_t, X_{t+1})$ and $P_{t|t,X_{t+1}} = Cov(X_t|\mathcal{F}_t, X_{t+1})$. Assuming that X is stationary, the unconditional mean and covariance matrix and the steady state probabilities can be used to start the filter. We will not go into any more detail, but a step-by-step explanation of the Kim filter can be found in Kim and Nelson (1999).

4.2.2 Parameter sampling

With the assumption that H, R, C, F and Q parameters are known for both regimes, the Kim filter is applicable to sample the values of X_t, and Kim and Nelson (1999) also suggest a way to sample S_t for all $t = 1, \dots, n$.

To get a sample for the parameters R, C, F and Q for a given $(X_t, S_t)_{1 \le t \le n}$ we use the distributions suggested by Sugita (2008) and Villani (2009). Our model is equivalent to the one used by Sugita. We can easily see this for example by substituting $k, q = 1$, $p = f_n$, $\Pi = F$, $d_t \equiv 1$, $\Phi = \mu$, $\psi = C$ and $\Sigma = Q$ into the notations of equation (7).

The selection of the starting covariance matrices V_0 and Σ_0 is crucial in a sense that it determines the parameter space explored.

Conditional on $(S_t)_{1 \le t \le n}$ P is independent of the dataset and the model's other parameter. Assuming independent beta distributions for the priors $p_{11} \sim beta(l_{11}, l_{12})$ and $p_{22} \sim beta(l_{22}, l_{21})$ Kim has shown that

$$p_{11}|\mathrm{S} \sim beta(l_{11} + k_{11}, l_{12} + k_{12}), \quad (23)$$

$$p_{22}|\mathrm{S} \sim beta(l_{22} + k_{22}, l_{21} + k_{21}), \quad (24)$$

where k_{ij} refers to the transitions from state i to j, which can be easily counted given $(S_t)_{1 \le t \le n}$.

To estimate the parameter H we use the Random Walk Metropolis Hastings algorithm, as H is only dependent on the time-decay parameters $\lambda_{t,k}$, where $k \in \{H, E, CDS\}$. $\lambda_{t,k}$ is determined using the $\lambda_{t,k}^{new} = \lambda_{t,k} + \kappa_t \varepsilon_{t,k}$ equation, where $k \in \{H, E, CDS\}$, κ_t can be arbitrarily chosen and $\varepsilon_{t,k} \sim N(0,1)$ for every t and k. Using the generated parameter we calculate a candidate H, which we keep with a calculated α probability, after the evaluation of the measurement equation's likelihood function.

4.2.3 Initial values

The first step in defining the initial set of values is the setting of X^0, which entails the substitution of the empirical values. For example, the level parameter (which is the short term level in our case) is the shortest available point of the yield curve. The observed data defines the matrix Y. H^0 is defined by the observed maturities, with the assumptions that $\lambda_{0,k} = 1$ and $k \in \{H, E, CDS\}$. R^0 can be calculated from X^0, Y and H^0.

Next step is the estimation of the parameters of the transition equation with the ordinary least square (OLS) method. A simple Kalman filter is used to improve the estimates. It is crucial to mention that so far no regime switching is included.

The prior transition matrix P_{prior} is based on expert estimates. Based on the number of observed periods (n) it defines the share of each regime on the observed time horizon. Squared errors for each period can be calculated based on the initial values above substituted in equations (6) and (7). Sorting the periods based on the squared errors define S^0. The empirical covariance matrices of the separated periods define the initial covariance matrices R_i^0 and Q_i^0, $i \in \{1, 2\}$. $F_i^0 = diag(F^0)$, $i \in \{1, 2\}$ is the modified Minnesota prior, while $C_i^0 = \bar{X}^0_{t \in \{S^0 = i\}}$ ($i \in \{1, 2\}$) or can be modified by expectations of the analyst.

4.2.4 The algorithm

Our parameter estimation algorithm is based on the works of Blake & Mumtaz (2012). The algorithm consists of the following steps:

1. Initialization. Setting the initial values of the sequence $(X_t, S_t)_{1 \le t \le n}$ and the parameters F_i^0, C_i^0, Q_i^0, R_i^0, $i \in \{1, 2\}$.
2. Sampling from $(X_t, S_t)_{1 \le t \le n}$. $(X_t, S_t)_{1 \le t \le n}$ is generated based on the steps of the Kim filter conditional on F_i, C_i, Q_i, R_i, $i \in \{1, 2\}$ and P.
3. Sampling P. P is drawn from a beta distribution based on the generated state-realizations $(S_t)_{1 \le t \le n}$ and P_{prior}.
4. Sampling F_i, C_i, Q_i and R_i, $i \in \{1, 2\}$ based on the appropriate distribution defined by Villani (2009).
5. Sampling H_t, $\lambda_{t,k}$, $t \in \{1, \dots, n\}$ and $k \in \{H, E, CDS\}$ using Random Walk Metropolis Hastings algorithm.
6. Repeat steps 2-5 until the convergence meets our expectations.

5. Calculation of costs and risks

In this section we address the issues regarding the calculation of different cost and risk factors. Quantifying costs and risks is important because our goal of creating Pareto-optimal composition of borrowing requires us to set objective, measurable criteria on which different composition of borrowing can be compared and ranked.

5.1 Cost factors

Cost factors can be divided into 4 groups. The most prominent cost factor is the interest expenditure, which is the cumulated sum of the coupon payments of all instruments. The second cost factor is the issuance price discount or premium (loss or gain). Treasury Bills do not pay coupons whereas all other instruments are issued exactly at, or closely to, *par* in the model. The third cost factor is the currency cost, which boils down from the deviation of the EUR/HUF exchange rate. In accordance with the strategic goal of the Hungarian DMO, all foreign liabilities are either issued in, or swapped into, Euro. The model calculates all costs in HUF (based on Hungarian accounting rules), therefore currency cost is a key factor in determining the optimal share of FX debt in the portfolio. The fourth cost factor is the so-called liquidity premium, which arises when excessive issuance of government bonds or treasury bills is needed to fulfill the funding requirements. We address this issue in Section 5.1.1.

All costs are aggregated in HUF over the time horizon on every trajectory using accrual accounting. Such time-proportional accounting applies for all coupon payment dates in the timeframe, for all instruments. Smoothing the costs on the time horizon makes the borrowing compositions (and different time horizons) comparable to each other. It also mitigates the importance of whether a payment date is before or after the model's timeframe.

If all the simulated trajectories are taken into account, we get the stochastic distribution of the costs. We call the expected cost of the stochastic distribution of the cumulated costs the cost of the specific borrowing composition. Minimizing expected cost is one of the objective functions we use for optimization.

5.1.1 Funding liquidity considerations

It is clear that meeting the funding needs by issuing in only one or two instruments is impossible due to limits of market demand, and it is also clear that excess issuance comes with a cost. Avoiding borrowing compositions that encourage excess issuance is desired by the DMO. The introduction of so-called liquidity constraints and liquidity premium arises as a possible solution to handle the cases of excess issuance.

We turn to the Hungarian DMO auction database to calculate issuance limits at a given time with the use of market demand. We calculate two values for every wholesale instrument. One representing the maximum amount to be issued at a given time at normal 'market' price, which we call 'liquidity threshold', while 'liquidity constraints' are introduced as the maximum available amount of an instrument to be issued at a given time. Therefore, liquidity constraints play an important role in the issuance algorithm of the simulation framework, detailed in Section 6.3. 'Liquidity premium' is introduced as the cost premium for the DMO to be paid for the amount issued above the liquidity threshold.

We assume that Discount T-Bills do not have a liquidity constraint. In practice, investors tend to buy short-term instruments even in periods of high volatility, although with a significant liquidity premium. Therefore, Discount T-Bills can be viewed as safety instruments in times of distress when funding requirements cannot be met with the issuance of other instruments. We introduce an indicator similar to the liquidity risk premium of Drehmann and Nikolaou (2013). Our indicator measures the difference between the rejected bids and the marginal rate of the analyzed auctions. Let $E(h_t)$ be the expected marginal rate of the auction (i.e. the highest accepted yield) held at time t. Let

$$\iota_{b,i,t} = \left(\rho_{b,i,t} - E(h_t)\right) v_{b,i,t} \quad (25)$$

be the *adjusted rejected bid* on the auction held at time t, by the auction participant $i \in \{1,2,\dots,N\}$. The bid $b \in \{1,2,\dots,B\}$ stands for the amount $v_{b,i,t}$ and rate $\rho_{b,i,t}$, and $E(h_t) < \rho_{b,i,t}$. Which means that $\iota_{b,i,t}$ is the premium expected by the bidder for the buying of an additional $v_{b,i,t}$ amount above the marginal rate. The liquidity premium at time t is the aggregate of the adjusted rejected bids

$$lp_t = 100\frac{\sum_{i=1}^{N}\sum_{b=1}^{B}\iota_{b,i,t}}{E(\bar{v}_t)} \tag{26}$$

in basis points, where $\bar{v}_t$ denotes the cumulated amount of unsuccessful bids. Liquidity premium thus gives us a quantified value of the investor's willingness of providing additional liquidity.

The liquidity premium can be quantified for all instruments and regimes, and then used to measure excess issuances. The liquidity premium formula above measures the increase in yield when the total issuance from one instrument in a month equals the liquidity constraint. The cost increase for that particular instrument also spills over to following months, simulating rising yields in case of excess issuance. Naturally, the liquidity premium can be increased further if there is excess issuance in the following month as well. This accrued liquidity premium decays exponentially on a monthly basis. We usually use a decay factor of 0.9.

5.2 Risk factors

Risks of a government bond portfolio can be measured in multiple ways. We separated risk metrics into three main categories. Volatility metrics, such as standard deviation, are adequate benchmarks for the risks arising from interest rate or exchange rate changes throughout the simulation horizon. However, they are, by definition, backward-looking measures. A portfolio having a low standard deviation throughout the simulation time horizon does not necessarily mean it is safe from future interest rate changes. The second category, interest rate sensitivity metrics, addresses this issue. Measures like Average Time to Re-fixing (ATR) tell us something about the inherent interest rate sensitivity of a portfolio, and can be viewed as a forward-looking measure. The third category, refinancing risk also contains forward-looking measures. A high refinancing ratio tells us that there could be serious funding liquidity issues in the future. Compressing the complex risk characteristics of a debt portfolio into a single number *ex-ante* would only be possible by assigning weights to different risk metrics. However, our intention was to allow the decision maker to do this *ex-post*. Choosing a single risk metric gives us too little information about the risk characteristics of a portfolio, while attempting to use every relevant measure makes the optimization space too large. Our solution for this dilemma was using one risk measure from each of the three categories as objective functions in our optimization scheme.

5.2.1 Volatility metrics

To measure the risks rising from the volatility of the yield curve, we calculate the standard deviation, the Cost-at-Risk and the Conditional Cost-at-Risk at different confidence levels of the stochastic distribution of costs (basically an implementation of the Monte Carlo simulation for calculating VaR or CVaR). The corrected sample standard deviation is well known. Let $c_{1,s} \le c_{2,s} \le \cdots \le c_{r,s}$ denote the ordered costs of r trajectories based on s borrowing composition, then we calculate the Cost-at-Risk at $0 < \alpha < 100$ confidence level as

$$CaR_\alpha(s) = c_{\left\lfloor r\frac{\alpha}{100}\right\rfloor}, \tag{27}$$

while the Conditional Cost-at-Risk at $0 < \alpha < 100$ confidence level is

$$CCaR_{\alpha}(s) = \frac{1}{\left\lfloor r\left(1-\frac{\alpha}{100}\right)\right\rfloor+1} \sum_{i=\left\lfloor r\frac{\alpha}{100}\right\rfloor}^{r} c_i. \tag{28}$$

The Cost-at-Risk at confidence level α tells us that based on the worst $(100-\alpha)\%$ of scenarios how much the minimum cost will be in the chosen timeframe, while the Conditional Cost-at-Risk at confidence level α tells us about the expected costs of the worst $(100-\alpha)\%$ of scenarios in the chosen timeframe.

Although measuring the deviation of costs is crucial, there are several other metrics to assess risks. We address this issue in the following sections.

5.2.2 Interest rate sensitivity

Changes in the yield curve may cause increase in the interest rate expenditures, and therefore it is crucial to measure interest rate sensitivity from a debt management perspective. Short-term or variable interest rate instruments are considered riskier than long-term or fixed rate instruments in this aspect. Duration and ATR can be used to capture the exposure of the debt portfolio to changes in interest rates.

The ATR of a fixed interest rate instrument is equal to its time to maturity, while for a floating rate instrument it measures the time until its next coupon re-fixing. Thus the ATR of the debt portfolio measures how long on average it takes for the interest rate changes to be incorporated into the costs of the overall debt. Let

$$atr_t = \frac{\sum_{i=1}^{N} \zeta_{t,i} v_{t,i}}{\sum_{i=1}^{N} v_{t,i}} \tag{29}$$

denote the ATR of the debt portfolio at time t, with N instruments present in the portfolio. $\zeta_{t,i}$ denotes the time to the next coupon fixing at time t for instrument i, while $v_{t,i} = FV_i P_{t,i}\left(\frac{100-\sum_{k\le t} C_{k,i}}{100}\right)$, where FV_i is the Face Value of instrument i, $P_{t,i}$ denotes the pieces of instruments i issued by the DMO at time t, and $C_{k,i}$ is the capital repaid at time k of instrument i given in percentage points. A higher value of ATR indicates a higher immunity against interest rate changes, while low values indicate that a high share of the debt portfolio will be subject to interest rate changes in the near future, thus signaling a higher exposure to interest rate risk.

5.2.3 Refinancing risk

The risk rising from the maturity structure of a given portfolio is called refinancing risk. Refinancing risk measures the share of the debt portfolio maturing in a given time period. Generally, in periods of turbulence or high volatility, market liquidity typically dries up, making the renewal of maturing debt expensive, or, in an extreme case, impossible. Therefore, it is vital for debt management to smooth the maturity structure, and thus avoid maturity peaks. Average Term-to-Maturity (ATM) measures how long it takes on average to renew outstanding debt. Let

$$atm_t = \frac{\sum_{i=1}^{N} \eta_{t,i} v_{t,i}}{\sum_{i=1}^{N} v_{t,i}} \tag{30}$$

denote the ATM of the outstanding debt portfolio at time t, with N instruments present in the portfolio. $\eta_{t,i}$ denotes the remaining term to maturity at time t for instrument i, while $v_{t,i}$ is the same as above. Refinancing risk is lower when ATM is higher, as it means a lower renewal rate in the short term.

The refinancing ratio measures the share of the debt portfolio to be renewed on a given time horizon. Let

$$refin_{t,\lambda} = \frac{\sum_{i=1}^{N} v_{t,i} \mathbf{1}_{\{\eta_{t,i} \leq \lambda\}} l_i}{\sum_{i=1}^{N} v_{t,i}} \tag{31}$$

be the refinancing ratio of the outstanding debt portfolio at time t, with time horizon λ. $\mathbf{1}_{\{\eta_{t,i} \leq \lambda\}}$ denotes the indicator function of whether instrument i at time t matures within the chosen time period, and $l_i = 1/2$ if i is retail, while 1 in every other case. We assume – and years of experience at the Hungarian Government Debt Management Agency supports – that retail investors' willingness to renew their government securities holdings tend to be higher than that of wholesale investors, especially in times of high volatility. As Hungarian retail rates are significantly higher than wholesale in a low interest rate environment, holding the retail rates constant is viable even as wholesale rates rise. Experience suggests that in a high volatility, high interest rate environment, retail investors tend to buy retail instruments even if wholesale alternatives are strictly superior. This stems from the strength of the retail brand and the general lack of financial knowledge among retail investors. Even though retail instruments can be redeemed under favorable conditions (98% to par depending on the instrument), the prevalence of inflation-linked and step-up coupon bonds may deter retail investors from doing so.

Keeping the refinancing ratio at a low level stabilizes the debt service, increases trust in investors and supports higher ratings given by credit rating agencies.

6. Simulation Framework

In this section we give an overview of the simulation and optimization process, including the selection of planned instruments, the issuance algorithm and the optimization algorithm. We also analyze the optimal allocation of resources (number of borrowing compositions and iterations) for the optimization algorithm.

6.1 Planned instruments

To analyze the characteristics of the costs and corresponding risk factors of the Hungarian debt portfolio we simulate issuances of chosen instruments on the specified time horizon. We categorize all portfolio instruments into three separate groups, namely the domestic wholesale, the FX, and the retail debt. There are several model instruments to choose from in each market segment:

Wholesale segment:

- 3-, 5- , 10- and 15-year fixed interest rate Government Bonds
- 5-year floating interest rate Government Bond
- 12-month Discount Treasury Bill

FX segment:

- 5- and 10-year fixed and floating interest rate, Euro denominated Bonds

Retail segment:

- 1-year Hungarian Government Security ("1MÁP")
- Premium Hungarian Government Securities (3- and 5-year inflation-linked bonds, "PMÁP")

- Hungarian Government Bond Plus (5-year step-up coupon bond, “MÁP+”)

All model instruments share the same characteristics and properties as those issued by the Hungarian DMO. The range of model instruments can be easily changed by adding or removing instrument types.

The issuance of retail securities is an external factor concerning the optimization framework. Retail issuances are trajectory dependent as described in Section 4.1, but are independent from the borrowing composition. A higher debt-renewal willingness is also assumed for the retail segment based on the DMO’s experience (as described in Section 5.2.3).

In the model, Government Bonds are issued three times a year, with the opportunity of a monthly reopening, while Treasury Bills are issued each month. FX bonds are issued yearly with a trajectory dependent choice for the issuance month[6], and are not reopened. Premium Hungarian Government Securities are issued at the start of every calendar year, with the opportunity of a monthly reopening. The other two retail securities are issued every month in the model.

The initial portfolio to start the simulation is identical to the actual government debt portfolio, with the exception that all actual instruments are listed as one of the above model instruments. Thus, the model is able to generate accurate and realistic results that can be used directly to set benchmarks for the government debt.

6.2 Optimization

The purpose of optimization is to construct composition of borrowing that minimize the costs and risks of the debt portfolio. We chose three different risk metrics: standard deviation of the costs, 1-year refinancing ratio and ATR. We intend to maximize the latter and minimize the former two as well as the expected costs. These goals are contradictory, therefore finding the set of Pareto-optimal solutions is our objective.

To achieve this, we use a multi-objective optimization algorithm applying evolutionary heuristics to the problem. We implement the algorithm of Sun, Zhu and Cai (2017). The algorithm finds the corner solutions first and fills the optimization space afterwards. The output of the optimization algorithm is a set of Pareto-optimal solutions. A two-dimensional Pareto-front can then be established using posterior weighting of the risk metrics, expressing the preferences of the decision maker. Using this method, we can produce a traditional mean-variance efficient frontier or plot the expected costs versus an arbitrarily weighted composite risk measure.

Similar to traditional computational optimization, our implementation relies on multiple iterations (repeated evaluations of the objective function) to approach the optimum. However, to attain multiple Pareto-optimal solutions, we continuously work with a set of inputs, consisting of a large amount of borrowing compositions. Borrowing compositions constitute the input of the issuance algorithm.

The objective function G can be mathematically expressed as:

$$\min_{f.h\ \sum_s=1;\forall s_i\in s:\ 0\leq s_i\leq 1} G(s)=(cost(s),std(s),refin(s),-atr(s)) \tag{32}$$

[6] In practice, the Government Debt Management Agency has a degree of freedom in deciding when to issue FX debt. This is modeled by a single issuance per calendar year. In the model, FX debt is issued in the first month where the level of Euro area yield curve declines for two months in a row, or in December if the criterion is not met throughout a given calendar year.

where s is a borrowing composition, serving as an input for the issuance algorithm. In the first iteration of the optimization process, each borrowing composition is randomized, taking a uniform distribution on the simplex of the appropriate dimension. As detailed in Section 6.1, we optimize for 10 (6 domestic wholesale and 4 FX) planned instruments, giving us 9 degrees of freedom.

6.3 Issuance algorithm

The issuance algorithm is an essential part of the optimization process, connecting input (borrowing composition) and the output (costs and risks). Issuances are simulated with a monthly frequency. The horizon of the simulation is the first calendar year after the start plus 5 years, adding up to a total of 60 to 71 months.

An important element of the simulation of issuances is the handling of the Treasury Single Account (TSA). The TSA is an account belonging to the Hungarian State Treasury, held at the Central Bank. In case of new issuances, the inflows are deposited on the TSA, while debt charges are paid from the TSA (beside other budgetary revenues and expenditures). The Hungarian Government Debt Management Agency actively manages the TSA to have a liquidity buffer in case of larger debt redemptions. In the model, new issuances increase the TSA balance, while redemptions and the budget deficit decrease it. In the model, interest payments do not decrease the TSA balance, because we assume that the externally given budget deficit includes interest expenditures as well. We call an n-month TSA requirement the total outstanding amount of government securities maturing within the next n months. Maturing Discount Treasury Bills, having a quasi-infinite demand in the model, are excluded from the TSA requirement, while retail instruments – assumed to have an inherently lower refinancing risk – have a weight 0.5 in the TSA requirement calculation. We designed the issuance algorithm so that the TSA account balance should fall in a given range. We set the minimum TSA balance as the 2-month TSA requirement and the maximum as the 4-month requirement.

Now let d be the number of simulated months, and $\mathrm{v} = [v_0\ v_1\ v_2\ \dots\ v_d]'$ the total outstanding amount of debt instruments minus the initial TSA balance we want to attain. Additionally, let v_0 be the outstanding amount of debt minus the TSA balance at the start of the simulation, both attained from factual data. Using the vector of yearly projected deficits, we create a monthly $\mathrm{f} = [f_1\ f_2\ \dots f_d]'$ vector. We can then recursively calculate $v_i = v_{i-1} f_i$, $(i = 1, 2, \dots, d)$. We also create a v^{max} maximal outstanding amount vector, where $\mathrm{v}_{\mathrm{i}}^{max} = v_i + TSA_i^{max}, (i = 1,2, \dots, d)$, and a v^{min} minimal outstanding amount vector, where $\mathrm{v}_{\mathrm{i}}^{min} = v_i + TSA_i^{min}, (i = 1,2, \dots, d)$. Naturally, the TSA^{min} and TSA^{max} vectors contain the minimal and maximal TSA requirement for every t. It has to be noted, that TSA requirements, and therefore the minimal and maximal debt amount vectors, depend on the given borrowing composition and trajectory.

As in reality, large maturing amounts can exist in the model, making it difficult to refinance them due to liquidity constraints. The usual solution in reality, used in the model as well, is pre-financing. In case a security is about to mature in the near future, we increase the amounts to issue from that type of instrument to avoid refinancing it in a single month. We do not use pre-financing for Discount Treasury Bills issued monthly. Most other domestic instruments are pre-financed 6 months in advance, while FX issuances can be pre-financed starting January the calendar year before maturity in order to have at least one FX issue date before maturity for certain.

If we intend to reach the desired composition of debt in m months (we generally use $m = 12$), let $\mathrm{w} = [w_1\ w_2\ \dots w_d]'$ be a vector of weights calculated by:

$$w_i = \begin{cases} i/m, & i < m \\ 1, & i \geq m \end{cases}. \tag{33}$$

Furthermore, let p denote the shares of the initial portfolio and T a $\mathrm{d} \times \mathrm{n}$ matrix, where

$$T_{ij} = v_i^{min}\left((1 - w_i)p_j + w_i s_j\right). \tag{34}$$

The value of T_{ij} gives the desired outstanding amount of instrument j for month i.

To calculate the net issuance of instruments for month i, let t denote the i-th row of T, u the current outstanding amounts of instruments at month i and u' the vector of amounts to be pre-financed. The net issuance vector x is the result of

$$\begin{aligned} &\underset{x}{lexmax}\left(min\left(\frac{x+u-u'}{t}\right)\right) \\ &s.t.: \quad x \geq 0, \\ &x \leq max(0\,, t - u + u'), \\ &Lx \leq b, \\ &1_n'(x+u) \leq max(v_i^{max}, 1_n' u), \end{aligned} \tag{35}$$

where b is the vector of liquidity constraints and L is the corresponding summary matrix. We use 5 different liquidity constraints: FX, Discount Treasury Bill and 3/5/10/15-year Hungarian Government Bond. Retail issuances are treated as external and calculated separately, before the issuance algorithm.

The so-called lexicographic maximization, inspired by the Constrained Equal Losses rule (Fleiner and Sziklai 2012), can be interpreted as trying to maximize the smallest share of the actual versus the desired outstanding amount. If it can be accomplished in multiple ways, we maximize the second smallest share and so on.

If the solution x does not fulfill an additional $1_\mathrm{n}'(\mathrm{x} + \mathrm{u}) \geq v_i^{min}$ criterion, meaning that the minimal total outstanding amount is not reached, we finance the remaining value by issuing Treasury Bills, even if its liquidity constraint is exceeded. This simulates emergency borrowing at a significantly higher cost.

6.4 Meta-optimization

Meta-optimization is the process of optimizing the optimization algorithm. In our case, this is essentially a resource allocation problem. We have a finite temporal constraint, wanting to limit the optimization process to 2-3 hours so that results can be calculated and analyzed in one day. This means that the number of borrowing compositions times the number of iterations is limited to about 5 million. We also have a "soft" limit on the number of borrowing compositions (approximately 50,000), as the optimization algorithm is quadratic in memory usage. We use several metrics to measure the performance of different borrowing composition and iteration distributions.

Table 1: Resource allocation descriptive statistics

No. FinComp/Iter	2,500/ 2,000	5,000/ 1,000	10,000/ 500	25,000/ 200	50,000/ 100
Minimum cost (%)	3.9955	3.9948	3.9949	3.9949	3.9949
Minimum STD (%)	0.3054	0.3054	0.3054	0.3054	0.3054
Maximum ATR (years)	4.8584	4.8584	4.8584	4.8583	4.8584

Minimum share of 1-year refinancing (%)	10.3012	10.3140	10.3313	10.2972	10.3174
Average cost (%)	4.0917	4.0884	4.0885	4.0890	4.0964
Average STD (%)	0.5101	0.5076	0.5056	0.5038	0.5088
Average ATR (years)	3.9990	3.9606	3.9714	3.9766	4.0063
Average share of 1-year refinancing (%)	12.3035	12.2596	12.2364	12.1900	12.0550
Hypervolume	557.63	558.39	558.66	559.92	560.16

Source: Own calculations

Table 1 shows a comparison of different resource allocation options. We examine numbers of borrowing compositions ranging from 2,500 to 50,000 and the corresponding iteration number, keeping a constant budget. The corner solutions are quite similar for every option, with the 25,000 borrowing composition one having a slight edge in finding the borrowing composition with the minimum share of 1-year refinancing. There are slight variations in the average objective function values, but it shows no conclusive evidence for the superiority of any allocation.

The hypervolume metric deserves some more explanation. Also known as the Lebesgue measure, this is the n-dimensional equivalent of the 3-dimensional volume. This is one of the most widely used and accepted measure when comparing different multi-objective optimization algorithms (Riquelme, Von Lücken and Baran 2015). We use the hypervolume to calculate the size of the covered optimization space with regards to a reference point. The hypervolume calculations were made using the algorithm of Fonseca, Paquete és López-Ibánez (2006). We use the so-called nadir point as the reference point, which can be described with a vector of the worst possible objective function values, and is shown in Table2.

Table 2: The nadir point

Maximum cost (%)	Maximum STD (%)	Minimum ATR (years)	Maximum share of 1-year refinancing (%)
8.41	2.46	1.86	30.73

Source: Own calculations

The nadir point was calculated by optimizing for maximum cost, maximum standard deviation, minimum ATR and maximum share of 1-year refinancing. The high costs were the result of issuing almost 100% Treasury Bills, the short end of the yield curve rising as a consequence, accruing excess liquidity cost.

The hypervolume comparison in Table 1 shows that increasing the number of borrowing compositions leads to greater coverage despite having fewer iterations to refine those compositions. We can also make pairwise comparisons between the different variants.

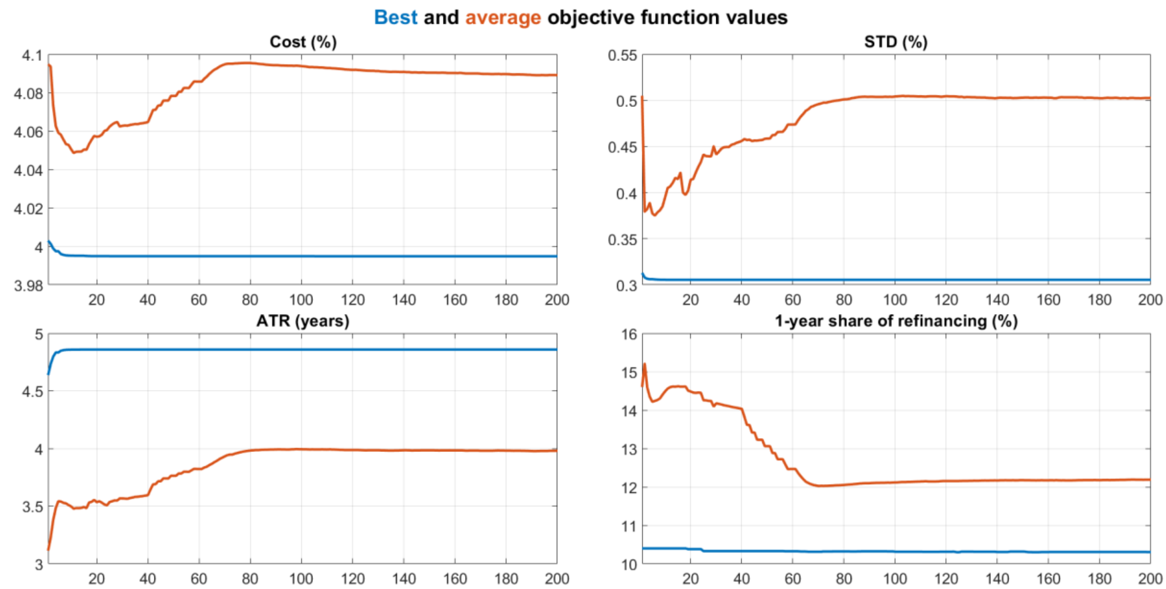
Table 3: Pairwise comparisons of Pareto-optimality

No. FinComp/Iter	2,500/2,000	5,000/1,000	10,000/500	25,000/200	50,000/100
2,500/2,000	100.00	79.00	63.88	46.72	56.20
5,000/1,000	97.08	100.00	80.08	62.66	67.76
10,000/500	99.01	96.43	100.00	77.20	77.81
25,000/200	99.66	98.66	95.66	99.97	89.39
50,000/100	96.33	93.00	88.39	80.56	99.93

Source: Own calculations, percentage points

Table 3 shows pairwise comparisons based on Pareto-optimality. The main diagonal shows the percentage of Pareto-optimal borrowing compositions of different borrowing compositions and iteration variants. This is very close to 100% in every case, which means that by the end of any optimization, almost all borrowing compositions were Pareto-optimal with regards to that specific pool of borrowing compositions. The non-diagonal elements of Table 3 show pairs of optimization results pooled together. The numbers tell the percentage of borrowing compositions from the row element that are Pareto-optimal in the combined pool. For example, if we pool together the 5,000 borrowing composition optimization with the 25,000 one, we get a total of 30,000 borrowing compositions. If we measure Pareto-optimality in the combined pool of 30,000, a total of 98.66% of the 25,000 borrowing compositions are Pareto optimal (despite being optimized through only 200 iterations), while only 79% of 5,000 borrowing compositions are optimal (despite being optimized through 1,000 iterations). Table 3 shows that increasing the number of borrowing compositions is a worthwhile trade-off to a certain degree. However, comparing 25,000 and 50,000 borrowing compositions, the former seems to be better based on this data. Therefore, we can say that 100 iterations are not enough for the optimization algorithm to converge.

Figure 1: Evolution of objective function values



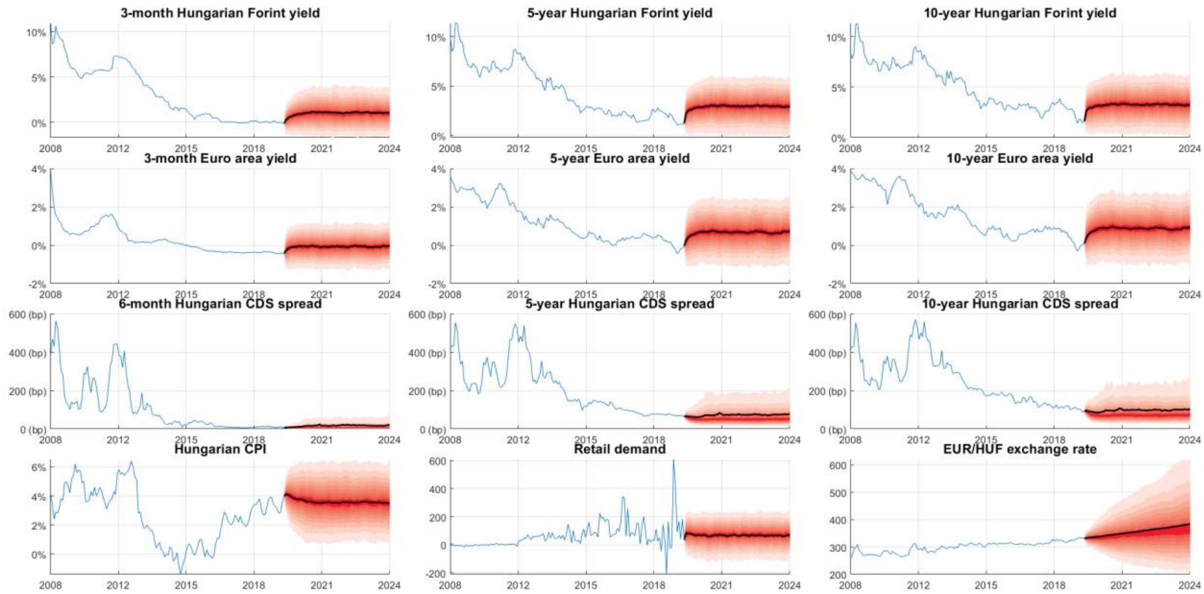
Source: Own calculations

Figure 1 shows the evolution of the best and average objective function values of 25,000 borrowing compositions through 200 iterations. One can see that the best objective function values converge in only a handful of iterations. This is unsurprising as the used optimization algorithm (Sun, Zhu and Cai 2017) finds the corner solutions first. However, there are large changes in the average objective function values after the algorithm finds the corner solutions and starts to diversify the Pareto-optimal compositions, covering more and more of the optimization space. One can see that changes continue on even after 100 iterations, with borrowing compositions getting more refined. This can explain why 25,000 borrowing compositions with 200 iterations was the standout performer in the pairwise Pareto-optimality comparison.

7. Results

In this section we present and analyze the results of forecasting and optimization.

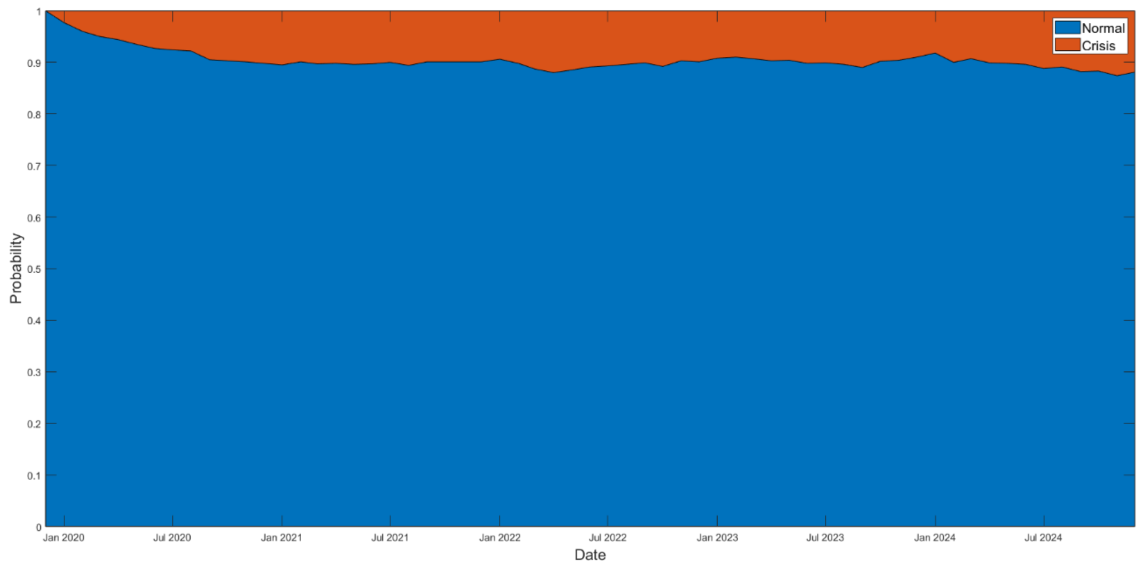
Figure 2: Evolution of yields and macro factors



Source: Own calculations

Figure 2 shows selected forecasts, including yields and macro factors, based on the results of the Markov regime switching model. Short Hungarian Forint yields are expected to rise to the 1% level, but remain negative in several trajectories. Long Hungarian Forint yields are expected to reach the 3.5% level. We expect Euro area yields to rise as well according to our forecast. Our medium-term expectation for the Hungarian CPI is 3.5%, while Hungarian CDS spreads are expected to remain stagnant for the next 5 years. Perhaps the most impactful result is the expectation that the EUR/HUF exchange rate will exceed 380 on average by the end of 2024. This means approximately a 3% yearly devaluation of the Hungarian Forint versus the Euro, raising the cost of issuing FX debt. Net retail demand is expected to stay positive throughout the simulation horizon.

Figure 3: Forecasted state probabilities



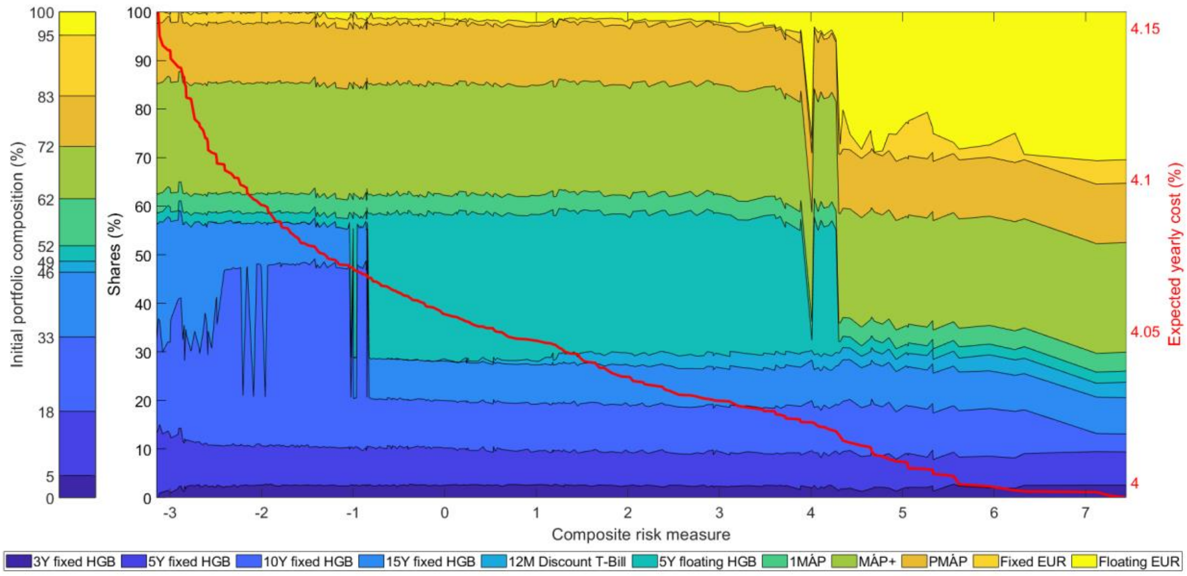
Source: Own calculations

Figure 3 shows the forecasted state probabilities. We are currently in a normal regime, but as we move forward in time, there is always a chance of entering the crisis regime. There is, according to our forecast, approximately a 10% chance of being in the crisis regime for most of the simulation horizon.

We used $25{,}000$ borrowing compositions for optimization and refined them through 200 iterations. We aggregated costs and risks from December 2019 to December 2024. Two-dimensional cost-risk frontiers can be constructed either by selecting a singular risk metric, using an arbitrary weighting scheme for the different risk measures. Our method of calculating a "composite risk measure" given the weights for different risk measures is standardizing every risk metric within the pool of $25{,}000$ borrowing compositions, and then taking the sum with appropriate weights in mind. The ideal way to use the model is to have the decision maker set the actual weights.

In this paper we show the results of setting equal weights for all three risk measures. Using this particular weighting scheme, 234 borrowing compositions are Pareto-optimal in a cost-composite risk trade-off.

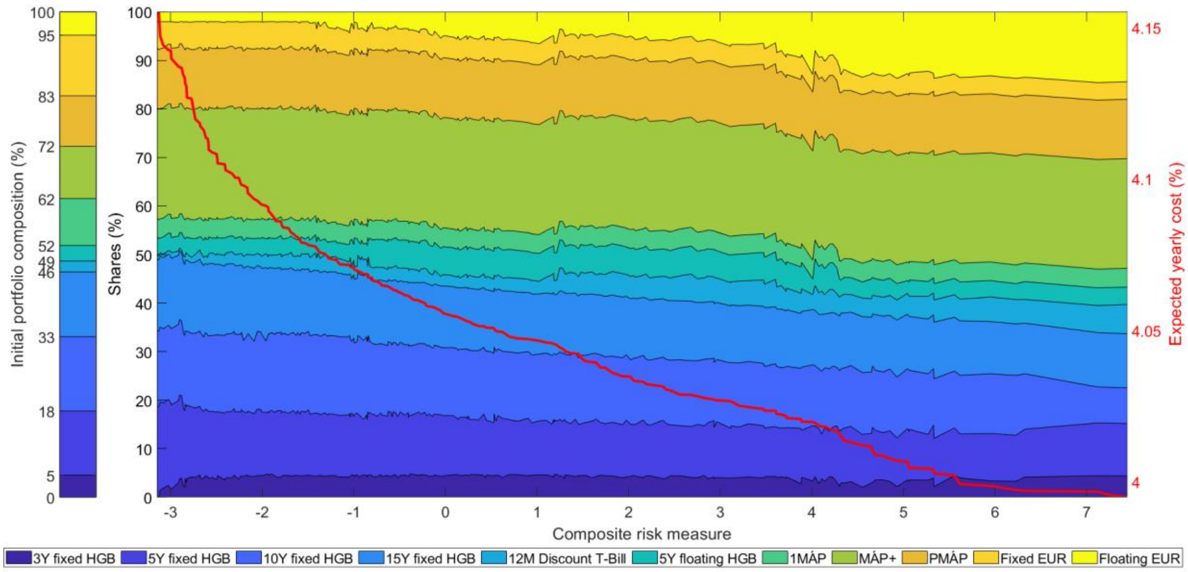
Figure 4: Optimal borrowing compositions, equal weighted standard deviation, ATR, 1-year share of refinancing



Source: Own calculations

Figure 4 shows the optimal borrowing compositions and the expected yearly cost of these compositions. We can also see the initial (December 2019) portfolio composition sorted into the most appropriate model instruments. The expected yearly costs of the optimal borrowing compositions have a tight range of $4-4.15\%$. The share of retail debt is mostly independent from the borrowing composition, treated as an external feature the debt manager has no control over. The expansion of retail funding is a cornerstone of Hungary's current economic policy and therefore controlling the retail premium to curb demand is not an option for the debt manager. The share of retail debt goes from around 30% to almost 40% of the total debt during the simulation horizon. FX debt is not preferred by the model, almost only the high-risk borrowing compositions have measurable FX issuance. The borrowing compositions seem "choppy" on occasion, with the 5-year floating government bond taking up a large share in mid-risk compositions and almost vanishing in low-risk or high-risk ones. This behavior merits further explanation.

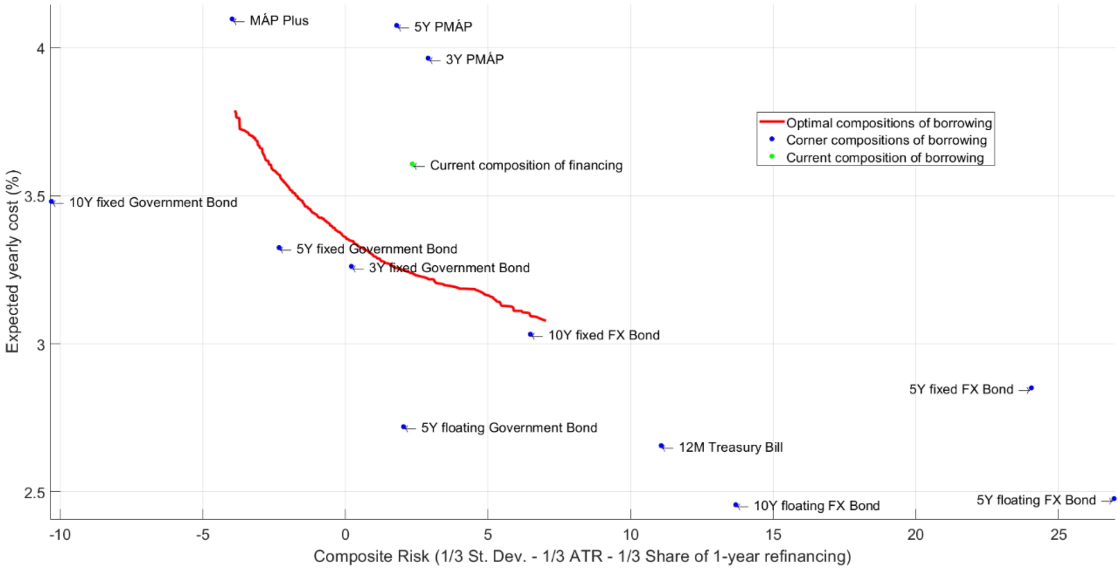
Figure 5: December 2024 portfolios, equal weighted standard deviation, ATR, 1-year share of refinancing



Source: Own calculations

Figure 5 shows the actual portfolios to be reached by December 2024. We can see that the transitions between different instruments are much more gradual compared to borrowing compositions. The real difference between low-risk and high-risk portfolios is a gradual decrease of long-maturity fixed interest rate bonds and an increase in T-Bills and floating rate FX bonds. We can also see that despite the existence of borrowing compositions with a large domestic floating rate bond share, it never reaches more than about 5% of the portfolio in reality. This is a limitation of the model: a borrowing composition with a large share in one instrument with a low liquidity constraint means that the issuance algorithm distributes that excess into other instruments by pre-financing, creating a more balanced portfolio than the borrowing composition would dictate. Nevertheless, borrowing compositions constructed in the current way seem to be the best alternative as an input for the optimization algorithm. However, recommending the end-of-simulation portfolios as a goal when creating a medium-term debt management strategy may be a better alternative than setting targets for the borrowing compositions the optimization algorithm returns.

Figure 6: Optimal cost-risk frontier, equal weighted standard deviation, ATR, 1-year share of refinancing



Source: Own calculations

Figure 6 shows the optimal cost-risk frontier with the same, equal weighted risk measures. The current composition of borrowing means that the issuance algorithm tries to keep the initial portfolio composition intact. The corner composition of borrowing show the theoretical costs and risks associated with issuing a single debt instrument throughout the simulation. Corner compositions do not issue the externally given retail debt either. Similar to the optimal composition of borrowing, corner compositions start from the initial portfolio. However, they take neither liquidity constraints nor liquidity costs into account.

Due to all optimal borrowing compositions having a large common share of issuances (that of retail debt), the costs and risks of the corner compositions and the optimal frontier have large differences. Even though - according to the corner compositions - issuing only 15-year fixed bonds would Pareto-dominate every optimal borrowing compositions, this opportunity is unavailable to the debt manager due to both liquidity constraints as well as retail demand.

We can see that retail debt has high expected costs with moderate risks. However, with the forecasts pointing toward an unfavorable exchange rate evolution, retail debt may still prove to be cheaper than FX bonds while having a significantly lower risk level. Figure 6 shows that domestic wholesale debt (both fixed and floating rate) is currently the preferable option for the debt manager if there is enough demand.

8. Conclusions

In this paper, we presented the Hungarian optimal debt portfolio model. We showed how a stochastic simulation model can be used to help the Hungarian Government Debt Management Agency achieve its goal of funding government borrowing needs while keeping costs minimal, and risks at an acceptable level. Our work goes beyond existing stochastic debt management models by using a two-economy Markov regime switching model and a multi-objective optimization framework. We also use a complex estimation of funding liquidity to simulate how supply and demand affect debt management.

The greatest advantage our model offers is flexibility. We can easily add or remove planned instrument types in order to aid the development of new products and estimate their costs and risks. If needed, many of the parameters can be modified to reflect real life changes. The model is well-equipped to handle the relatively complex characteristics of Hungarian government debt. Consequently, it can be adapted or simplified to handle sovereign debt structures with different features. The multi-objective framework allows any debt manager to select risk metrics appropriate to their goals. The relatively low computational requirement is also an advantage of the model, requiring only a single high-end desktop computer for meaningful results in an acceptable timeframe instead of clusters or cloud applications.

The model has some limitations as well, of course, with room for improvement. Without knowledge and expertise in using the model, the results can seem black box at first glance. The calculation of costs also poses an accounting dilemma. Our methodology does not discount future costs when comparing different borrowing compositions. A debt manager might prefer accruing costs at a later time and adjust for inflation or yields. Another limitation is the lack of feedback from interest expenditure or otherwise accrued costs toward the budget deficit or other funding requirements. This compromise was made to lower the computational requirement of the model, and does not need a workaround unless deviations in debt service have a serious budget impact. Finally, in some cases, borrowing compositions do not adequately represent the resulting portfolio. There is possible room for improvement by adjusting the issuance algorithm or including penalty terms if the borrowing composition and the resulting portfolio differ too much.

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The Benefits of Reducing Hold-Out Risk: Evidence from the Euro CAC Experiment, 2013-2018*

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Abstract

The introduction of collective action clauses in advanced economies' sovereign bonds is an understudied phenomenon. An important concern is whether these clauses produce segmentation, pushing apart the price of those bonds issued with and without collective action clauses (CACs). This paper uses the introduction in 2013 of mandatory two-limb CACs in euro area sovereign bonds issued under domestic law to evaluate the price impact of these provisions. In the euro area, bonds with CACs trade at a small premium. On average for those bonds, yields were up to six basis points lower. This average, however, masks heterogeneity. While Germany and Netherlands have not seen a sustained reduction in borrowing costs, in Italy and Spain the effect has been large (between five and ten basis points). These findings support the argument that the introduction of euro CACs in domestic law bonds helped investors reassess the risks associated with those instruments in both countries.

JEL Codes: F34, H63, K41

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1. Introduction

The economic dislocation accompanying sovereign debt defaults worsens the longer it takes debtors and creditors to find a negotiated solution (House et al., 2017; Schumacher et al., 2018).[5] History shows that rogue creditors (also known as hold-out creditors) have often blocked restructuring processes, making these unnecessarily protracted and painful (Aguiar and Amador, 2014; Zettelmeyer, 2018). In reaction, the international community has over time developed tools to minimize the costs created by these hold-out creditors. These include official procedures to unlock official lending (like the IMF's lending into arrears policy), codes of conduct, and legal remedies in the form of clauses introduced into bond contracts.[6] Within the last, collective action clauses (CAC), which are meant to facilitate debt workouts by removing the unanimity requirement to agree on a restructuring, have gained prominence (Gelpern et al., 2015). Following the global crisis, governments began to add new

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[5] See Pitchford and Wright (2012) for a theoretical model on debt restructuring delays and the role of CACs.

[6] Introducing explicit safeguards in bond documentation is the globally accepted market-based approach to debt restructuring. Legal practice has focused on contract provisions relating to equal treatment of creditors (pari-passu and cross-default) and clauses setting voting rules for changing reserved matters.

collective action clauses to their bonds. In this paper, we study the impact of these innovations on the pricing of sovereign bonds.

Collective action clauses became popular in the early 2000s as the debate on how to tackle sovereign debt crisis tilted away from a statutory (Krueger, 2002) toward a market-based regime (Taylor, 2002). Traditional CACs allow for changes in the terms of bond contracts, based on approval by a majority of bondholders in terms of outstanding principal. Two-thirds or three-quarters majorities are often seen as reasonable thresholds. In reaction to the euro area crisis, as part of the setting up of the European Stability Mechanism, euro area countries agreed to include in all new sovereign bonds CACs (see Article 12(3) of the ESM Treaty).[7] The EA Model CAC (euro CAC) departed from the earlier model by lowering to two-thirds the majority needed at the level of each bond to approve a proposed amendment (counted as the aggregate principal amount of the outstanding debt securities of affected series capable of aggregation).[8] The euro CAC also contains an additional three-quarters majority, needed when counting all bonds targeted together (cross-series). Because of the dual majority requirement, this voting model is known as double-limb aggregation.

In 2014, the International Capital Markets Association proposed a new CAC (ICMA CAC) featuring a different aggregation technique.[9] The ICMA CAC includes the possibility of using a unique aggregate vote across all bonds (single-limb), in addition to a lower approval threshold for the double-limb aggregation than under the euro CAC.[10] This single-limb aggregation mechanism replaces the double threshold requirement with a single vote (subject to a majority of at least 75%) across all series, with no majority needed at the bond level.[11]

Given that double-limb aggregation may not prevent bondholders from obtaining blocking positions in specific bonds, there is an ongoing debate within the euro area regarding the convenience of adding ICMA-like CACs to the documentation of sovereign bonds (Zettelmeyer, 2018; Andritzky et al., 2018). Those in favour argue this would reduce uncertainty and provide incentives to buy these bonds. Those against highlight the negative signalling (potential defaults) and liquidity effects.[12] Remarkably, this debate proceeds with limited empirical evidence.

An important consideration regards the underlying legal system into which the CACs are introduced (Schumacher et al., forthcoming). While, originally, CACs were introduced in foreign law instruments with the aim to reduce the hold-out problem, their role can radically different in domestic law obligations (Buchheit et al., 2013). Indeed, under domestic law, CACs are not necessary to restructure sovereign debt. The government can do it through a legislative act. In this context, the introduction of CACs might help reassuring investors by reducing government discretion (Carletti et al., 2018).[13]

This paper contributes to filling this analytical gap with two separate sets of evidence: one for euro CAC in domestic law issuances and another for ICMA CAC in foreign law issuances. To evaluate the impact of two-limbed CAC structures on euro area governments borrowing costs, we follow the work of Carletti et al. (2018). As they do, we combine a matching technique with panel regressions. To

[7] A specific design of CACs was agreed separately and implemented individually by each issuer.
[8] CACs contain two different thresholds under two-limb aggregation: 1) if the decision is approved in a meeting and 2) if it is passed by a written resolution signed on behalf of a majority of note-holders. The majorities are different in the two cases: 2/3 of votes cast in a meeting (meaning that abstentions are ignored) or 50%+1 of outstanding principal signing a written resolution (meaning that whoever doesn't sign is counted as a no vote).
[9] In October 2014, Kazakhstan was the first country to issue a bond with the new ICMA CAC (Gelpern et al., 2015).
[10] More specifically, ICMA CACs apply the majority requirements of written resolutions under current CACs to meetings.
[11] In reaction to the issues faced by Argentina at the time, ICMA (2014) also provided a new drafting for pari-passu clauses.
[12] CACs create segmentation in sovereign bond markets (Cannata, 2018). Bonds of the same issuer but with different CACs provisions might not be seen as perfectly fungible from a credit perspective, influencing secondary market liquidity.
[13] According to the findings in Carletti et al. (2018) this is the case for issuers with strong legal institutions.

provide additional insights we extend the sample data up until 2018 (theirs stops in 2015). Given that various transitory factors could affect the effect of the CACs overtime, our larger sample allows us to test whether the effects of CACs have changed over time.[14] Moreover, thanks to the larger pool of bonds and observations at our disposal, we study country-specific time-varying effects of the CACs. Additionally, while Carletti et al. (2018) match bonds with differences in remaining maturities of up to three years, we use an alternative (tighter) matching, with a narrower remaining maturity window (one year) to match the bonds, and also limit the difference between matches as regards coupons (below 5 percent) and original maturity at issuance (not more than ten years difference).[15]

In line with the findings in Carletti et al. (2018), our evidence shows that the dual-limbed euro CACs reduce borrowing costs; with the caveat that there is heterogeneity across countries. Of particular interest, we find a large effect in both Italian and Spanish bond markets. In both cases, there is scope to argue that the inclusion of the CACs led investors to feel an increased degree of protection over a redenomination risk and the domestic legal character of the bonds.[16]

Our evaluation of the pricing impact of single-limb CACs takes advantage of the fact that Sweden introduced the new ICMA CAC in 2017. Evidence on the effect of single-limb structures is not easy to find even though these new clauses have already been adopted by several emerging market economies (Zandstra, 2017). Our results for Sweden point to a small effect from shifting to a single-limb aggregated CAC in foreign-law sovereign bonds, roughly between half and four basis point. While these findings are robust to different specifications, the few bonds and short time series available suggest caution is necessary in drawing conclusions from them.

The rest of this paper is organized as follows. Section 2 reviews the existing literature related to CAC provisions. Section 3 describes the euro area experience with the two-limb CACs and the related empirical analysis. Section 4 provides a preliminary evidence of the single-limb clause pricing effect for Sweden. Section 5 concludes.

2. Literature Review

As the role of contractual protection in managing sovereign risk has increased in recent decades, a growing body of empirical work has studied their effect on market dynamics. CACs seek to avoid that a minority of debtors blocks a restructuring operation (hold-out problem) and prevent legal action that can obstruct the process. In theory, while CACs support a fast restructuring process, driving yields down, they may also generate moral hazard, making default more likely, driving yields up.[17] In this

[14] According to Ratha et al. (2018), these transitory effects could include first issue effects and changes in the investor base of the bonds. Additionally, given that the larger proportion of debt with CACs the likelier these will be effective, one could think that the dynamics of the proportion of debt with CACs also matter for their effect.

[15] This choice is motivated by the fact that bonds with very different coupons and or original maturities may be viewed differently by market participants, even when their remaining maturity is not too different. One reason why very different coupons can make bonds look different is that they affect the sensitivity of duration to changes in interest rates. In turn, bonds issued with long maturities are often acquired by buy-and-hold investors (see Feldman et al. (2015)). As a result, these bonds remain structurally different than shorter bonds, even when their remaining maturity becomes shorter.

[16] We note that the large effect on Italy from the introduction of CACs may be the result of the euro CACs reducing the uncertainty related to the possibility of using a unilateral maturity extension embedded in some bonds (Edelen et al., 2012). We note, however, that this is an Italian law provision, not a clause directly embedded in the terms of the bonds.

[17] Theory does not provide a unique answer. While Haldane et al. (2005) show that CACs reduce the coordination problem and lower yields, Shleifer (2003) points to an opposite effect because CACs make restructuring easier. Ghosal and Thampanishvong (2013) show in a theoretical model with debtor moral hazard and creditor coordination problems that moving CACs threshold away from unanimity might reduce welfare.

section we summarize the existing empirical literature, with a focus on double and single-limb aggregation clauses.

Early studies found little evidence of rising costs. Eichengreen and Portes (1995), Tsatsaronis (1999) and Eichengreen and Mody (2003), and Eichengreen and Mody (2004) study the effect of CACs assuming that bonds under English law always include them while those under NewYork law never do.[18] In line with theories arguing that senior debt is harder to restructure and should trade at lower yields (Bolton and Jeanne, 2009), Tsatsaronis (1999) finds that CACs sometimes imply greater yields. Eichengreen and Mody (2003, 2004) show that CACs decrease borrowing costs for strong issuers and increase them for poorly-rated issuers. Becker et al. (2003); Richards and Giugiatti (2003) find that after controlling for creditworthiness CACs have a limited price impact.

More recent studies have had the benefit of more and better data. However, the results of these studies have not been consistent. Motivated by the innovations that followed the global crisis, Bradley and Gulati (2013) were able to code for specific vote thresholds, and control for the type of governing laws. They found CACs to slightly decrease the cost of borrowing, particularly for weaker sovereigns. Bardozzetti and Dottori (2014) found a similar effect, albeit for sovereign issuers with ratings in the middle of the scale.[19] Ratha et al. (2018) find an ambiguous correlation between CACs and yields. In contrast with this evidence, focusing on the Venezuelan debt crisis, Carletti et al. (2016) provide evidence that passing from unanimity to CACs with a 75% of vote requirement produced higher yield (between 8.6% and 10.86%). Instead, they find no pricing difference when the threshold was moved from 75% to 85%. Scott et al. (2018), instead, found no evidence that different CAC provisions in Venezuela were priced differently, even close to default conditions. They claim that differences might show up after litigation-oriented funds initiate their legal action, as this is when the market can understand which bonds are targeted by holdout creditors.

Focusing on the euro area CACs, early evidence comes from Steffen and Schumacher (2014) found no significant effect coming from the euro CAC. In turn, Carletti et al. (2018) find that bonds with euro CACs trade at lower yields, and that the quality of the legal system matters for the size of this effect. Countries whose legal system is more efficient feature lower yields in bonds with CACs. This, they argue, supports the idea that CACs decrease the legal risk associated with sovereign debt issued under domestic legislation. Focusing on Italy alone, De Santis (2017) finds that bonds with CACs trade at marginally better prices, around 10 bps. These findings regarding domestic law bonds confirm the theory in Bolton and Jeanne (2009). Domestic bonds without CACs can be restructured simply by fiat. Therefore, they are easier to restructure than bonds including CACs, and should trade at a higher yield.

To date, given the lack of data (single-limb CACs are a relatively new phenomenon), there are no studies that we are aware of that examine the impact of single-limb collective action provisions. The only indication we have of their price impact is from the IMF, which reported on a preliminary basis in

[18] Originally, there were almost no bonds issued under New York-law without a unanimity requirement. Instead, most sovereign bonds issued under English-law allowed for contractual changes with less than unanimity. However, this kind of comparison was not taking into account two aspects of English-law bonds: 1) they did not have only the 75% vote threshold but they also required the physical meeting of bondholders (potentially exacerbating the holdout problem); 2) they had diminishing quorum requirements (Eichengreen and Mody, 2004).

[19] They argue this could be due to the fact that these sovereigns benefit most from an orderly restructuring, given they face a non-negligible probability of default (while the reputational cost of opportunistic behaviour is higher). Countries with higher ratings face such a low default probability that the impact from including CACs is negligible.

2017, that the IMF staff had not perceived any observable impact of sovereign bond pricing from the introduction of single-limb CACs.[20]

3. The euro area experience with two-limb CACs

In 2003, as part of a coordinated initiative to promote collective action clauses, EU Member States decided to include them in their foreign-law bonds from 1 January 2004. These CACs stipulated that approval by a three-quarters majority of bondholders in each bond series would be needed to restructure the terms of that series (bond-by-bond). The issue then was seen as relevant for emerging economies, given that Euro area countries issued local-law bonds for the most part. The issue of CACs did not resurface until the global crisis hit the euro area. In November 2010, the Euro group agreed that standardised and identical CACs would be included in all new euro area government bonds.[21] This obligation was codified in Article 12(3) of the ESM Treaty, which requires that the euro area Model CAC (euro CAC) be included in all securities with a tenor of more than one year, issued from 1 January 2013 onwards.[22] The euro CAC departs from the post-2003 model by lowering to two-thirds of the outstanding principal the majority needed at the bond level to approve a proposed amendment. In contrast, it also requires a three-quarters majority when counting all targeted bonds together.

The rest of this section uses pre-sampling matching techniques and panel regressions to study the effect of the inclusion of euro CACs on the pricing of sovereign bonds. We first introduce the dataset we built for the analysis. Then we briefly explain the econometric strategy, and discuss our results. Tables with regression results and the larger figures are presented in the appendix.

4. Data and Methodology

Our evaluation of the effect of euro CACs extends the analysis in Carletti et al. (2018). As they do, we focus on sovereign bonds issued under domestic law and use matching and panel regression techniques to gauge the effect of the clauses. We deviate, however, in three critical aspects: we use a larger sample, a stricter matching and also target country-specific time-varying effects. We collected all CAC bonds issued after the introduction of CAC with a cut-off date of 7 September 2018, and no-CAC bonds issued before 1 January 2013 but maturing after that date (297 bonds in total). We obtained weekly information for all active and matured euro-denominated government bonds issued by euro area countries under domestic law, with/without CAC provisions, and maturity above one year from Bloomberg.[23] Using the extracted ISIN from Bloomberg, we retrieved the governing law for each bond. In order to supplement the information on governing law (and crosscheck the information coming from Bloomberg), we applied the same filtering using the Dealogic database. We further narrowed down our bond sample to include only standard fixed coupon bonds.[24] After applying these

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[20] Results of surveys among public debt managers indicate that the inclusion of enhanced CACs has not had a pricing impact on new bond issuances. The available information suggests that market acceptance has been strong, yet the impact on pricing is considered to be rather insignificant. See International Monetary Fund (2017).

[21] To preserve the liquidity of existing debt issues, issuers can tap existing securities up to a maximum per year.

[22] Unlike in 2003, this law specifically envisioned applying the euro CAC to securities governed both by foreign and by domestic law.

[23] CACs are included only in bonds with maturity above one year. For that reason, we restrict our analysis to them.

[24] In addition, bonds with embedded options, such as convertible, sinkable, puttable and callable were excluded. Finally, we delete bonds issued for retail investors, issued by sovereign-backed agencies.

filters, we are left with 235 CAC bonds (see Table 2). We found no eligible bonds issued by Cyprus, Estonia, Greece, Latvia, Lithuania and Malta. [25]

5. Bond matching

To improve the estimation accuracy, as per Carletti et al. (2018), we pre-sample instruments that are sufficiently similar by applying a matching technique (Ho et al., 2007). This technique is used as a pre-screening instrument in order to select bonds. We construct two data samples: bonds with, and without, CAC provisions. We perform our matching by coupling each CAC bond in the CAC bonds pool with another no-CAC bond in the no-CAC bonds pool. The matching is based on three criteria: same issuer, same currency, and closest residual maturity. We then turn to the treatment and control groups we built for our analysis. We read Carletti et al. (2018) as placing no restriction on the maximum distance on residual maturity that the matching allows. This produces matches with up to three years difference. To achieve similar results, we adopt a strategy (henceforth loose matching) where we look for pairs of bonds with a difference in residual maturity between -3 and +3 years. This allows us to identify 201 pairs coming from Austria, Belgium, Finland, France, Germany, Ireland, Italy, Netherlands, Portugal and Spain (Table 2).

One concern with this matching approach is that market participants may not view bonds with such differences in residual maturity as comparable.[26] Moreover, we further evaluate the quality of our matches by analysing how our matched bonds differ in two additional features critical to investors. As shown in Figure 1 and 2, we look at coupon and original maturity differences. We observe that some of our matches have large differences in these dimensions. Some matches feature coupon differences of up to eight percent, in others original maturities vary by as much as 25 years. To make sure that these differences are not affecting our estimates, we create a tighter set of matches. First, when performing the matching, we limit the maturity difference between the CAC and no-CAC bond to one year. In addition, we eliminate all matches in which the difference in coupons is more than five percent and all those where the difference in original maturity between the matched bonds is above 10 years.[27]

The final dataset includes 115 pairs for the following countries: Austria, Belgium, Finland, France, Germany, Italy, Netherlands and Spain.[28] Table 2 in the appendix provides the country breakdown during each phase of data filtering and shows the maturity differential between CAC and no-CAC bonds in our sample. Some descriptive statistics of our sample are reported in Table 1. A similar message emerges from both samples. On average, CAC bonds have lower yields, lower durations and are more liquid (as reflected in lower bid-ask spreads).

[25] Luxembourg, Slovakia and Slovenia are dropped because of limited price history. We also deleted a pair of Belgian bonds as the pricing history was incomplete.

[26] Given sovereign bonds markets are populated by investors that specialize in different segments of the curve, multi-year differences in maturity can generate differences in pricing due to differences in investor types. The pricing effect of CACs might depend on the type of investors holding the bonds (Ratha et al., 2018; Choi et al., 2018).

[27] As already mentioned, bonds with long original maturities are often acquired by buy-and-hold investors, making them structurally different even as their remaining maturity shortens.

[28] Portugal and Ireland are removed from the sample as only one pair can be formed.

Table 1: Summary statistics for the loose and tight sample – CACs and matched no-CACs bonds

Loose sample

Variable	CACs bonds		Non-CACs bonds		Difference.
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	
Yield	73.12	112.71	120.99	142.27	47.87***
Duration	7.01	4.24	7.48	4.33	0.47***
Liquidity	0.03	0.24	0.22	2.96	0.19***

Tight sample

Variable	CACs bonds		Non-CACs bonds		Diff.
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	
Yield	65.28	111.90	110.52	140.28	45.24***
Duration	6.12	3.35	6.45	3.31	0.33***
Liquidity	0.03	0.27	0.26	3.24	0.22***

*Note: The table shows mean and standard deviation for our sample of CAC and no-CAC matched bonds. The last column reports the difference between the means of CAC and no-CAC bonds for each variable, together with the t-test on statistical significance. *** significant at 1%, ** at 5% and * 10%.*

6. Econometric analysis and discussion of results

Following Carletti et al. (2018), we estimate our benchmark econometric model using pooled OLS with robust standard errors:

$$y_{i,c,t} = \alpha + \beta \cdot CAC_i + \gamma \cdot Controls_{i,c,t} + \chi_c + \phi_t + \varepsilon_{i,c,t} \qquad (1)$$

where $y_{i,c,t}$ is the yield of bond i from country c, at time t. CAC_i is a dummy variable that equals 1 for bonds including CACs and 0 otherwise. $Controls_{i,c,t}$ is a vector of control variables including: credit ratings, to control for a country's creditworthiness, euro area 10-year government bond yield index to consider structural movements in sovereign bond yields, the bond's duration as a proxy for bond risk, the flow of bond purchases and stock of bond holdings by the ECB, and the bid-ask spread of the bond to control for liquidity.[29] χ_c stands for a set of country-fixed effect and ϕ_t contains weekly fixed-effects. Within this framework, the effect of including a collective action clause on a bond from country c is represented by β.[30]

Table 4 contains the results. In all of our specifications controls are highly significant and mostly show the expected signs.[31] Limiting the sample to 2013 and 2014, as in Carletti et al. (2018), we find that CAC provisions imply yields 11 bps to 6.5 bps lower, depending on whether we consider weekly and

[29] We convert the rating into a numeric scale; with higher values representing higher ratings.
[30] All data are in weekly frequency.
[31] The coefficient associated with ECB purchases presents a positive sign, which we see as a reflection that purchases focus on the cheapest bonds available (see Nordea (2016)). As noted by JP Morgan (2018), if the ECB would reach its purchase limits (33% of the outstanding volume of each bond), it would more likely buy additional non-CAC bonds. This should reduce yields on non-CAC bonds more than on CAC bonds.

country fixed effects (column 2) or not (column 1). These coefficients remain highly significant but lower (5.3 and 4.45 bps) when we extend the sample until September 2018 adopting a loose matching (column 3 and 4). When we tight the matching, considering only one year difference in term of maturity date, maximum four percent difference in coupon rate and 10 years for original maturity, the values remain similar, highly significant and slightly lower (column 5 and 6). Given the predominance of Italian bonds in the sample, we run the same regression considering all the countries in our sample but Italy. The effect of CACs remains significant but it reduces by half.

This remarkable difference in the effect of CACs between Italy and the rest of our sample further motivates us to study the dynamic country-specific reaction to the introduction of CACs. We begin by producing country specific effects and then move to allow these effects to be time varying.

7. Country-specific effects

Taking advantage of our large sample of observations, we study the country-specific effect of CAC by running equation (1) separately for each country.[32] Figure 3 depicts how the introduction of CACs seems to have produced heterogeneous country specific effects in both samples. In the loose matching the effect is always yield reducing whereas in the tight matching Netherlands is the only country presenting a tiny yield increasing effect. Once again, Italy stands out because of the large value of the CAC, although we also observe a large coefficient for Spain.

8. Time variation

Next, we estimate equation (1) at the year/country level.[33] This we do in order to assess whether, as discussed in Ratha et al. (2018), the findings from papers focused on the early period after implementation of the euro CAC could reflect also transitory effects. By measuring the extent to which the effects have changed since the inception of the CACs our analysis also allows us to understand whether one needs to wait until the dust settles to be able to measure the long-run effect of a deep reform in sovereign bond markets.

Table 5 and 6 presents the results. In both the loose and the tight matching, all countries in the sample show a decrease in yields of CAC bonds especially in the first years after the mandatory introduction of CAC provisions. Looking at the loose matching, the effect seems to stabilize in the territory of lower yields for CAC bonds (Belgium, Finland, France, Italy and Spain) or to converge toward zero over time (Germany and Netherlands). Results are broadly similar when considering the tight matching. Germany and Netherlands represent the only difference that shows slightly larger yields for CAC bonds in 2018. Figure 4 and 5 show some comparison effects respectively for the loose and the tight matching. Netherlands shows a convergence toward a zero difference between CAC and non-CAC bonds yields (Figure 4). Interestingly, Italy shows a sustained reduction in yields coming from the introduction of CACs of around ten basis points. The difference is even larger when looking at the tight matching where yield differential for Italian CAC-bonds stabilize above 10 bps. The comparison between Spain and Germany shows a similar path. German CAC-bonds converge toward a zero difference with no-CAC bonds whereas Spanish CAC-bonds seem to stabilize at a lower yield of around 5 bps. The paths are broadly unchanged when looking at the tight matching.

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[32] Austria is dropped because of the low number of observations.

[33] In this way, we allow for all of the explanatory variables to have time-varying effects. We also estimated time-varying CAC effects using the following country-specific model: $y_{i,t} = \alpha + \sum_{\forall j \in \{2013,2018\}} \beta_{cj} \cdot CAC_i{}^j + \gamma \cdot Controls_{i,t} + \chi_c + \phi_t + \varepsilon_{i,t}$, where the set of β_{cj} collects the time-varying effects coming from CACs on country c yields. Results were similar.

Following the arguments put forward in Carletti et al. (2018), in both cases there is scope to argue that the inclusion of the CACs led investors to feel an increased degree of protection against the risk of redenomination. There is indeed empirical evidence that financial markets actually priced in the possibility of these countries to convert their domestic law debt in another currency.[34] More specifically for Italy, two indicators were signalling a high redenomination risk perceived: the *ISDA basis* and the spread between local law bonds and foreign law bonds with CACs.[35] With the introduction of CACs in domestic law bonds, this possibility to convert domestic law debt was significantly reduced since it would have exposed the country to a non-negligible litigation risk. This, in line with our results, produced a significant drop in bond yields.

Another possible explanation for these significant results in Italy and Spain relate to the extent to which CACs interfere with the room of manoeuvre that the domestic legal character of the bonds provides. In the Italian case the effect may come from the fact that the inclusion of euro CACs arguably limits the ability of the Italian authorities to use the option of unilaterally extending the maturities of pre-2013 Italian local-law bonds - although the ability of the Italian government to uncontestably apply this option is not guaranteed.[36] In the case of Spain, the introduction of CACs came at a similar time as a modification in the Spanish constitution to grant the payment of public debt priority over any other budget item (Sanchez-Barrilao, 2013).[37] The large effect (five bps) that we find for Spain may be driven by such renewed constitutional protection.[38]

9. A look at the frontline: Single-limb CACs in Swedish foreign law bonds

The Executive Board of the IMF endorsed the ICMA CAC proposal in October 2014. Since then it has been used in approximately 85% of foreign-law sovereign bonds issued. Among EU (non-euro area) member states, Bulgaria, Croatia, Romania, and Sweden have adopted the single-limb model in all non-domestic law issuances made by since October 2014. It has not yet been adopted in Hungary or Poland.[39]

This section focuses on the Swedish experience. Given that the number of available bonds is rather small, we restrict ourselves to analyze the effect of the clause using panel regression techniques. In order to reduce the incidence of comparing bonds that are not that similar, we enlarge the set of explanatory variables to include other characteristics of the bonds such as their coupon and original maturities. An additional complication in this case is that Sweden issues its foreign bonds in both euro and dollar. We estimate effects separately in each of these markets.[40]

[34] Italy and Spain were the countries most vulnerable to redenomination risk especially after the OMT. See Borri (forthcoming); De Santis (2015).

[35] The ISDA basis refers to difference of the sovereign CDS price computed according to the ISDA 2014 standard (that includes currency conversion as credit event) and the price computed according to the ISDA 2003 standard (that does not include this possibility). In the first half of 2018, the ISDA basis increased from 27.5 to 115 bp. The spread between local law bonds and foreign law bonds with CACs indicates the risk underlying local law bonds without CACs and it reached a peak of 26bp between May and June 2018. See Minenna (2018); Scaggs (2018); Clare and Schmidlin (2014).

[36] The use of this maturity extension might be costly for the government since it might trigger sovereign credit default swaps and lose the eligibility for ECB purchases (see (Edelen et al., 2012)). Additionally, as the proportion of Italian debt including CACs increases, the potential advantage provided to the Italian government by this clause is being diluted.

[37] This constitutional change was part of the measures adopted in order to regain confidence from investors.

[38] One reason why increased creditor protection should affect more bonds with CACs is presented in (Bolton and Jeanne, 2009), who shows that "easier-to-restructure" liabilities are more likely to be involved in a partial default. Then, reforms that make partial default less likely should affect junior debt more, which in the Spanish case were the bonds with CACs.

[39] Denmark has issued no foreign law governed debt since October 2014. See International Monetary Fund (2017).

[40] Currency-specific effects of CACs are discussed also in Eichengreen and Mody (2003).

10. Data and Methodology

We collect all active and matured foreign currency bonds issued by the Swedish government since 2010 from Bloomberg, which gives us 38 eligible bonds. We also retrieve the governing law from Bloomberg, supplementing with data from Dealogic database and International Monetary Fund (2017). From the documents of the Swedish National Debt Office, we found that bonds issued under the Euro Medium Term Note Programme (EMTN), after December 2016, contain the single-limb clause. In order to identify these bonds, we cross-checked information about governing law. Also, from the documents of the Swedish National Debt Office, we know that only bonds included in the EMTN or in the Euro-Commercial Paper (ECP) programmes are issued under English law and that bonds in the ECP programme have maturity lower than one year. Therefore, from the pool of bonds listed in the Swedish National Debt Office's website, we were able to identify six single-limb bonds. Our sample is then made of 6 single-limb bonds and 30 traditional CAC bonds. Details on each of these bonds are presented in Table 3 in the appendix. In terms on methodology, we use the same approach that we have used for the previous section using robust standard errors:

$$y_{i,t} = \alpha + \beta \cdot CAC_i^{single} + \gamma \cdot Controls_{i,t} + \theta_c + \psi_i + \phi_t + \varepsilon_{i,t}$$

where $y_{i,t}$ is the yield of bond i at time t. CAC_i^{single} is a dummy variable that equals to 1 for bonds including enhanced CACs and 0 otherwise. $Controls_{i,t}$ is a vector of control variables including: duration, liquidity, total assets of the Central Bank in percentage of GDP, stock market index, US policy rate and the original maturity and coupon of the bond. ψ_i collects bond fixed-effect, ϕ_t contains time fixed-effects. Since in the sample we have bonds denominated in euro and dollar, we add θ_c as US dollar bond dummy.

We run the same regression considering two samples: 1) post-2009 and 2) post-2013. The first choice is motivated by the fact that until 2009 Sweden had not issued euro-denominated bond for a decade. The second choice relates to the date on which ICMA introduced its enhanced CACs.

Since in these specifications we are forcing a homogeneous relation between CACs and yield in both markets, we run a similar experiment allowing effects to be different according to currency of denomination of the bonds included in the analysis. More specifically, the equation will be:

$$y_{i,t} = \alpha + \sum_{\forall i \in (euro, dollar)} \beta_i \cdot CAC_i^{single} + \gamma \cdot Controls_{i,t} + \psi_i + \phi_t + \varepsilon_{i,t}$$

Table 7 shows the results for the post 2009 sample and Table 8 for the post 2013. Column 2 represents our baseline specification with weekly fixed effects and bond fixed effects. Yields increase with duration and are larger for dollar-denominated bonds. Bid-ask spread shows instead a negative coefficient. Regarding our variables of interest, ICMA CACs seem to reduce sovereign yields by between half and four basis points (depending on the sample).

Columns 3 to 5 in both tables control respectively for weekly-fixed effects (column 3), bond-fixed effects (column 4), and weekly-fixed effects plus random bond effects (column 5). Comfortingly, control variables present the same sign and significance. Interestingly, when looking at the currency separation, we notice some differences between bonds. ICMA CACs seem to have a consistently significant effect in the euro market. Euro-denominated bonds with ICMA CACs trade at lower yields (between half and one basis point depending on the model). We document a yield decreasing effect also on dollar-denominated bonds when controlling for weekly fixed effects (column 5). [41]

As last step, in order to look at structural differences across markets, we run the model for each currency separately. Given the low number of observations, we do not include time or bond fixed-effect. Column 6 refers to dollar-denominated bonds whereas column 7 focuses on the euro denominated ones. The effects on these specifications while statistically significant are economically minimal (below 0.2 bps).

11. Conclusions

In this paper, we have studied the pricing implications from the introduction of two-limb CACs in euro area sovereign bonds. The narrow existing literature points to a beneficial effect for euro area sovereign yields from introducing CACs. This paper complements this literature by using a sample that covers the entire period since the euro CACs were introduced. Taking advantage of this large dataset, we present both country-specific and time-varying effects. This approach allows us to evaluate the extent to which CACs have heterogeneous effects in different economies (because of differences, for example, in the quality of their domestic legal regimes). It also allows us to test whether the effects obtained in previous studies, focused on the early period after implementation, are to be seen as permanent or transitory effects.

We find that yields for bonds with euro CACs are between six and two basis points lower. Additionally, we document a significant degree of heterogeneity in the response of yields to CACs, both in the cross-section and over time. We document large long-run effects in both Italian and Spanish bond markets, while we observe no beneficial effect for Germany and Netherlands. Our results can be interpreted as implying that CACs helped mitigating redenomination fears, but also that they interplay with domestic legal systems that were considered weaker, reassuring investors and reducing the cost of issuing under domestic-law (Carletti et al, 2018). Interestingly, our results also show that in the early years since the implementation of the CACs, it was Netherlands and Germany who seem to have benefited from the inclusion of CACs. We read these dynamics as showing that transitory effects were important during the first years after the CACs were introduced. More generally, we see these results as indication that one needs to wait until the dust settles before being able to measure the long-run effect of deep reforms in sovereign bond markets.

Our paper also tries to contribute the current debate regarding the introduction of a single limb clause in euro area bonds, by presenting preliminary evidence on the effect of ICMA CACs on Swedish sovereign bond yields. Our results show that single-limb CACs lower yields. Given the low number of bonds and short time series, caution is necessary in drawing conclusions from these results.

[41] This differential effect could be the result of differences in the investor base of dollar- and euro- denominated bonds (anecdotally, we have heard that dollar Swedish bonds are held by Asian institutions as part of their safe asset portfolios).

Appendix

Table 2: Country breakdown of matched CAC and no-CAC bonds

Country breakdown during data preparations				
Issuer	**All bonds with CAC provisions**	**Usable bonds with CAC provisions**	**CAC & No-CAC matched pair (loose matching)**	**CAC & No-CAC matched pair (tight matching)**
Austria	19	13	11	6
Belgium	23	21	15	5
Finland	12	12	10	8
France	34	27	24	12
Germany	53	44	43	28
Ireland	14	10	5	1
Italy	80	59	53	30
Netherlands	16	8	8	6
Portugal	11	9	5	1
Spain	35	32	27	18
Total	297	235	201	115

Note: The above table describes the evolution of country breakdown during data preparations. We perform the initial filtering using Bloomberg to retrieve the fixed or zero coupon euro-denominated medium- and long-term sovereign bonds issued by euro area governments between the introduction of Euro-CAC and 5th Sep. 2018. All filtered bonds from Bloomberg have CAC as a contractual provision. We further narrow down to the bonds with domestic law as flagged either by Bloomberg or Dealogic. In the last two columns, we show the number of pairs we form by matching the residual maturity of CAC and No-CAC bonds with two different limits.

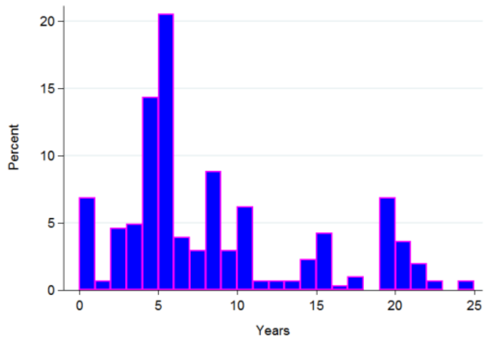
Table 3:

Sweden - Bonds included in the sample

CAC - single limb				
ISIN	**Issue date**	**Maturity date**	**Amount (bn)**	**Coupon**
US87020DBE31	15/02/2018	15/02/2021	3.00	2.375
XS1756338551	24/01/2018	24/04/2023	4.96	0.125
US87020DBC74	11/01/2018	15/02/2023	3.00	2.375
US87020DBB91	02/11/2017	02/11/2020	2.50	1.875
US87020DBA19	25/07/2017	25/07/2019	2.75	1.5
US87020DAZ78	06/04/2017	06/04/2020	2.00	1.625
CAC - traditional				
ISIN	**Issue date**	**Maturity date**	**Amount (bn)**	**Coupon**
US87020DAY04	21/10/2016	21/10/2019	3.00	1.125
US87020DAV64	05/10/2015	05/10/2018	1.00	1
US87020DAX21	08/09/2016	08/09/2021	2	1.25
US87020DAW48	15/03/2016	15/03/2019	2.00	1.125
US87020DAU81	13/05/2015	15/05/2018	2.25	1.125
US87020DAT19	24/03/2015	24/03/2020	2.00	1.625
US87020DAS36	16/03/2015	16/03/2017	1.50	0.75
XS1189262345	12/02/2015	12/02/2020	1.71	0.05
US87020DAR52	23/01/2015	23/01/2018	2.50	0.875
US87020DAQ79	13/11/2014	13/11/2017	3.00	1
US87020DAP96	19/09/2014	19/09/2016	2.00	0.625
XS1081254465	25/06/2014	25/06/2017	0.68	0.13
US87020DAN49	28/05/2014	15/08/2017	1.50	0.88
XS1062909384	02/05/2014	02/05/2019	3.12	0.75
US87020DAM65	25/03/2014	12/04/2017	2.00	0.75
XS0997474639	27/11/2013	27/11/2016	1.36	0.25
US87020DAL82	30/08/2013	15/11/2016	3.00	1.00
US87020DAK00	25/06/2013	15/01/2015	1.50	0.25
US87020DAJ37	13/05/2013	13/11/2014	1.50	0.25
XS0914804686	11/04/2013	11/04/2014	1.00	0.20
US87020DAG97	28/03/2013	29/03/2016	1.00	0.375
XS0899755226	14/03/2013	14/03/2015	1.00	0.17
XS0886063709	06/02/2013	06/02/2014	1.00	0.20
XS0882814386	31/01/2013	31/01/2018	5.43	0.875
US87020DAC83	29/10/2012	22/12/2015	1.00	0.38
US87020DAB01	18/05/2012	18/05/2015	2.25	0.38
XS0747754892	20/02/2012	20/02/2015	1.99	0.63
XS0670833853	02/09/2011	02/09/2013	1.42	0.875
US87020DAA28	03/06/2011	03/06/2014	1.50	1
XS0610298936	25/03/2011	30/09/2013	2	1

Figure 1: Assessing the quality of the match between CACs and no-CACs bonds: Original maturities

Full loose sample



Pre-2015 loose sample

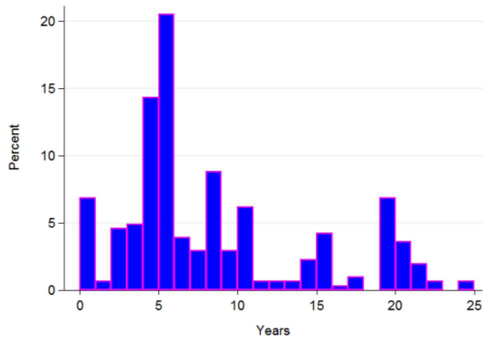
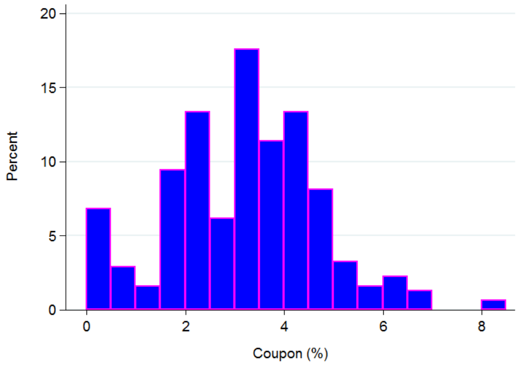
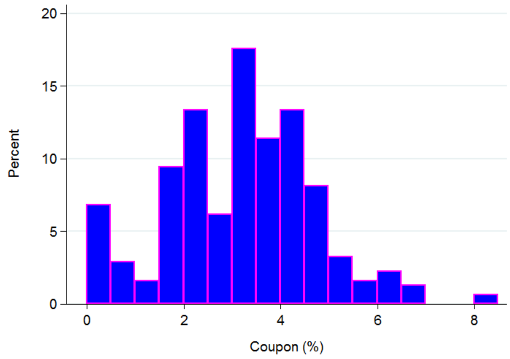


Figure 2: Assessing the quality of the match between CACs and no-CACs bonds: Coupons

Full loose sample



Pre-2015 loose sample



List of variables included in the analysis

Variable	Sources
CAC provisions	Bloomberg
Weekly secondary market yield (in bps)	Bloomberg
Duration	Bloomberg
Bid-ask spread	Bloomberg
Credit rating	Bloomberg
Euro area 10-year government bond yield	Bloomberg
Total government debt securities	ECB
Net purchases of debt securities under the PSPP (Public Sector Purchase Programme) in % of total goverement debt securities	Haver Analytics
Holdings of debt securities under the PSPP (Public Sector Purchase Programme) in % of total goverement debt securities	Haver Analytics
US policy rate	Haver Analytics
Swedish Central Bank total assets in % of GDP	Haver Analytics
Swedish stock market index	Haver Analytics

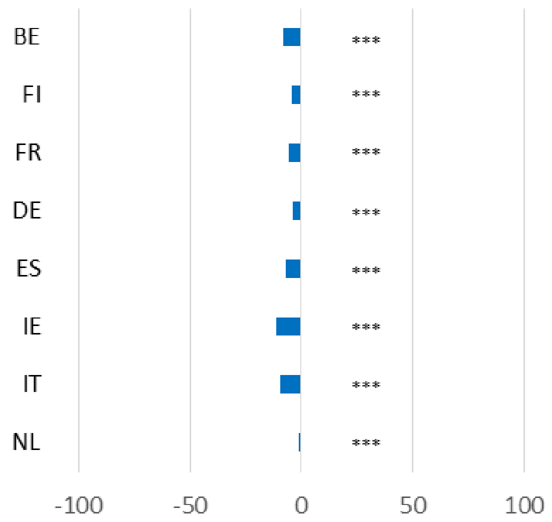
Table 4: Euro-CACs and sovereign yields

	Carletti et a. (2018)	Carletti et a. (2018)	Loose matching	Loose matching	Tight matching	Tight matching	Tight matching - Italy excluded
Euro area reference yield	1.008***	1.008***	1.154***	1.257***	1.082***	1.243***	1.283***
	(145.66)	(25.24)	(22.42)	(24.20)	(15.05)	(17.35)	(22.07)
Credit rating	-27.10***	-17.07***	-20.42***	-19.34***	-18.50***	-19.99***	-45.42***
	(-210.52)	(-13.76)	(-305.69)	(-35.99)	(-214.91)	(-25.10)	(-57.32)
Central bank bond holdings	-	-	1.291***	1.812***	1.184***	2.055***	2.810***
			(14.76)	(20.23)	(11.75)	(19.32)	(36.93)
Central bank flow purchases	-	-	50.78***	72.82***	86.53***	122.4***	25.81***
			(22.72)	(29.44)	(32.95)	(37.30)	(9.58)
Bond duration	14.80***	14.40***	14.96***	14.68***	18.37***	18.50***	15.76***
	(103.70)	(102.37)	(222.90)	(215.69)	(174.14)	(160.54)	(193.10)
Bond bid-ask	-1.621***	-2.146***	0.354***	0.132*	0.444***	0.306***	0.270***
	(-6.01)	(-8.16)	(4.40)	(1.70)	(5.64)	(3.93)	(3.58)
Collective action clause dummy	-10.83***	-6.410***	-5.300***	-4.450***	-3.725***	-4.141***	-2.257***
	(-10.86)	(-7.03)	(-14.07)	(-12.22)	(-8.24)	(-9.93)	(-6.51)
Country fixed effect	N	Y	N	Y	N	Y	Y
Weekly fixed effects	N	Y	Y	Y	Y	Y	Y
Numer of observations	12920	12920	55064	55064	30683	30683	22866
R-squared	0.889	0.906	0.892	0.899	0.897	0.907	0.939

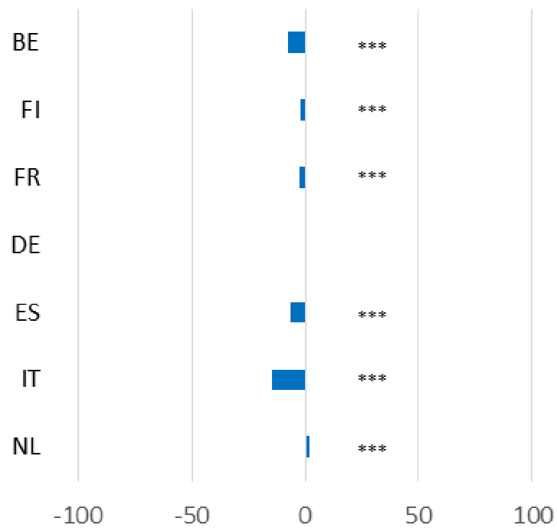
t statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Figure 3: Country-specific effects

Loose matching



Tight matching



Note: These figures plot the coefficient corresponding to the CAC variable for each of the country-specific regressions.

Table 5: Country-specific time varying effect

	Loose matching					
	2013	2014	2015	2016	2017	2018
Belgium	-4.987***	-8.384***	-6.882***	-8.819***	-8.738***	-6.427***
	(-3.55)	(-7.29)	(-6.77)	(-10.35)	(-11.13)	(-7.13)
Finland	4.994***	-0.612	-5.194***	-3.586***	-4.119***	-4.127***
	(6.25)	(-0.79)	(-4.92)	(-4.74)	(-8.60)	(-6.06)
France	-5.545*	-5.563***	-4.345***	-5.500***	-6.891***	-4.107***
	(-1.72)	(-5.15)	(-6.19)	(-9.29)	(-10.33)	(-6.00)
Germany	-4.921**	-7.508***	-2.766***	-1.496***	-2.036***	0.0657
	(-2.00)	(-5.66)	(-3.70)	(-2.77)	(-3.08)	(0.07)
Italy	-5.476**	-16.82***	-8.705***	-9.100***	-7.203***	-6.877***
	(-2.25)	(-9.38)	(-7.68)	(-10.52)	(-6.00)	(-3.99)
Netherlands	-14.48***	-2.175**	-0.711	2.897***	1.855*	1.212
	(-13.28)	(-1.98)	(-0.68)	(2.97)	(1.68)	(1.31)
Spain	0.412	-2.760**	-9.116***	-6.803***	-8.359***	-6.239***
	(0.17)	(-2.48)	(-9.06)	(-9.49)	(-11.80)	(-9.18)
All countries	-4.220***	-7.978***	-4.740***	-4.498***	-3.852***	-2.008**
	(-3.37)	(-9.76)	(-8.32)	(-8.59)	(-6.13)	(-2.25)

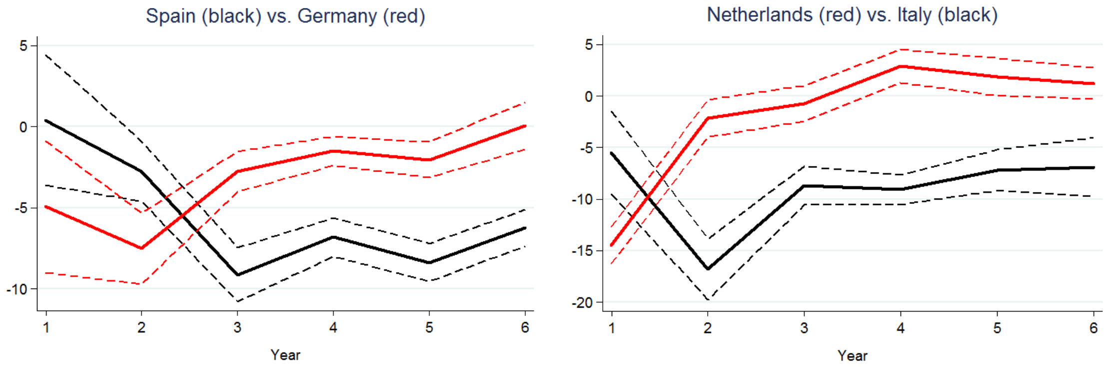
t statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Table 6: Country-specific time varying effect

	Tight matching					
	2013	2014	2015	2016	2017	2018
Belgium	-5.135***	-7.957***	-10.42***	-7.825***	-6.345***	-4.291***
	(-5.38)	(-7.21)	(-8.40)	(-9.11)	(-7.50)	(-4.93)
Finland	-0.180	-3.429***	-4.385***	-0.849	-1.982***	0.521
	(-0.22)	(-3.35)	(-4.92)	(-1.18)	(-5.91)	(1.01)
France	-12.76***	-1.521	-3.893***	-1.174*	-2.866***	-0.558
	(-3.30)	(-0.79)	(-4.78)	(-1.69)	(-3.44)	(-0.64)
Germany	-5.822***	-1.750***	-1.891***	0.108	0.968***	2.309***
	(-15.10)	(-3.09)	(-5.99)	(0.37)	(3.27)	(5.68)
Italy	0.446	-15.34***	-16.07***	-12.88***	-14.01***	-13.26***
	(0.35)	(-13.28)	(-20.20)	(-22.43)	(-25.84)	(-16.61)
Netherlands	-10.75***	-2.271**	1.249	3.818***	4.822***	4.590***
	(-15.16)	(-2.25)	(1.58)	(4.42)	(3.37)	(5.05)
Spain	5.078**	-3.893***	-7.920***	-7.791***	-7.701***	-4.622***
	(2.20)	(-3.87)	(-8.87)	(-11.12)	(-10.79)	(-6.82)
All countries	-2.460**	-5.939***	-4.721***	-2.598***	-2.294***	-1.929*
	(-2.03)	(-7.60)	(-8.41)	(-4.85)	(-3.61)	(-1.78)

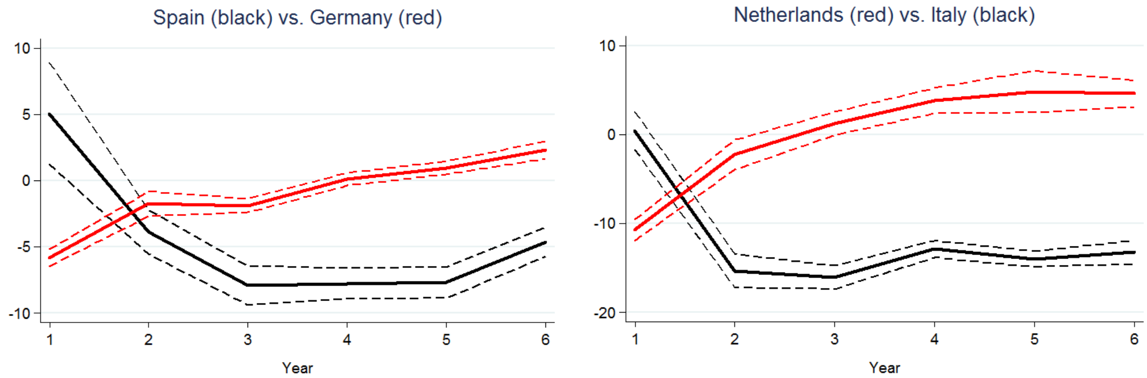
t statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Figure 4: Country comparison (loose matching)



Note: Yield time-varying effect

Figure 5: Country comparison (tight matching)



Note: Yield time-varying effect

Table 7: Traditional vs. Enhanced CACs in Swedish sovereign bonds. Post-2009 sample

	Post-2009 sample						
	Common effects	Common effects	Currency-specific effects	Currency-specific effects	Currency-specific effects	Only US Dollar	Only Eur
Bond duration	0.371***	0.391*	0.380***	0.270***	0.380***	0.239***	0.179***
	(40.10)	(1.80)	(42.10)	(16.59)	(7.60)	(23.70)	(15.00)
Bond bid-ask	-235.7***	-263.2***	-248.4***	-171.8***	-248.4***	1.031	-46.06***
	(-12.42)	(-11.13)	(-13.08)	(-9.37)	(-3.29)	(0.04)	(-2.95)
Central bank size (% GDP)	-373.1	-386.8*	-425.8	-0.611***	-425.8	0.237***	-1.187***
	(-0.97)	(-1.71)	(-1.11)	(-4.64)	(-0.93)	(4.13)	(-11.19)
US policy rate	6548.5	6781.7*	7467.4	69.69***	7467.0	89.56***	9.611***
	(0.98)	(1.73)	(1.11)	(28.01)	(0.93)	(61.43)	(4.65)
Stock market index	0.213	0.220*	0.242	0.0000424	0.242	0.00157***	-0.000791***
	(0.99)	(1.74)	(1.13)	(0.30)	(0.94)	(19.92)	(-5.86)
US dollar bond dummy	0.452***	0.434	0.462***	0.272***	0.462***		
	(34.70)	(1.25)	(35.81)	(7.42)	(4.68)		
Bond coupon	0.737***	0.322	0.668***	0.232***	0.668***	0.264***	0.184***
	(43.17)	(1.22)	(43.37)	(5.13)	(7.77)	(14.76)	(8.37)
Bond original maturity	-0.371***	-0.457	-0.363***	-0.332***	-0.363***	-0.0844***	-0.0982***
	(-37.48)	(-1.41)	(-36.95)	(-12.67)	(-5.52)	(-8.68)	(-6.03)
ICMA CAC dummy	-0.644***	-1.199*				-0.194***	0.0632**
	(-20.84)	(-1.94)				(-7.98)	(2.00)
ICMA CAC dummy - Euro			-1.245***	-0.675***	-1.245***		
			(-20.51)	(-11.64)	(-5.96)		
ICMA CAC dummy - Dollar			-0.534***	0.877***	-0.534***		
			(-21.36)	(6.30)	(-4.15)		
Bond-level effect	N	Fixed	N	Fixed	Random	N	N
Weekly fixed effects	Y	Y	Y	N	Y	N	N
Numer of observations	3653	3653	3653	3653	3653	2560	1093
R-squared	0.876	0.919	0.880	0.896		0.901	0.798

t statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Table 8: Traditional vs. Enhanced CACs in Swedish sovereign bonds. Post-2013 sample

	Post-2013 sample						
	Common effects	Common effects	Currency-specific effects	Currency-specific effects	Currency-specific effects	Only US Dollar	Only Eur
Bond duration	0.337***	1.206***	0.349***	0.214***	0.349***	0.233***	0.123***
	(34.56)	(3.29)	(36.48)	(6.96)	(7.80)	(22.98)	(12.04)
Bond bid-ask	-328.0***	-382.1***	-339.8***	-319.6***	-339.8***	3.373	64.99
	(-17.39)	(-12.94)	(-18.13)	(-9.69)	(-5.84)	(0.10)	(1.24)
Central bank size (% GDP)	-285.4	-421.4	-368.1	-1.003***	83.58	0.152*	-1.418***
	(-0.51)	(-1.54)	(-0.68)	(-4.51)	(0.62)	(1.94)	(-14.60)
US policy rate	4548.6	6817.7	5855.3	62.56***	0	95.63***	9.650***
	(0.51)	(1.58)	(0.69)	(17.38)	(.)	(60.68)	(6.11)
Stock market index	0.105	0.164*	0.134	-0.000518***	0.134	0.000576***	-0.000835***
	(0.53)	(1.70)	(0.70)	(-3.31)	(0.61)	(4.03)	(-5.01)
US dollar bond dummy	0.637***	1.721***	0.668***	0.185***	0.668***		
	(32.93)	(2.94)	(34.52)	(3.53)	(5.40)		
Bond coupon	0.682***	1.196***	0.594***	0.0728	0.594***	0.295***	0.175***
	(33.75)	(2.74)	(31.54)	(1.25)	(7.30)	(8.16)	(5.01)
Bond original maturity	-0.271***	-1.596***	-0.259***	-0.161***	-0.259***	-0.0846***	-0.122***
	(-27.81)	(-2.92)	(-27.26)	(-3.11)	(-4.45)	(-8.24)	(-4.58)
ICMA CAC dummy	-0.513***	-3.550***				-0.211***	0.220***
	(-17.42)	(-3.38)				(-7.51)	(6.15)
ICMA CAC dummy - Euro			-1.082***	-0.513***	-1.082***		
			(-17.89)	(-5.61)	(-7.07)		
ICMA CAC dummy - Dollar			-0.397***	1.668***	-0.397***		
			(-16.36)	(6.22)	(-3.48)		
Bond-level effect	N	Fixed	N	Fixed	Random	N	N
Weekly fixed effects	Y	Y	Y	N	Y	N	N
Numer of observations	2951	2951	2951	2951	2951	2111	840
R-squared	0.898	0.925	0.902	0.905		0.886	0.807

t statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01

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