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Othman Bouabdallah, Pascal Jacquinot,
Valeria Patella

Monetary/fiscal policy regimes in post-war Europe

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Abstract

In most euro area countries, the monetary/fiscal policy mix is responsible for the changing history of debt and inflation facts. Using a Dynamic Stochastic General Equilibrium model with Markov-switching policy rules, we identify three distinct monetary/fiscal regimes in France and Italy: a Passive Monetary-Active Fiscal regime (PM/AF) before the late 80s/early 90s; an Active Monetary-Passive Fiscal regime (AM/PF) with central bank independence and EMU convergence; a third regime with policy rates at the effective lower bound combined with fiscal active behaviour to sustain the recovery. Our simulations reveal that the PM/AF regime in France led to price volatility and debt stabilisation, while the AM/PF regime resulted in disinflation and rising debt trajectory. Meanwhile, Italy's procyclical fiscal policy in downturns contributed to persisting imbalances, high aggregate volatility, and low growth.

Keywords: Monetary-Fiscal policy mix, euro area, Debt, Inflation, Markov-switching

JEL Codes: E63, E62, E32, E52, C32

Non-technical summary

The recent COVID-19 crisis hit the economy in an environment of low interest rates and high debt levels at the global level. Central banks have adopted extraordinary measures, and the role of fiscal macroeconomic stabilisation has been restored to jumpstart recovery. This motivated an increased interest in the future of monetary/fiscal policy interaction, where the threat of fiscal dominance to central bank independence has been a major concern. Renewed emphasis has been put on whether short-run primary balances are consistent with the sustainability of public debt and whether central bank independence and its ability to control inflation can be preserved. Both controversial issues depend on the monetary-fiscal policy mix in place, the equilibrium dynamics it generates to determine debt and price levels, and the expectations agents form over future policy interaction behaviour.

While the US policy interaction has been largely studied, euro area countries provide each a different story for the monetary/fiscal policy mix, whose convergence process is much more complex to track and might have yet to be completed. We take Italy and France as countries with high debt levels and different fiscal and monetary policy histories to build empirical evidence on policy regimes, generate model-based simulations, and formulate scenarios based on agents' beliefs about the future of the policy mix.

We estimate a Dynamic Stochastic General Equilibrium model on a long history of post-war fiscal and monetary facts for Italy and France. Markov-switching policy rules generate monetary/fiscal policy regimes, where we account for the shifts to the common currency and the effective lower bound. Using the terminology by (Leeper, 1991), we find that a Passive Monetary-Active Fiscal policy mix regime (PM/AF) prevailed up to the late 80s/early 90s, switching to an Active Monetary-Passive Fiscal policy mix (AM/PF) with central bank independence, fiscal backing, and EMU convergence. Our simulations reveal that the PM/AF regime in France led to price volatility and debt stabilisation, while the AM/PF regime resulted in disinflation and rising debt trajectory. Meanwhile, Italy's procyclical fiscal policy in downturns contributed to persisting imbalances, high aggregate volatility, and low growth. Since 2009, the monetary policy has been constrained by the ELB and has been sustained by active fiscal behaviours. We consider this state a third regime where the ELB imposes a deterministic constraint, and the fiscal behaviour is estimated.

Stochastic simulations of monetary, fiscal, demand, and supply shocks highlight relevant dynamic features within each regime. In France, an expansionary expenditure shock triggers price and GDP increases more significantly under the PM/AF regime, partially controlled by interest rates, leading to drops in real rates and debt contraction. Differently, the AM/PF regime predicts a lower impact on output as agents expect monetary policy will react by increasing interest rates, thus limiting its effect on consumption, growth, and prices. In this configuration, real rates remain almost unchanged, with a substantial debt build-up. A tightening monetary shock, instead, is recessionary and generates increases in real rates and long-run debt accumulation under all regimes. The effect on inflation is compelling in a regime-specific perspective and reconciles with the *stepping on a rake* mechanism. When the fiscal authority is leading, the monetary policy shock backfires. This is because the increase in the real cost of debt and the associated recession make the debt burden larger, calling for an increase in inflation.

In Italy, instead, procyclical fiscal policy explains increasing and persisting imbalances, especially under the PM/AF regime. Indeed, expectations of the stepping-on-a-rake effect already matter in the AM/PF regime, where monetary policy shocks increase real rates, future debt, and inflation through the expected transition to the PM/AF regime. On the other hand, fiscal shocks are more persistent and destabilizing in the PM/AF regime. Procyclicality in discretionary expenditure amplifies fluctuations, contributing to further accumulating debt than in the AM/PF regime, both in the face of short-term and long-term expenditure shocks.

Simulated scenarios on policy credibility are built to quantify the role of agents' beliefs in model dynamics. They show that if agents believe the transition to the AM/PF regime is more likely to realise, they behave already in the PM/AF regime as if they were in AM/PF. Hence, the credibility of announcing a different policy can significantly affect the efficacy of the current policy stance. At last, we also build a second set of simulated scenarios where agents face uncertainty about the AM/PF regime duration while observing the regime in place in each period. We model this behaviour as a learning mechanism, where agents cannot precisely infer whether the AM/PF regime is a short- or long-lasting phenomenon. It results that agents' learning leads to a gradual adjustment to the change in regime after the shift dates.

1 Introduction

The recent pandemic hit the economy in an environment of low interest rates and high debt ratios. Central banks have adopted extraordinary measures, and the role of fiscal macroeconomic stabilisation has been restored to jumpstart recovery. This macroeconomic environment may be perceived as a threat to central bank independence. Since then, the macroeconomic context has changed, with high levels of inflation bringing back standard monetary operations and questioning the role of fiscal policy. The key policy trade-offs and emerging risks depend on the monetary/fiscal policy mix in place and on the credibility it inspires to determine inflation expectations, hence real rates and debt sustainability (see Sims (1994), Cochrane (1998)).

While the US reflects a clear history of prevailing policy regimes as a dynamic interaction between a single monetary authority and one fiscal authority (see Davig and Leeper (2006), Bianchi and Melosi (2017)),[1] European countries feature a process of institutional convergence that is much more complex to track and is yet to be completed. The monetary union has defined a special case of institutional framework formalized by the Maastricht treaty. A single common - credible and independent - central bank targets aggregate inflation, and European fiscal rules discipline multiple independent fiscal policies implemented at the member level. This design has provided a new form of policy interaction where the European Central Bank (ECB) acts on its price mandate, and different fragmented fiscal authorities take inflation as given.[2]

Motivated by the evolving policy framework in the euro area, we study the history of monetary-fiscal policy interactions since the 50s for Italy and France as cases of high fiscal imbalances with different fundamentals. By estimating a Dynamic Stochastic General Equilibrium (DSGE) model with Markov-switching monetary and fiscal policy rules, we build empirical evidence on policy regimes, generate model-based simulations, and formulate scenarios for policy credibility.

We interpret the policy behaviour in terms of active/passive monetary or fiscal policy (Leeper, 1991), where policy regimes arise because of Markov-switching changes in the policy mix in the spirit of Bianchi and Ilut (2017). We identify an Active Monetary-Passive Fiscal Policy mix (AM/PF) as a regime where the central bank controls inflation and the fiscal authority passively accommodates by adjusting primary surpluses to debt. In this regime, fiscal imbal-

[1] The US history shows that low debt-to-GDP ratio is consistent with high inflation and low real interest rates, even with primary deficits (US pre-Volker era), while high debt arises typically in economic environments of low inflation and primary surpluses. These facts are well rationalised through the lens of policy interactions.

[2] See Reichlin, Ricco and Tarbé (2023) for an empirical treatment of the special institutional setting introduced with the EMU regarding aggregate versus national determination of fiscal and monetary outcomes.

ances are backed by fiscal adjustments. A passive monetary-active fiscal policy mix (PM/AF) is then a regime where the fiscal authority is not constrained by its budget balance and the monetary authority allows inflation to stabilise debt.

In these two policy interaction frameworks, inflation and debt are determined uniquely. Fiscal and monetary behaviours generate recurrent regimes of policy interaction, with general equilibrium implications for growth, debt, and inflation. Agents form expectations considering the probabilistic distribution over future regime changes (Bianchi, 2013).

We also introduce the effective lower bound (ELB) as a deterministic monetary state with nominal interest rates set at zero, over which we estimate the behaviour of the fiscal authority. This practically imposes a particular type of monetary behaviour, where the central bank cannot use standard measures to adjust to inflation variations.[3]

Our empirical results draw a narrative of policy interaction strategies for the two countries in post second world war era. In both, a PM/AF regime describes the first period of sustained growth, the run-up of inflation, primary deficits, and low fiscal imbalances. It switches to AM/PF with the convergence to the monetary union, defined on the principle of a rigid separation between a central bank committed to inflation and fiscal authorities disciplined by European rules. This switch in France preceded that in Italy because the ERM semi-pegged system accommodated by Mitterand's fiscal consolidation initiated the transition in 1987. Our simulations reveal that the PM/AF regime in France led to price volatility and debt stabilisation, while the AM/PF regime resulted in disinflation and rising debt trajectory. Meanwhile, Italy's procyclical fiscal policy in downturns contributed to persisting imbalances, high aggregate volatility, and low growth. Later, the ELB constrained the ECB action, leading to an immediate switch in France to active fiscal behaviour to stimulate demand and exit the deflationary trap. In Italy, austerity measures under Monti's Government postponed the switch to active fiscal to the end of the sovereign debt crisis.

Relevant within-regime dynamics emerge by simulating fiscal, monetary, demand, and supply shocks in the two economies. In France, an expansionary expenditure shock triggers price and GDP increases under the PM/AF regime, which is partially controlled by interest rates, leading to drops in real rates and debt contraction. In contrast, the AM/PF regime predicted less inflationary pressure. Agents expect the shock to be covered in the future by opposing variations, thus limiting its effect on consumption, growth, and prices. The interest rate rises,

[3] We also estimate the model by introducing the ECB shadow policy rate after the ELB becomes binding, to account for the total accommodation provided by both conventional and unconventional policies (Krippner (2013), Wu and Xia (2016)). This exercise has not significantly changed our results, thus validating them.

while real rates remain almost unchanged, with a substantial debt build-up. Instead, a monetary contraction is recessionary and generates increases in real rates and long-run debt accumulation under all the regimes. The effect on inflation is compelling from a regime-specific perspective and reconciles with stepping on a rake mechanism (Sims, 2011). When the fiscal authority is leading, the monetary policy shock backfires. This is because the increase in the real cost of debt and the associated recession increase the debt burden, calling for an increase in inflation. Finally, a positive preference shock generates real economic expansion and an initial increase in inflation across all regimes. However, under a PM/AF regime, this initial inflationary effect was followed by a drastic drop. This is because expansion determines the reduction in the fiscal burden, which is deflationary.

In Italy, a procyclical fiscal policy explains the increasing and persisting imbalances, higher aggregate volatility, and low growth, especially under the PM/AF regime. Expectations about stepping on a rake effect already matter in AM/PF, where monetary policy shocks increase real interest rates, future debt, and inflation through the expected transition to the PM/AF regime. However, fiscal shocks are more persistent and destabilising in PM/AF. Indeed, procyclicality in discretionary expenditure amplifies fluctuations, contributing to further debt accumulation than in the AM/PF regime. This is also the case for the preference shock, which, while boosting demand and prices, also increases expenditure and inflates debt evaluations after a few periods.

Simulated scenarios on policy credibility are then built to quantify the role of agents' beliefs in model dynamics. They show that if agents believe the transition to the AM/PF regime is more likely to realise, they behave already in the PM/AF regime as if they were in AM/PF. Hence, the credibility of announcing a different policy can significantly affect the efficacy of the current policy stance. At last, we also build a second set of simulated scenarios where agents face uncertainty about the duration of the AM/PF regime - while still observing the regime in place in each period. We model this behaviour as a learning mechanism, where agents cannot precisely infer whether the AM/PF regime is a short- or long-lasting phenomenon. It results that agents' learning leads to a gradual adjustment to the change in regime after the shift dates.

The remainder of this paper is organised as follows. Section 2 reviews the literature, and Section 3 recovers relevant stylised facts for monetary and fiscal policy historical regularities in the French and Italian data. The model is presented in Section 4. Section 5 provides the estimation results, extracts policy regimes, interprets stochastic simulations, and builds scenarios on policy credibility and agent uncertainty. Section 6 concludes.

2 Literature Review

This study relates to three strands of the literature. First, the Fiscal Theory of the Price Level (FTPL) explains fiscal inflation (Sims, 2011). Following the seminal contribution of Sargent and Wallace (1981), various studies (Sims (1994), Woodford (1994, 1995, 2001)) placed fiscal policy in coordination with the monetary authority. Leeper (1991) defines the conditions for the uniqueness and existence of model solutions under combinations of policy regimes.[4] The latter have been studied both in isolation (Cochrane (1998, 2001), Bhattarai, Lee and Park (2012)) and within a unified general equilibrium framework of power imbalances between two policy authorities (Fragetta and Kirsanova (2010), Davig and Leeper (2011), Bianchi and Melosi (2017)).

While the empirical validation of the FTPL is well established for the US, it is not fully explored for European countries. Reichlin, Ricco and Tarbé (2023) explains how the European special institutional setting determine aggregate/domestic fiscal and monetary outcomes. Kliem, Kriwoluzky and Suarez (2016) elect the central bank independence process as a turning point between monetary-fiscal policy regimes. Jarociński and Maćkowiak (2018) and Bianchi, Melosi and Rogantini-Picco (2022) study policy interaction in the EMU using a two-country DSGE model.[5] We inherit the general equilibrium approach within a closed economy framework to cover the long mixed history of Treasury-Central Bank agreements, monetary policy independence, and the growing fiscal instability of the two European economies.

Second, we build upon the empirical literature on the interaction between monetary and fiscal feedback rules. Based on the seminal work by Bohn (1998), several works have estimated fiscal rules in isolation to test debt sustainability (see Bohn (2008), Canzoneri, Cumby and Diba (2011) for the US; Melitz (2000), Mendoza and Ostry (2008), Ghosh et al. (2013), Mauro et al. (2015) for a panel of advanced and emerging economies; Favero and Monacelli (2005) and Paniagua, Sapena and Tamarit (2017) in nonlinear settings).[6] Davig and Leeper (2006) introduces the simultaneous consideration of a monetary policy rule. However, such reduced-form estimates are subject to a simultaneity bias arising from failing to bring the forward-looking nature of nominal debt valuation (Leeper and Li, 2017). We use a fully specified DSGE framework to account for the general equilibrium determination of fiscal/monetary policy mix

[4]See also Barthélemy and Marx (2017) and Barthélemy and Marx (2019) for more details.

[5]See Corsetti et al. (2019) for a review of standard business cycle models to formulate lessons for business cycle stabilisation policy in the euro area. They suggest that a joint accommodative behaviour of monetary and fiscal policies is necessary for macroeconomic stabilisation when a large adverse disturbance occurs.

[6]see D'Erasmo, Mendoza and Zhang (2016) and for an overview on fiscal rule estimation.

regimes.

Finally, our study borrows from the literature on the role of agents' beliefs over policy mix regimes. Markov-switching (MS)-DSGE models provide a good understanding of how agents' decision rules are affected by the degree of credibility of the changing policy stance (Sims, 1982). Agent's beliefs are relevant both within regimes and as a source of shifts over them (for monetary policy see Schorfheide (2005), Fernández-Villaverde, Guerron-Quintana and Rubio-Ramírez (2010), Liu, Waggoner and Zha (2011) and Foerster (2015, 2016); for the monetary/fiscal policy mix Davig and Leeper (2006, 2007), Bianchi and Ilut (2017) and Bianchi and Melosi (2017)). Moreover, Davig and Leeper (2007), Farmer, Waggoner and Zha (2009), Ascari, Florio and Gobbi (2020) show that MS models explain expanded regions of equilibrium determinacy through the role of expectations across regimes. We use this framework to simulate scenarios of agents' beliefs on the future of the policy mix.

3 Narratives on the policy mix

We present fiscal and monetary stylised facts for France and Italy by drawing a narrative over historical policy events characterizing the last few decades. Figure 1 and Figure 2 show the evolution of inflation, GDP growth, and nominal interest rates and that of the primary deficit-to-debt ratio as a measure of the fiscal stance (Sims, 2011), the debt-to-GDP ratio as an index of fiscal sustainability, and the ex-post real interest rate to measure the debt service cost.[7]

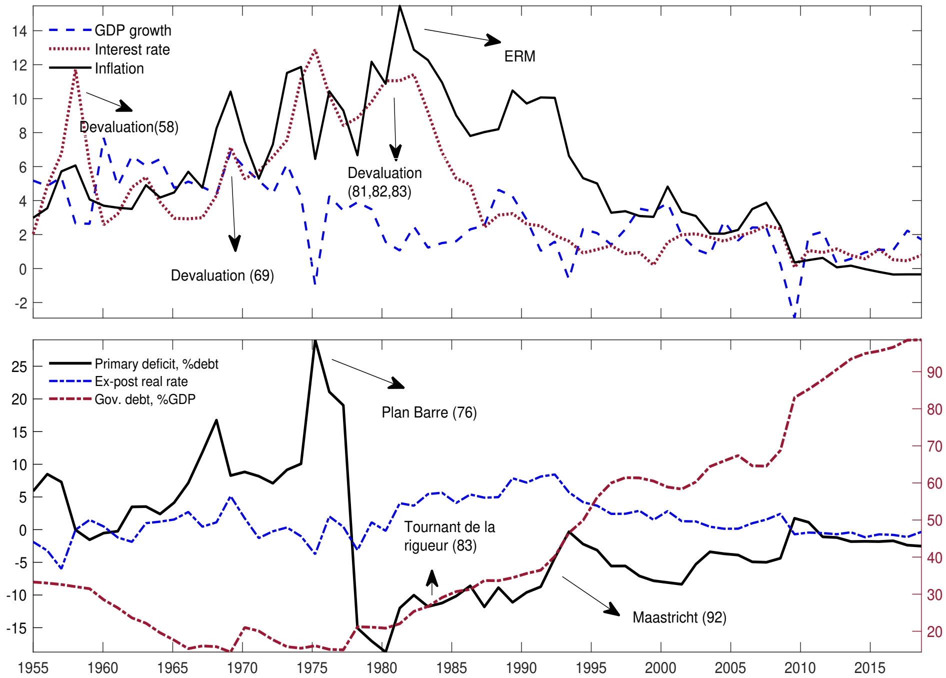
3.1 France

The history of the French monetary and fiscal phenomena can be recovered through identified policy behaviours and key events. First, during the 1955-1980 period a low debt-to-GDP ratio was driven by high inflation (inflation tax) and low real rates, despite the primary deficits. This is when devaluation events (1958, 1969) were used to boost growth and offset the lack of competitiveness. They were overheating the economy and feeding inflation. Monetary policy was conducted through quantitative controls on money and credit (Monnet, 2014).[8]

[7]In contrast to the debt-to-GDP ratio or debt growth, the primary deficit-to-debt ratio is not influenced by variables not controlled directly by the fiscal authority, such as output or the real interest rate. This measures debt growth net of the gross real interest rate and summarises the net payments to bondholders through interest rates or the retirement of bonds. Thus, a change in the deficit over debt measures a change in the fiscal authority's future liabilities.

[8]The French financial system was rigidly separated, mainly according to the maturity of the credit instruments and the type of participants. Strict regulations and barriers divide the financial market into three major segments: the money market (short-term), capital market (long-term), and mortgage market. Each segment was regulated by a different authority, with access to each segment restricted to well-defined participants. This mar-

Figure 1: France. Monetary and fiscal policy facts



The top panel displays French data for inflation, interest rate and GDP growth. The bottom plot displays the primary deficit-to-debt, the ex-post real interest rates, and the debt-to-GDP ratios. All series are collected at annual frequency spanning the period 1955-2019.

After the government of Charles de Gaulle (*Les Trente Glorieuses*), three policy attempts were made to face the 1974-75 recession and escape the inflation-depreciation cycle. First, a countercyclical fiscal stance translated into a significant deterioration of the fiscal balance in 1975-76. Faced with higher inflation and a sharp deterioration in fiscal and external imbalances, the government adopted an austerity package in the second half of 1976, the *Plan Barre*, resulting in higher inflation and deficits. The inflation peaked further with the second oil shock (1979, 1980). Later, in 1981-82, Mitterand launched the *politique de relance*, which, inspired by the Keynesian *Programme Commun*, implemented expansionary fiscal measures to boost global demand and reduce unemployment. The consequences on the external current account, fiscal imbalances, and inflationary pressures were negative. The franc was devaluated in 1981, 1982, and 1983.

Since early 1983, a major rethinking of French economic policy occurred (Artus et al., 1991). A broad adjustment program was adopted to eliminate the trade deficit within two years and

ket segmentation prevented the transmission of central bank operations, which affected reserves in the interbank market, to other financial sectors via interest rate movements. Monetary policy had to be implemented through quantitative credit allocations to control liquidity, as measures to influence interest rates would not have been fully effective and, in particular, would not have had the same impact on the different segments of the financial system.

bring the fiscal stance back into balance. This era of consolidating efforts went under the name *tournant de la rigeur* or austerity turn (Martin, Tytell and Yakadina, 2011). Profound changes also characterised the French monetary policy system: a quasi-fixed exchange rate under the ERM aimed at achieving nominal convergence with Germany.[9] A firm policy to uphold the external value of the franc with strict compliance to the ERM rules defined the *franc fort* or stable policy (external exchange rate targeting). Disinflation and exchange rate stability were achieved by 1987 (Smets, 2007), coinciding with an increase in real interest rates. This balanced policy mix was implemented in the context of growing financial integration, culminating in 1987 with the adoption of a monetary policy mechanism based on interest rate variations and liberalised credit markets.

However, the structural improvement of fiscal accounts was blunted by the adverse impact of the economic slowdown on revenue. Moreover, higher interest payments on the rapidly growing public debt offset the consolidation efforts made. As the 1997 deadline for the monetary union was getting closer, in 1994, the authorities adopted a five-year budgetary plan (Public Finance Programming Law), prepared to put France on a path toward meeting the fiscal convergence criteria set forth under the Maastricht Treaty. The Programming Law contributed to the government deficit's decline and the ensuing public debt stabilization. After that, in 1999, although adopting the common currency led to a period of low interest rates, the increased fiscal deficit combined with lower inflation put the debt-to-GDP ratio upward.

Subsequently, France was put under Excessive Deficit Procedures (EDP) during 2003-2007 to enforce a significant fiscal adjustment to reduce the general government deficit below 3% of GDP. With the global financial crisis in 2008, the ECB reacted by lowering interest rates up to the ELB and implementing Quantitative Easing. On the fiscal side, government deficits were high under Fillon and Hollande, despite the consolidation announcements (General Review of Public Policies).

We interpret these events as the result of changing fiscal and monetary policy behaviour, whose joint determination has differently described the recent decades of macroeconomic outcomes. Debt sustainability concerns are closely tied to inflation and the dynamics of real returns. In this respect, our study provides a framework for France's history of inflation and debt. The fiscal authority was leading from the 50s until inflation started declining, and exchange rate stability was achieved in the late 80s under the ERM pegged system. The consolidating Mit-

[9] As part of the EMS, the ERM was intended to reduce exchange rate variability and achieve monetary stability in Europe. The ERM relied on the concept of a fixed currency exchange rate in the European unit of account (ECU). Currency fluctuations were contained within a certain margin.

terand fiscal plans and those to sustain the EMU convergence accommodated the new leading conduct of the monetary authority, a principle that the Maastricht Treaty has formalized. This policy regime lasted until the Global Financial Crisis, when the large contraction in real activity prompted policymakers to take extraordinary monetary policy actions. The ECB cut the interest rates aggressively to reach the ELB. Since then, we have observed low real rates, deflation, and mounting debt ratios.

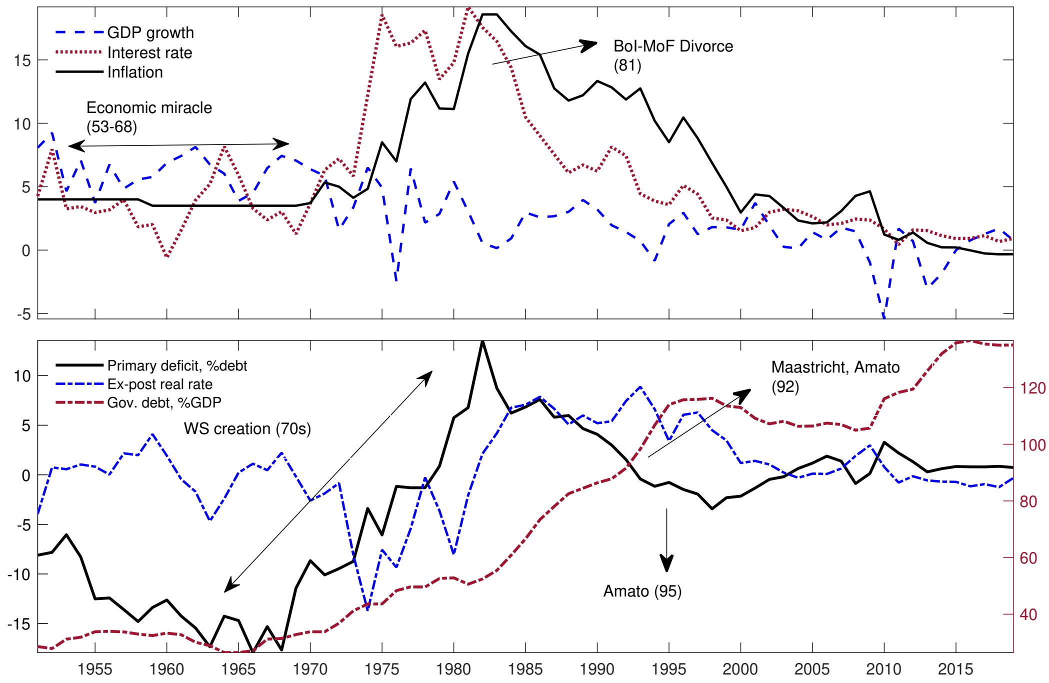
3.2 Italy

In Italy, the 1950s marked a period of sustained economic development (the economic miracle of 1953-68) in the context of monetary and fiscal stability. The choice of international opening, which introduced a salutary competitive stimulus into the economy, was consolidated by membership in the European Economic Community (1957) and lira external convertibility for non-residents (1958). The monetary policy instruments include discount rates, central bank advances, and credit controls. Periodically, excess liquidity is mopped up through bond issues. Since 1963, the Bank of Italy's official interest rates were implemented with a decree issued by the Treasury, and public debt was entirely monetised. A moderate fiscal stance and favourable macroeconomic environment led to a meager debt-to-GDP ratio.

The 1960s ended amidst severe economic difficulties. At the end of the Bretton Woods System (August 1971), the switch to a floating exchange regime and the sharp rise in oil prices ushered in several devaluation events of the lira and a long period of stagnation and inflation (stagflation). This is mainly an Italian phenomenon, pointing to domestic causes: severe labour market tensions (the so-called *autunno caldo* in 1969), a wage indexation mechanism (1975) resulting in a vicious wage-price circle, the creation of a welfare state (with an increase in public expenditure without a corresponding increase in revenue), and the lack of competition leading to balance of payments difficulties. In 1973, strict credit control measures (a ceiling on bank lending and portfolio constraints) and foreign exchange controls were introduced to sustain investment and domestic demand while containing rises in interest rates. However, the 1976 foreign exchange crisis forced the bank to make the lending ceiling more binding and tighten foreign exchange controls. The inflation peaked at 19.2% in 1980, dramatically impacting debt dynamics and fiscal imbalances. In 1979, Italy joined the EMS to stabilise inflation.

However, only the divorce between the Bank of Italy and the Treasury in 1981 marked the beginning of a gradual change in curbing inflationary pressures (Passacantando, 1996), in line with what had already occurred in other European countries and the US (Clarida,

Figure 2: Italy. Monetary and fiscal policy facts



The top panel displays Italian data for inflation, interest rate and GDP growth. The bottom panel displays the primary deficit-to-debt, the ex-post real interest rates and the debt-to-GDP ratios. All series are collected at annual frequency spanning the period 1950-2019.

Gali and Gertler, 1998). Divorce freed the central bank from the obligation to buy all unsold government securities in the market. Capital controls were dismissed in late 1983 when Governor Ciampi announced that the Bank of Italy would no longer consider total domestic credit as an intermediate monetary policy target. The real interest rates returned to positive values. Since then, monetary authorities have used outright and repurchase open-market operations in the secondary market as the primary operating tool for monetary intervention, marking a gradual transition from government-to market-oriented operations. With the introduction of an efficient auction system for issuing treasury bills and a functioning interbank deposit market, a true money market came into being. This happened in a framework of rapid technological changes and deep financial and currency liberalisation.

Although divorce marked a significant change in the institutional monetary setting, 1981 did not represent a sharp breaking point between regimes (Fratianni and Spinelli, 1997). The monetary reform was gradual and slow. The central bank did not immediately stop buying government securities in the primary market; neither did the Treasury immediately abandon the practice of setting base rates. The minimum purchase prices for government securities were eliminated in 1989. Between 1983 and 1986, the Bank of Italy adopted an intermediate monetary target to obtain disinflation and control inflation volatility.[10] Inflation declined to 6% in 1989, but the literature (see Gressani, Guiso and Visco (1988), Giavazzi and Spaventa (1990)) attributes this success to the real exchange rate appreciation obtained by anchoring the currency to the Deutsche Mark. Since 1988, participation in the *hard* ERM has enhanced the role of the nominal exchange rate, with the entrance of the lira in the ERM narrow band and the full liberalisation of short-term capital movements. Nominal interest rates have become an effective new intermediate target for monetary policy (De Arcangelis and Giorgio, 1998). Indeed, in the early 90s, money market interest rates were often used to guide capital flows and sustain currency, and an efficient money market was established in Italy. The fiscal authority did not support these changes toward monetary independence. An expansionary fiscal stance, coupled with an increase in interest rates, caused a veritable debt explosion (from 50 to 88% in 1980 and 1990) with further inflationary pressures and only partial and fragile economic rehabilitation. Italy achieved price stability but failed to control public finance (Bartoletto, Chiarini and Marzano, 2014).

The Bank of Italy became operationally independent in 1992 and started acting with an explicit aim to control inflation. In 1993, the Bank of Italy started to rely on an interest rate corridor delimited by two official interest rates (the discount rate and the rate on fixed-term advances). In February 1992, the Maastricht Treaty was signed, marking a turning point in fiscal policy (Paesani and Piga (2002), Balassone, Francese and Pace (2013)). The process of adjusting public finances to join the EMU in 1997 took place (reform Amato in 1992 and reform Dini in 1995), and explicit constraints on the public budget were introduced. During this phase, the collapse of the EMS semi-pegged framework and the return to managed floating allowed us to consider exchange rate devaluations as a relevant channel of monetary policy transmission. However, despite consolidation efforts, the EMS currency crisis and the risk premium required by the markets on the Italian bonds (Paesani and Piga, 2002) exposed the debt ratio to a peak of 114% in 1994.

The configuration of inflation targeting accommodated by the fiscal authority has characterised the entire period up to the global financial crisis, with low inflation, high real rates, and peaking debt-to-GDP ratios. In 2009, the policy rates hit the ELB, while the fiscal authority

[10]Monetary targeting was in line with the decisions of other European central banks that had already converted to the 1979 US switch to a monetary approach with the appointment of Paul Volker as the FED Chairman. This stance was widely perceived as the best strategy to reduce inflation differentials with Germany and other European countries.

pursued austerity measures until the end of the sovereign debt crisis in 2012.

4 The model

Our framework builds on a basic monetary DSGE model in the tradition of Lubick and Shorfeide (2004) and Clarida, Galí and Gertler (2010), augmented by Markov-switching policy rules capturing recurrent monetary/fiscal policy mix regimes (Bianchi and Ilut, 2017).

We consider a production economy subject to nominal rigidities à la Rotemberg (1982). Sticky prices introduce revaluation effects and channels for policy interactions, implying that monetary policy can influence real interest rates and, in turn, debt dynamics. We also introduce a maturity structure for government debt, external habits in consumption, and inflation indexation. Rules on tax revenues and government expenditure describe fiscal policy.[11] Monetary policy is described by an augmented Taylor rule, accounting for the switch to the monetary union and the ELB on nominal interest rates.

Policymakers' decisions - the monetary policy rule and tax rule - change between active and passive behaviours according to a two-state Markov-switching process, ξ^p, identifying policy mix regimes. They evolve according to the transition matrix H^p, as defined in Table 1, collecting transition probabilities across regimes. Since 2009, the monetary policy is constrained and set at the ELB.[12]

4.1 Agents and decision problems

The structure of the economy is as follows. A representative household consumes, saves, and supplies labour. The final output is assembled by a competitive final good producer who uses a continuum of intermediate goods manufactured by monopolistic competitors as inputs. Intermediate goods producers rent labour from households and set prices à la Rotemberg (1982). Finally, the central bank fixes the one-period nominal interest rate, while the government sets taxes and determines government expenditures.

Ten shocks hit the economy: a preference shock, a technology, a cost-push shock, and seven policy shocks (two monetary, five fiscal).

[11] The assumption of explicit rules for fiscal instruments reflects the last stabilisation measures privileging government expenditure adjustments more realistically (Leeper, Traum and Walker, 2017).

[12] This practically imposes a particular type of monetary behaviour, where the central bank cannot use standard measures to adjust to inflation variations.

4.1.1 Households

The representative household's preferences, logarithmic in consumption C_t and linear in labour h_t, are described by the following discounted flow β of period utilities:

$$\mathbb{E}_0\left\{\sum_{t=0}^{\infty}\beta^t e^{d_t}\Big[\log(C_t-\Phi C_{t-1}^A)-h_t\Big]\right\} \tag{1}$$

Preferences exhibit external habits defined on lagged aggregate consumption ΦC_{t-1}^A, where $\Phi \in [0,1)$ is the degree of habit formation. The preference shock d_t follows an AR(1) process: $d_t = \rho_d d_{t-1} + \sigma_d \varepsilon_t^d$.

Agents have access to two kinds of government bonds, differing in maturity: a one-period bond in zero net supply B_t^s and a long-period bond in non-zero net supply B_t^m.[13] Short- and medium-term bonds' prices are respectively given by P_t^s and P_t^m, and $R_t = \frac{1}{P_t^s}$ and $R_{t+1}^m = \frac{1+\rho P_{t+1}^m}{P_t^m}$ are the respective nominal interest rates. The price recursion for long-term bonds is defined as $P_{t+j}^{m-j} = \rho^j P_{t+j}^m$, where $\rho \in [0,1]$ controls the degree to which the maturity of bonds decreases and yields the average debt maturity of $(\beta\rho-1)^{-1}$. With P_t as the consumer price, households receive labour income $P_t W_t h_t$, pay lump-sum taxes T_t, gain profits from firms $P_t D_t$, and lump-sum government transfers TR_t. The nominal flow budget constraint for households is:

$$P_tC_t + P_t^mB_t^m + P_t^sB_t^s = P_tW_th_t + B_{t-1}^s + (1+\rho P_t^m)B_{t-1}^m + P_tD_t - T_t + TR_t \tag{2}$$

Then, the bond-pricing equations for short- and long-term securities are:

$$1 = \beta\mathbb{E}_t\left\{e^{d_{t+1}-d_t}\frac{u_c(t+1)}{u_c(t)}\frac{R_t}{\Pi_{t+1}}\right\} \tag{3}$$

$$1 = \beta\mathbb{E}_t\left\{e^{d_{t+1}-d_t}\frac{u_c(t+1)}{u_c(t)}\frac{R_{t+1}^m}{\Pi_{t+1}}\right\} \tag{4}$$

where $u_c(t) = C_t - \Phi C_{t-1}^A$ is the marginal utility of consumption and $\Pi_t = \frac{P_t}{P_{t-1}}$ is the inflation rate. Combining these two conditions, we derive the no-arbitrage condition $R_t = \mathbb{E}_t\{R_{t+1}^m\}$. Finally, the labour supply condition is $W_t = C_t - \Phi C_{t-1}^A$.

[13]The long-term bonds are modeled as a portfolio of infinitely many bonds, with weight along the maturity structure given by $\rho^{T-(t+1)}$ for $T > t$ (see Eusepi and Preston (2013) and Woodford (2001) for a detailed explanation).

4.1.2 Firms and price setting

The production sector is populated by a continuum of monopolistically competitive firms and perfectly competitive final goods producers. The first produce intermediate differentiated goods $Y_t(j)$ with $j \in [0,1]$, which are combined in a final good Y_t through CES technology, $Y_t = \left(\int_0^1 Y_t(j)^{1-\nu_t} dj\right)^{\frac{1}{1-\nu_t}}$, where $\frac{1}{\nu_t}$ is the time-varying elasticity of substitution for intermediate goods. The latter translates into a price markup shock $\mu_t = \frac{\kappa}{1+\iota\beta} \log\left(\frac{1-\nu}{\nu_t}\right)$, where $\kappa = \frac{1-\nu}{\nu\psi\Pi^2}$, ι controls the indexation to lagged inflation, ψ determines the degree of nominal price rigidity, ν and Π represent the steady-state levels of ν_t and Π_t, respectively. Finally, we assume an exogenous process for the markup shock $\mu_t = \rho_\mu \mu_{t-1} + \sigma_\mu \varepsilon_t^\mu$.

Intermediate firms are price takers in factor markets and price makers in the goods market. Given technology, profit maximisation yields the demand for intermediate inputs, $Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{\frac{1}{\nu_t}} Y_t$, where $P_t(j)$ is the price of intermediate good j and P_t the price of final goods. Intermediate producers operate under monopolistic competition and are endowed with the production technology $Y_t(j) = A_t h_t(j)^{1-\alpha}$, where labour is the only input, $\alpha \in (0,1)$ and A_t is the total factor productivity evolving according to a random walk with drift process $\ln(A_t/A_{t-1}) = \gamma + a_t$ with $a_t = \rho_a a_{t-1} + \sigma_a \varepsilon_t^a$. The parameter γ is the growth rate of the economy.[14] The labour demand is given by $W_t = \varphi_t(j)(1-\alpha)A_t h_t(j)^{-\alpha}$, where $\varphi_t(j)$ is the real marginal cost. Each firm j has monopolistic power in producing its variety and, therefore, solves the price-setting problem. To allow for the real effect of monetary policy, we introduce nominal rigidities à la Rotemberg (1982). Firms face a quadratic cost in adjusting their prices in the form of output loss:

$$AC_t(j) = \frac{\psi}{2}\left(\frac{P_t(j)}{P_{t-1}(j)} - \frac{\Pi_{t-1}^{j}}{\Pi^{\iota-1}}\right)^2 Y_t(j)\frac{P_t(j)}{P_t} \tag{5}$$

Each firm sets its price $P_t(j)$ to maximise the present value of future profits

$$\mathbb{E}_t\left\{\sum_{t=0}^{\infty} Q_t\left[\left(\frac{P_t(j)}{P_t}\right)Y_t(j) - W_t h_t(j) - AC_t(j)\right]\right\} \tag{6}$$

subject to the production function, labour demand, and price adjustment costs. $Q_t = \beta(c_t - \Phi c_{t-1})^{-1}$ is the marginal value of a unit of the consumption good. Firms face the same problem. Therefore, they choose the same price ($P_t(j) = P_t$) and produce the same quantity ($Y_t(j) = Y_t$, $\varphi(j) = \varphi_t$). After imposing the symmetric equilibrium, the optimal price-setting rule is given

[14] The economy is non-stationary as it grows at rate γ. We de-trend aggregate variables to guarantee stationarity. Given the variable X_t, we define the respective de-trended variable $\hat{X}_t = \frac{X_t}{A_t}$.

by:

$$\frac{1}{\nu_t}[1-(1-\alpha)\varphi_t] = 1-\psi\left(\Pi_t - \frac{\Pi_{t-1}^{\iota}}{\Pi^{\iota-1}}\right)\Pi_t - \frac{\psi}{2}\left(\Pi_t - \frac{\Pi_{t-1}^{\iota}}{\Pi^{\iota-1}}\right)^2\frac{\nu_t-1}{\nu_t}$$
$$+\mathbb{E}_t\left\{\beta\frac{C_t-\Phi C_{t-1}^A}{C_{t+1}-\Phi C_t^A}\psi\left(\Pi_{t+1}-\frac{\Pi_t^{\iota}}{\Pi^{\iota-1}}\right)\Pi_{t+1}\frac{Y_{t+1}}{Y_t}\right\} \quad (7)$$

Finally, using labor supply and demand schedules, we derive the real marginal costs $\varphi_t = \left(C_t - \Phi C_{t-1}^A\right)\frac{h_t}{(1-\alpha)Y_t}$.

4.1.3 Government

The government collects revenues from lump-sum taxes and sells nominal bonds to finance interest payments and expenditures, given the government's budget constraint $E_t + B_{t-1}^m(1+\rho P_t^m) + TP_t = P_t^m B_t^m + T_t$, where $P_t^m B_t^m$ is the market value of debt, T_t stands for tax revenues, E_t government expenditure. The shock TP_t captures changes in the maturity structure and the term premium and follows: $tp_t = \rho_{tp}tp_{t-1} + \sigma_{tp}\epsilon_t^{tp}$. Rewriting the government budget constraint in terms of the GDP ratio yields:

$$e_t + b_{t-1}^m\frac{R_t^m}{\Pi_t}\frac{Y_{t-1}}{Y_t} + tp_t = b_t^m + \tau_t \quad (8)$$

where $b_t^m = \frac{P_t^m B_t^m}{P_t Y_t}$, e_t, tp_t and τ_t are the GDP ratios. The government expenditure collects good purchases (G_t) and transfers: $E_t = P_t G_t + TR_t$. It can be divided into a short- and a long-term component: $e_t = e_t^s + e_t^L$. Short-term expenditure accounts for cyclical fiscal measures and follows:

$$e_t^S = \rho_{e^S}e_{t-1}^S + (1-\rho_{e^S})\left[e^S + \phi_y\left(\hat{y}_t - \hat{y}_t^n\right)\right]\sigma_{e^S}\varepsilon_t^{e^S} \quad (9)$$

where $\left(\hat{y}_t - \hat{y}_t^n\right)$ indicates the output gap, that is, the deviation of the actual output from its *natural* level prevailing in the absence of nominal rigidities, and ϕ_y is the parameter measuring the cyclicality of fiscal policy.[15] Long-term expenditure is assumed to capture large programs following political processes and is exogenous:

$$e_t^L = \rho_{e^L}e_{t-1}^L + \sigma_{e^L}\varepsilon_t^{e^L}$$

[15]The cyclicality of expenditure, namely the cyclicality of short-term expenditure vis-à-vis output gap, is a better indicator of the cyclicality of fiscal policy than budget balances because tax receipts are endogenous to the business cycle, and expenditure better reflects discretionary fiscal policy.

Moreover, we define the fraction of public expenditure devoted to government goods' purchases with $\chi_t = \frac{P_t G_t}{E_t}$, which in terms of GDP ratios becomes $\chi_t = \left(\frac{G_t}{Y_t}\right) e_t^{-1}$, where $\chi_t = \rho_\chi \chi_{t-1} + \sigma_\chi \epsilon_t^\chi$.

4.1.4 Monetary/Fiscal policy mix

We assume that the central bank behaves according to a modified Taylor rule, where we account for two key events in the history of euro area countries: the creation of the EMU in 1999 and the ELB for policy rates since 2009. Therefore, the monetary authority sets the short-term nominal interest rate R_t to adjust to inflation and output as follows:

$$\begin{aligned}\frac{R_t}{R}_{\text{pre-EMU}} &= \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{\Pi_t}{\Pi}\right)^{\psi_{\pi,\xi_t^p}} \left(\frac{Y_t}{Y_t^n}\right)^{\psi_{y,\xi_t^p}} \right]^{(1-\rho_R)} e^{\sigma_R \varepsilon_t^R} \\ \frac{R_t}{R}_{\text{EMU}} &= \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{\Pi_t^\omega \Pi_{rEA,t}^{(1-\omega))}}{\Pi}\right)^{\psi_{\pi,\xi_t^p}} \left(\frac{Y_t}{Y_t^n}\right)^{\psi_{y,\xi_t^p}} \right]^{(1-\rho_R)} e^{\sigma_R \varepsilon_t^R}\end{aligned} \quad (10)$$

where we consider the switch to the monetary union framework in 1999 by allowing ECB policy rates to react to euro area inflation.[16] The parameter ω measures the weight of domestic inflation in the EA inflation aggregate. During the EMU period, policy rates are also determined by inflation in the rest of the euro area, $\Pi_{rEA,t}$. The latter is assumed to be exogenous following an AR(1) process, $\Pi_{rEA,t} = \rho_{\Pi_{rEA}} \Pi_{rEA,t-1} + \sigma_{\pi_{rEA}} \varepsilon_t^{\Pi_{rEA}}$. The monetary policy shock ε_t^R has persistence ρ_R and size σ_R. R is the steady-state gross nominal interest rate.[17]

Monetary regimes are driven by ψ_{π,ξ_t^p} and ψ_{y,ξ_t^p}, capturing the interest rate's response to inflation and the output gap. The active monetary regime (AM) realises when the Taylor principle is satisfied, $\psi_{\pi,AM} > 1$, as opposed to a passive monetary (PM) regime, where $\psi_{\pi,PM} < 1$.

When the policy rates hit the ELB (since 2009), we introduce a deterministic state of constrained monetary policy for nominal interest rates:

$$\frac{R_t}{R}_{\text{ELB}} = \left(\frac{R_{t-1}}{R}\right)^{\rho_{R,I}} (1/R)^{(1-\rho_{R,I})\psi_I} e^{\sigma_I \varepsilon_t^R} \quad (11)$$

where the parameter $0 < \psi_I \leq 1$ controls the average interest rate, such that when $\psi_I = 1$ and

[16]Since we know the exact date for the creation of the EMU (1999), we do not search for it in the data (as in Ciccarelli and Rebucci (2006) and Weber, Gerke and Worms (2011)).

[17]We denote all variables in steady state without the time sub-index: given the general variable X_t, the respective steady-state level is indicated by X.

$\sigma_I = \rho_R, I = 0$, we obtain $R_t = 1$ and a zero net interest rate. The monetary policy shock at the ELB has $\rho_{R,I} = 0.1$ and $\sigma_I = \sigma_R/10$.

The fiscal authority sets tax revenues, τ_t, in response to debt and the output gap according to the following rule:

$$\tau_t = \rho_\tau \tau_{t-1} + (1-\rho_\tau)\Big[\tau + \delta_{b,\xi_t^p}(b_t - b) + \delta_y(y_t - y_t^n)\Big]e^{\sigma_\tau \varepsilon_t^\tau} \tag{12}$$

where ε_t^τ is the exogenous tax shock. The tax adjustment to debt, measured by δ_{b,ξ_t^p}, determines fiscal regimes. In a passive fiscal (PF) regime, the fiscal authority sets taxes to stabilise debt variations, $\delta_{b,PF} > \beta^{-1} - 1$, whereas when fiscal policy is active (AF), it behaves unconstrained, $\delta_{b,AF} < \beta^{-1} - 1$. If fiscal policy acts according to the former behaviour, when real debt rises, future surpluses rise by more than the net real interest rate with the change in debt to cover more than the debt service.

4.1.5 Market clearing

The model closes with the aggregate resource constraint, given by $Y_t = C_t + G_t$. This specification for the market clearing condition assumes that losses from quadratic adjustment costs are paid by intermediate goods producers and transmitted to households through distributed profits. Expressing the market clearing condition in terms of $g_t = \frac{1}{1-\frac{G_t}{Y_t}}$ yields:[18]

$$Y_t = C_t + Y_t\left(1 - \frac{1}{g_t}\right) \tag{13}$$

4.2 Solution and estimation methods

Since the technology process A_t exhibits trend growth, the model is rescaled before being linearized around the unique deterministic steady state. Indeed, the policy regimes enter only on variables expressed as deviations from steady states. We solve the model using the efficient perturbation methods applied to Markov-switching models elaborated by Maih (2015), and differently proposed also by Foerster et al. (2016).[19] A detailed description of the solution method is reported in Appendix D. The model's first-order approximated solution can be written in

[18] This specification of the market clearing conditions simplifies the log-linearized version of the model and translates into $\tilde{y}_t = \tilde{c}_t + \tilde{g}_t$, where the generic variable $\tilde{x}_t$ indicates percentage deviations, except variables in GDP ratios, which are in linear deviations.

[19] They differ in the fixed point around which they perform the Taylor series expansion. Foerster et al. (2016) expand around the steady state associated with the parameters' ergodic mean. The approach pioneered by Maih (2015), instead, uses the steady state associated with each regime taken in isolation. In our case, the regimes do not alter the steady state. Therefore, the two approaches would not differ.

the following form:

$$\Upsilon_t = T_{\xi_t^p}(\Upsilon_{t-1}, \chi, \epsilon_t) \tag{14}$$
$$T_{\xi_t^p} = T_{\xi_t^p}(z) + DT_{\xi_t^p}(z)(z_t - z)$$

where Υ_t is the vector of the model variables, $T_{\xi_t^p}$ the Taylor first-order expansion, χ defines the perturbation parameter, ϵ_t the vector of structural shocks and DT the matrix of first-order derivatives. The vector of model state variables is denoted by $z_t = (\Upsilon_{t-1}, \chi, \epsilon_t)$, where $z = (\Upsilon, 0, 0)$ identifies the expansion point. The above law of motion is combined with observation equations to build a state space system. The model is estimated with Bayesian methods to construct the parameters' posterior distribution. The likelihood is computed with a variant of the Kim filter, originally proposed by Kim and Nelson (1999).[20] The states' probabilities are extracted using the Hamilton (1989) filter instead. The obtained likelihood is combined with a prior distribution for the parameters, forming the posterior kernel. We first find the posterior modes and then use them as starting points to initialize the Metropolis-Hastings (MH) algorithm to sample from the posterior distribution. We generate two chains, each consisting of 100,000 draws (1 every ten draws is saved), with a burn-in period of 15% of them. The scale parameter is set to obtain an acceptance rate of around 35%. After running the MH algorithm, we perform diagnostics to ensure convergence of the MCMC chain.

5 Policy mix regimes

The model is estimated using eight post-war time series for France and Italy, collected at an annual frequency, spanning samples 1955-2019 and 1950-2019 respectively. These include real GDP growth, domestic GDP deflator inflation, euro-wide consumer price inflation, short-term interest rate, and four fiscal variables expressed as GDP ratios: government debt, tax revenues, government expenditure, and government purchases. Appendix E provides a detailed description of the data used and their mapping in the model.

For both economies, we calibrate the discount factor β to 0.9804, implying an annual real interest rate of 2%. We set the labour share at 66%, $\alpha = 0.33$, and the average maturity at five years, implying $\rho = 0.816$. To separate the short- from the long-term component of government

[20] In the regime-switching case, the Kalman filter cannot be used because the shocks' distributions are no longer Gaussian, being a mixture of Gaussians. Furthermore, they depend on the entire history of regimes. The exact distributions cannot be recovered, but the likelihood can be approximated through the Kim filter by truncating the mixture to contain only the Gaussians associated with a few regimes.

expenditure, we fix $\rho_{e^L} = 0.99$, and $\sigma_{e^L} = 0.001$, in line with Bianchi and Ilut (2017). Finally, we calibrate the steady-state value of inflation for the rest of the EA to its empirical average value, $\Pi_{rEA} = 1.1\%$ for France and $\Pi_{rEA} = 1.3\%$ for Italy.

Table 1 reports priors and posterior estimates for both economies. The former is set according to the following criteria. The priors for the Markov-switching policy parameters are asymmetric across regimes and follow Bianchi and Melosi (2017).[21] The steady-state parameters are centered at the country-specific empirical average value, except for debt-to-GDP, where we rely on the annual equivalent prior by Bianchi and Melosi (2017). We adjust their quarterly priors to the lower annual frequency for the consumption habit, the slope of the Phillips curve, and inflation indexation. The priors on shocks' persistence and standard deviations are relatively loose and uninformative.

The posterior estimates are displayed by country. The first panel shows the results for the regime-switching parameters. For both countries, the response of interest rates to inflation, ψ_π, is higher in the AM regime and lower in PM. Differences are less striking for the response to output, ψ_y, and even less for Italy. Regarding the response of taxes to debt, δ_b, we fix its value in the AF regime at 0, namely, imposing no responses of taxes on debt-to-GDP deviations. Instead, we leave it unconstrained in the PF regime, where, for both economies, the response is higher than the threshold value used to identify passive fiscal behaviour ($\beta^{-1} - 1 = 0.0171$). Moreover, under France's PF regime, taxes adjust more to debt than they do in Italy.

Regarding the other parameters, Italy features more aggregate shock volatility, less growth, and a procyclical fiscal policy. Indeed, while for France expenditure acts countercylical, it is procyclical for Italy, namely increasing in booms and decreasing in downturns ($\phi_y > 0$ for Italy). This result indicates that a procyclical discretionary policy fully offsets automatic stabilisers, in line with the empirical evidence presented by Aghion, Hemous and Kharroubi (2014) and Balassone and Kumar (2007).

Active and passive policy behaviours combine into three policy mix scenarios: an AM/PF regime; a PM/AF regime; an ELB monetary-active fiscal regime (ELB/AF). To link regime changes to historical accounts of the interaction of the monetary and fiscal authorities in France and Italy, Figure 3 plots the smoothed probabilities assigned to the three policy mix regimes, as defined in Section 4.

The three policy mix regions reconcile with the historical events presented in Section 2:

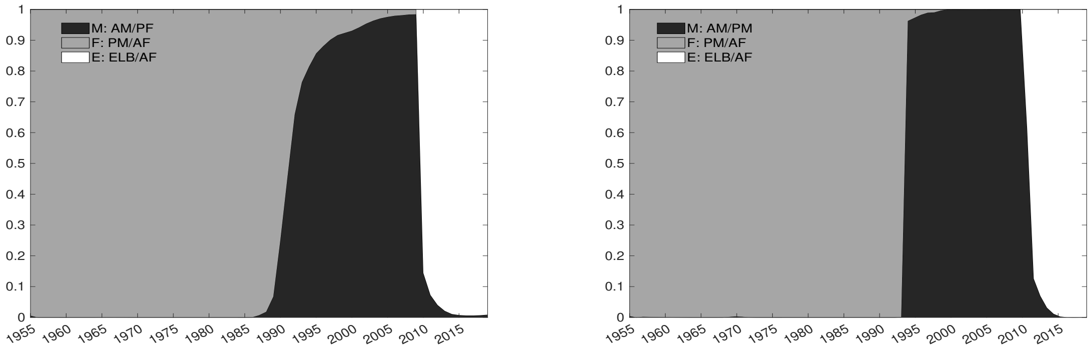
[21] Since Bianchi and Melosi (2017) use data at annual rate, the priors on the policy rules can be used without adjustments in our annual framework.

Table 1: Priors and Posteriors of the Model Parameters

	Prior Distribution			Posterior Distribution					
				France			Italy		
Parameter	Dist.	Mean	SD	Mode	Mean	90% CI	Mode	Mean	90% CI
$\psi_\Pi(AM)$, int-infl adj.	G	2.5	0.3	2.405	2.452	[2.17,2.75]	2.367	2.454	[1.99,2.94]
$\psi_\Pi(PM)$, int-infl adj.	G	0.8	0.3	0.628	0.715	[0.41,0.99]	0.781	0.796	[0.56,1.15]
$\psi_y(AM)$, int-out adj.	G	0.4	0.2	0.664	0.469	[0.09,1.01]	0.123	0.068	[0.02,0.24]
$\psi_y(PM)$, int-out adj.	G	0.15	0.1	0.118	0.140	[0.01,0.31]	0.028	0.050	[0.00,0.10]
$\delta_b(PF)$, tax-debt adj.	G	0.07	0.02	0.088	0.081	[0.02,0.17]	0.048	0.049	[0.01,0.09]
ψ_I, int-output adj.	B	0.95	0.02	0.959	0.949	[0.87,0.99]	0.962	0.940	[0.84,0.99]
δ_y, tax-output adj.	N	0.4	0.2	0.317	0.309	[-0.04,0.61]	0.258	0.269	[0.16,0.42]
ϕ_y, exp-output adj.	N	-0.4	0.2	-0.557	-0.565	[-0.84,-0.38]	0.189	0.198	[0.13,0.31]
$H^{F,M}$, prob. F to M	Dir	0.03	0.02	0.007	0.0067	[.0003,.0267]	0.003	0.006	[0.00,0.03]
$H^{M,F}$, prob. M to F	Dir	0.03	0.02	0.017	0.0106	[.0006,.0382]	0.012	0.012	[0.00,0.03]
B, ss debt-to-GDP	N	0.25	0.05	0.279	0.272	[0.16,0.43]	0.316	0.297	[0.22,0.37]
G, ss govt. purch.	N	1.29/1.18	0.05	1.280	1.279	[1.24,1.31]	1.179	1.173	[1.15,1.20]
T, ss taxes-to-GDP	N	0.26/0.2	0.01	0.314	0.300	[0.26,0.34]	0.208	0.201	[0.17,0.24]
$\ln(\Pi)$, ss inflation	N	0.05/0.06	0.01	0.023	0.0024	[-0.01,0.03]	0.024	0.035	[0.00,0.07]
$\exp(\gamma)$, ss growth	N	1.03	0.01	1.012	1.013	[0.99,1.03]	0.997	0.984	[0.97,1.01]
Φ, habit	B	0.2	0.1	0.604	0.617	[0.34,0.79]	0.890	0.882	[0.83,0.90]
κ, PC inclination	G	0.1	0.05	0.02	0.024	[0.006,0.05]	0.003	0.004	[0.001,0.011]
ι, Π indexation	B	0.2	0.1	0.333	0.337	[0.09,0.52]	0.302	0.274	[0.05,0.52]
ω, Π share	B	0.25	0.1	0.269	0.358	[0.11,0.75]	0.241	0.371	[0.06,0.606]
ρ_d, preference	B	0.5	0.2	0.799	0.799	[0.56,0.96]	0.920	0.919	[0.80,0.97]
ρ_χ, gvt purch/exp	B	0.5	0.2	0.982	0.975	[0.92,0.99]	0.926	0.909	[0.80,0.99]
ρ_{e^S}, ST exp.	B	0.2	0.05	0.230	0.210	[0.08,0.38]	0.250	0.255	[0.10,0.43]
ρ_{tp}, term premium	B	0.5	0.2	0.815	0.775	[0.56,0.91]	0.781	0.784	[0.67,0.86]
ρ_μ, price mark-up	B	0.5	0.2	0.565	0.592	[0.27,0.83]	0.358	0.413	[0.07,0.69]
ρ_r, monetary policy	B	0.5	0.2	0.443	0.484	[0.24,0.67]	0.702	0.635	[0.46,0.81]
ρ_a, technology	B	0.5	0.2	0.804	0.756	[0.57,0.92]	0.669	0.747	[0.46,0.87]
ρ_τ, taxes	B	0.5	0.2	0.961	0.957	[0.91,0.98]	0.931	0.928	[0.89,0.95]
$\rho_{\Pi_{rEA}}$, MP rest EA	B	0.5	0.2	0.877	0.882	[0.77,0.97]	0.954	0.915	[0.82,0.99]
σ_R, monetary policy	IG	1	1	1.748	1.901	[1.47,2.35]	1.179	1.259	[0.99,1.59]
σ_χ, gvt purch/exp.	IG	1	1	1.998	2.04	[1.69,2.39]	3.882	3.748	[3.07,4.17]
σ_τ, taxes-to-GDP	IG	1	1	0.697	0.794	[0.51,0.91]	0.792	0.798	[0.65,1.04]
σ_{e^S}, ST exp.	IG	1	1	0.447	0.444	[0.29,0.61]	0.845	0.816	[0.62,1.04]
σ_{tp}, term premium	IG	1	1	0.258	0.259	[0.20,0.34]	0.244	0.248	[0.18,0.36]
σ_a, technology	IG	1	1	1.393	1.376	[0.89,2.38]	5.983	5.995	[5.44,6.60]
σ_d, preference	IG	1	1	0.938	1.044	[0.58,1.37]	3.467	3.442	[2.59,4.18]
σ_μ, price mark-up	IG	1	1	0.523	0.491	[0.24,0.76]	0.662	0.584	[0.32,0.92]
$\sigma_{\Pi_{rEA}}$, mp rest EA	IG	1	1	1.463	1.522	[1.24,1.74]	1.912	1.933	[1.59,2.36]

The table reports the prior specification for model parameters (functional form, mean, standard deviation),and the posterior estimates (modes, means and 90% confidence intervals), for France and Italy. In the prior distribution specification, {G, N, B, IG, Dir} correspond to gamma, normal, beta, inverse gamma, and Dirichlet distribution, respectively.

Figure 3: Posterior States' Probabilities



(a) France (b) Italy

The figure shows the states' smoothed probabilities evaluated at the posterior mode of the model, associated to regimes {[M], [F], [E]}, for the two model economies.

a PM/AF regime covering the first period of sustained growth, high inflation, and low fiscal imbalances; an AM/PF regime describing the switch to the monetary union framework, with a rigid separation between the ECB controlling inflation and fiscal policies committed to debt adjustments; a regime of constrained monetary policy combined with active fiscal behaviour. The latter can be interpreted as a special case of PM/AF regime.

The timing of the regime shifts differs in the two countries to reflect substantial differences in their historical events. In France, from 1955 to the early 90s, a PM/AF regime marked the first years of steady economic and industrial development and policies of economic dirigisme (1955-75). Several devaluations (1958,1969) boosted growth, favouring competitiveness, while high inflation overheated the economy. Primary deficits and low debt-to-GDP ratios stimulated the economy while opening further fiscal space for sustainability. The PM/AF regime not only covers expansionary behaviours but also characterises disinflation attempts, as well as policies of external balance and nominal exchange rate stability (Plan Barre, 1976). In 1983, the monetary policy started pegging the exchange rate to Mark under the ERM to restore inflation and exchange rate stability via an external anchor in 1986-87 (Smets, 2007), when Mitterand fiscal consolidation accommodated the new monetary policy conduct. Since then, the monetary union convergence reinforced the transition to an AM/PF regime, in line with the institutional framework designed by the euro membership: the ECB acting on its price mandate and fiscal budgets set in compliance with a European plan of fiscal discipline - the Stability and Growth Pact (SGP) - created to operationalise the prohibition of excessive deficits. Low interest rates, sluggish growth, and debt accumulation describe this period until the global financial crisis.

Since 2009, the constrained state of monetary policy triggered a shift in the policy mix in which the fiscal authority turned from stabilising debt to stimulating the economy out of recession. This jointly determined a switch back to a regime of active fiscal behaviour. Under constrained monetary policy can be interpreted as a different regime of policy mix (ELB/AF). Active fiscal behaviour at the ELB is justified by the need for fiscal expansion to stimulate demand and exit the deflationary trap (Sims, 2016).

The results for Italy show that the low-frequency relationship between deficits and inflation is strongly related to the independence of monetary policy and its interaction with fiscal policy.[22] The narrative source relates the times of central bank monetisation of government debt to a PF/AM regime and the times of central bank independence backed by fiscal discipline to an AM/PF regime (Kliem, Kriwoluzky and Suarez, 2016). The switch to the AM/PF regime was realised a few years later with respect to France, when the divorce between the Bank of Italy in 1981 defined a significant change in the interaction between policy institutions, initiating an effective turn in the policy mix (Kliem, Kriwoluzky and Sarferaz, 2016). As supported by Fratianni and Spinelli (1997), this event did not represent a sharp breaking point between policy regimes. Indeed, inflation rates remained high, and the fiscal authority did not support the gradual independence of the central bank (Bartoletto, Chiarini and Marzano, 2013). The transition process lasted some years until the Bank of Italy became operationally independent in 1992, when, to comply with the Maastricht Treaty, the law forcing the monetary authority to act as a residual buyer at treasury bill auctions was abolished de jure. This coincided with a turning point in the conduct of fiscal policy (Paesani and Piga (2002), Balassone, Francese and Pace (2013)), and a process of adjustment of public finances to join the EMU in 1997 took place (reform Amato in 1992, and reform Dini in 1995).

Inflation targeting accommodated by the fiscal authority has characterised the entire period up to the global financial crisis, describing low inflation, high real rates, and peaking debt-to-GDP ratios. In 2009, the policy rates hit the ELB, while the fiscal authority kept pursuing austerity measures, especially when threatened by high market pressures following government Berlusconi in 2011 up to 2012 with government Monti. Only later, in 2012, a reversal in the policy mix determined a switch to active fiscal behaviour, where a vicious cycle of deflation, output contraction, and high debt was realised.

[22] Gaiotti and Secchi (2012) also documents a significant correlation between budget deficits, Treasury financing, and monetary base creation in the 1970s, meeting the definition of a PM/AF regime. They also found that the change in the monetary regime required the central bank's independence, in line with our results.

5.1 Policy mix transmission

The propagation of shocks in our model depends on the policy regime in place and the state variables of the economy. Stochastic simulations of policy and non-policy shocks, as shown in Figure 4 and 5, highlight relevant dynamic features within and across regimes. Specifically, impulse responses are computed conditionally for each policy regime prevailing over the entire horizon, but they continue to reflect the possibility of regime changes.

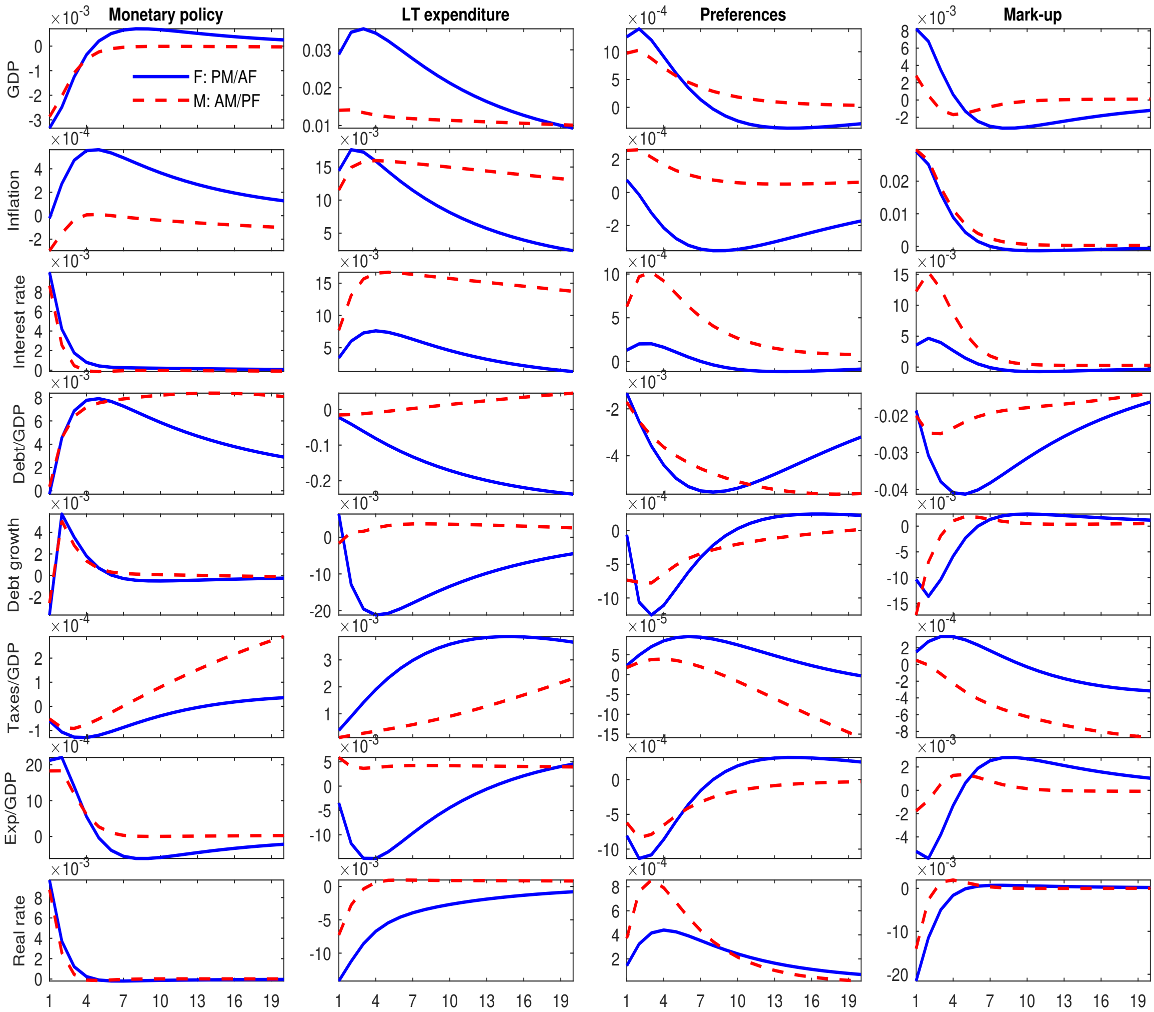
In France, a monetary contraction generates increases in real rates through sticky prices and long-run debt accumulation under all the regimes. In regime PM/AF, inflation increases, followed by a lagged expansionary effect. This result is in line with the stepping on a rake prediction of the FTPL (Sims, 2011). When the fiscal authority is leading, the monetary policy shock backfires: following an interest rate increase, spending increases due to a positive wealth effect, which then increases output and inflation. When the economy is in the AM/PF regime, the impulse responses to a monetary shock are in line with standard models of price determination: a monetary contraction leads to a decrease in output and inflation.

An expansionary long-term expenditure shock, financed by nominal debt, triggers expansion, increasing output, and inflation. Under the PM/AF regime, interest rate increases only weakly responding to higher inflation due to passive monetary policy. This leads to a drop in real rates and debt contraction. Indeed, the FTPL predicts that a positive fiscal shock, under no prospect that future taxes will rise, leads to a positive wealth effect, which increases spending and thereby inflation and output. The revaluation of government debt through higher inflation and the decrease in real rates stimulate further aggregate demand and real growth, ultimately generating a persistent drop in the debt-to-GDP ratio. Conversely, the AM/PF regime predicts almost no effects on output because agents expect fiscal policy to counteract the initial expansionary effects of the shock with future fiscal corrective adjustments (passive fiscal behaviour).[23] Given the Taylor principle, the central bank reacts more than one-to-one, thus limiting the shock's positive effects on consumption and growth. The interest rate rises and the real rates decrease less than in the PM/AF regime, contributing to an increasing debt-to-GDP response. This is a conventional Ricardian equivalence result.

A positive preference shock generates expansion and an increase in inflation under the AM/PF regime, in line with the standard predictions of new Keynesian models. However, under the AM/PF regime, the induced drop in the debt-to-GDP ratio was deflationary. The

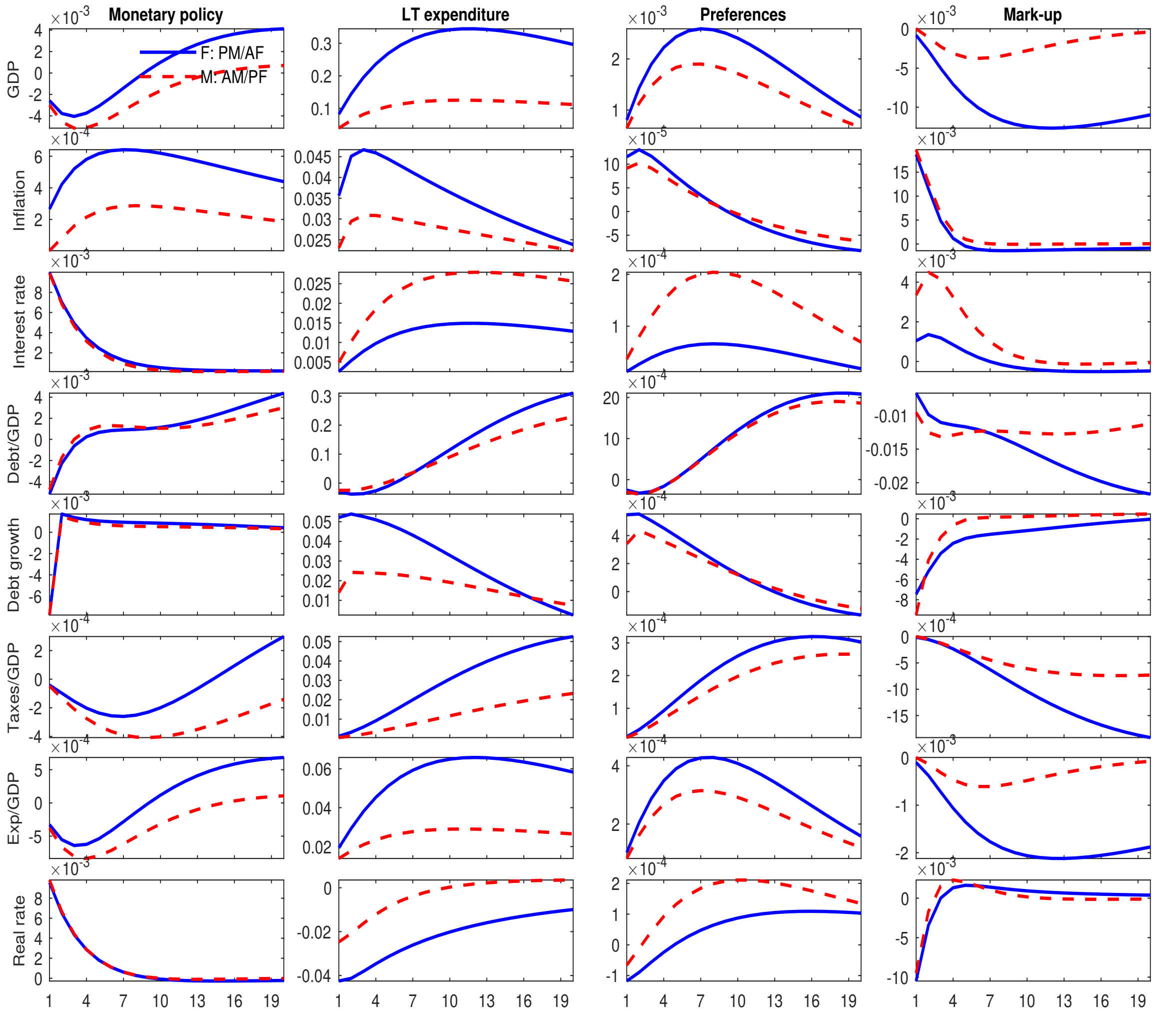
[23] In more technical terms, in the AM/PF regime changes in the real value of debt induce changes in expectations of future real government claims on private resources. The bond evaluation equation holds in real terms.

Figure 4: France. Impulse responses



Responses are conditional to the regime in place, implying that it will prevail over the entire simulation window. The displayed impulse responses are simulated over a monetary policy shock (ϵ_t^R), a shock to the long-term expenditure ($\epsilon_t^{e^L}$), a preference shock (ϵ_t^d), and a mark-up shock (ϵ_t^μ). The blue solid line corresponds to the PM/AF regime, the red dashed one to the AM/PF regime. Results refer to the estimates on French data.

Figure 5: Italy. Impulse responses



Responses are conditional to the regime in place, implying that it will prevail over the entire simulation window. The displayed impulse responses are simulated over a monetary policy shock (ϵ_t^R), a shock to the long-term expenditure ($\epsilon_t^{e^L}$), a preference shock (ϵ_t^d), and a mark-up shock (ϵ_t^μ). The blue solid line corresponds to the PM/AF regime, the red dashed one to the AM/PF regime. Results refer to the estimates on Italian data.

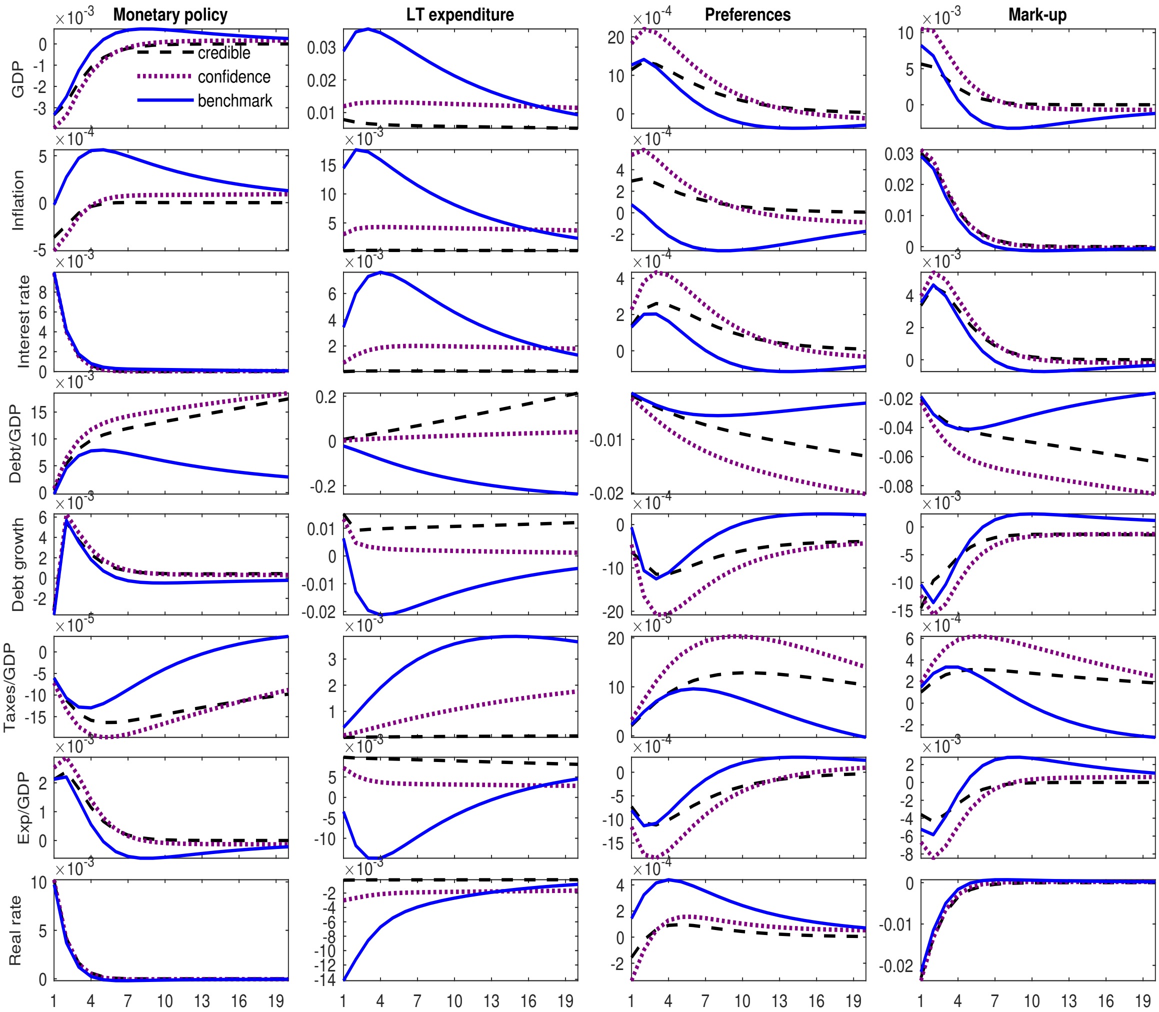
markup shock acts as a shock to inflation, and its effect on output differs across regimes. A drop in output is registered under the AM/PF regime after a few periods, whereas under the PM/AF regime, this happens only with some more delay. Simulated scenarios on agents' beliefs prove that this initial expansion features the PM/AF regime and the AM/PF regime only when agents attach some probabilities to switch back to the PM/AF regime. Moreover, in AM/PF, interest rates adjust more, and real rates decrease. The fiscal burden first decreases but converges to zero over the long run. Under the PM/AF regime, the positive increase in output and the deeper drop in real rates explain the larger and more permanent contraction in the debt ratio.

The results differ for Italy, where a procyclical fiscal policy explains the increasing and persisting imbalances, especially under the PM/AF regime. Expectations of the stepping-on-a-rake effect already matter in the AM/PF regime, where monetary policy shocks increase real rates, future debt, and thus inflation through the expected transition to the PM/AF regime. However, fiscal shocks are more persistent and destabilising in the PM/AF regime. Indeed, procyclicality in discretionary expenditure amplifies fluctuations, contributing to further debt accumulation than in the AM/PF regime, both in the face of short- and long-term expenditure shocks. This is also the case for the impact of a preference shock, which, while boosting demand and prices, also increases expenditure and inflates debt evaluations after a few periods. Finally, a supply-side markup shock in Italy suddenly brings the economy into recession (more than in France), consolidating finances, real rates decrease under both regimes, and debt-to-GDP drops permanently under PM/AF.

5.2 Beliefs' scenarios: policy credibility and uncertainty

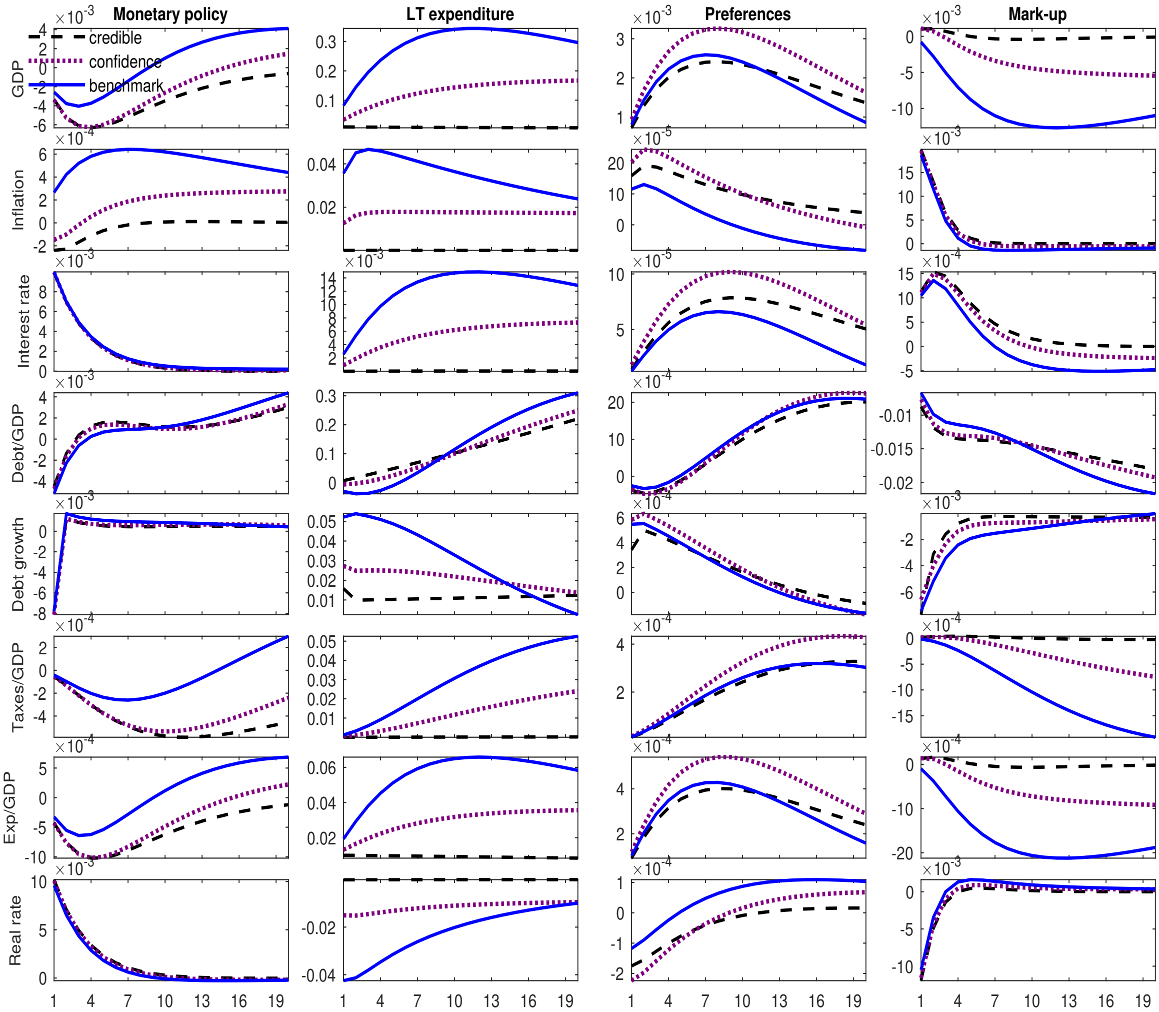
First, we compare the benchmark impulse responses with simulated responses built with alternative transition probabilities across regimes. These simulations aims to highlight the role played by agents' beliefs about the future of the policy mix and can be interpreted as different **policy credibility scenarios**. More specifically, the transition matrix is modified such that once in the PM/AF regime, it is more likely to return to AM/PF. We define a *confidence scenario*, where we increase the probability of going from the PM/AF to the AM/PF regime from 0.007 to 0.11 for France and from 0.003 to 0.04 for Italy, and decrease the probability of going from AM/PF to PM/AF from 0.02 to 0.001 for France and from 0.012 to 0.001 for Italy. Then, a more extreme scenario denoted as a *fully credible scenario*, is simulated by increasing the probability of going from PM/AF to AM/PF to 1 (absorbing regime) and making the

Figure 6: France. Impulse responses under beliefs' scenarios



Responses are computed by simulating scenarios on the transition probabilities. A confidence scenario is generated by increasing the probability to go from the PM/AF to the AM/PF regime from 0.007 to 0.105, and decreasing the probability to go from AM/PF to PM/AF from 0.017118 to 0.001. A credible scenario is simulated by increasing the probability to go from PM/AF to AM/PF to 1 and decrease the probability to go from AM/PF to PM/AF to 0. The displayed impulse responses are simulated over a monetary policy shock (ϵ_t^R), a shock to the long-term expenditure ($\epsilon_t^{e^L}$), a preference shock (ϵ_t^d), and a mark-up shock (ϵ_t^μ). The blue solid line corresponds to the PM/AF regime from the estimated model, the purple dotted one to the PM/AF regime from the confidence scenario, the black dashed one to the PM/AF regime from the credible scenario. Results refer to the estimates on French data.

Figure 7: Italy. Impulse responses under beliefs' scenarios



Responses are computed by simulating scenarios on the transition probabilities. A confidence scenario is generated by increasing the probability to go from the PM/AF to the AM/PF regime from 0.003 to 0.04, and decreasing the probability to go from AM/PF to PM/AF from 0.012 to 0.001. A credible scenario is simulated by increasing the probability to go from PM/AF to AM/PF from to 1 and decrease the probability to go from AM/PF to PM/AF to 0. The displayed impulse responses are simulated over a monetary policy shock (ϵ_t^R), a shock to the long-term expenditure ($\epsilon_t^{e^L}$), a preference shock (ϵ_t^d), and a mark-up shock (ϵ_t^μ). The blue solid line corresponds to the PM/AF regime from the estimated model, the purple dotted one to the PM/AF regime from the confidence scenario, the black dashed one to the PM/AF regime from the credible scenario. Results refer to the estimates on Italian data.

transition from AM/PF to PM/AF impossible.

All impulse responses are generated under the PM/AF regime and vary when beliefs about the AM/PF regime change (Figure 6 and 7). Therefore, the credibility of announcing a different policy can significantly affect the efficacy of the current policy stance. When agents expect the AM/PF regime to realise tomorrow with a higher probability, that is, when policy announcements effectively anchor expectations, they behave as if they were already in that regime. Indeed, the stepping-on-a-rake effect disappears under the two scenarios. The same occurs for the expenditure shock, which increases debt, and the inflationary preference shock. The same logic applies to Italian results, where the likely exit from the PM/AF regimes stabilises the economy, dampening the impact of procyclical expenditure.

In a second set of simulations, interpreted as **uncertainty scenarios**, we consider that agents learn about the *persistence* of regime changes and perceive them as either short- or long-lasting (Figure 8 and 9). They can still observe the regime in place at each point in time, but they face uncertainty about the nature of deviations from the AM/PF benchmark regime; namely, they are not sure if the policy authorities are engaging in a short or long-lasting AM/PF regime. This simulation is like introducing a learning mechanism on the persistence of regime changes.[24]

We build scenarios about beliefs regarding the duration of the AM/PF regime by expanding the number of regimes to account for either short- or long-lasting perceived AM/PF regimes. We assume three states: a PM/AF regime, a short-lived AM/PF regime, and a long-lasting AM/PF regime. Uncertainty arises because the two AM/PF regimes share the same parameter values governed by ξ^p, which agents recognise as belonging to AM/PM regime. However, they cannot precisely infer whether it is a short- or long-lasting regime. It is something they learn after switching to the new regime. After the switch to AM/PF, they initially perceive it as a temporary deviation while adjusting only afterward to persistent changes.

In Figure 8 and 9, we compare our benchmark impulse responses in the AM/PF regime (red line) to those when AM/PF is perceived as temporary (black dotted) or long-lasting (black dashed). In the first case, we assume a transition matrix where the probability of going from AM/PF temporary to AM/PF long-lasting is 0.01, and the probability of going from AM/PF temporary to the PM/AF regime is 0.49. We denote this as the AM/PF-short scenario, which lasts for two years. In the second case, we assume the probability of going from AM/PF

[24] Bianchi, Lettau and Ludvigson (2022) performs a similar simulation to explain extrapolative behaviours of investors' asset valuation to monetary policy regime changes.

temporary to AM/PF long-lasting is 0.49, and the probability of going from AM/PF temporary to the PM/AF regime is 0.01. We denote this scenario as AM/PF-long scenario.

This simulation allows evaluation of the impact of agents' learning about the duration of regimes on regime-specific transmission mechanisms. In the French case, it implies that when agents expect the AM/PF regime to be short-lasting, thus quickly reverting to PM/AF, the monetary shock becomes inflationary, expenditure debt-augmenting, and the preference shock deflationary. When agents realize the shift is more persistent, all the relevant dynamics of the AM/PF regime are reinforced. Hence, agents react to a shift in a new AM/PF by underreacting and then overreacting when they believe it will persist. The same logic applies to the interpretation of Italian results.

6 Conclusions

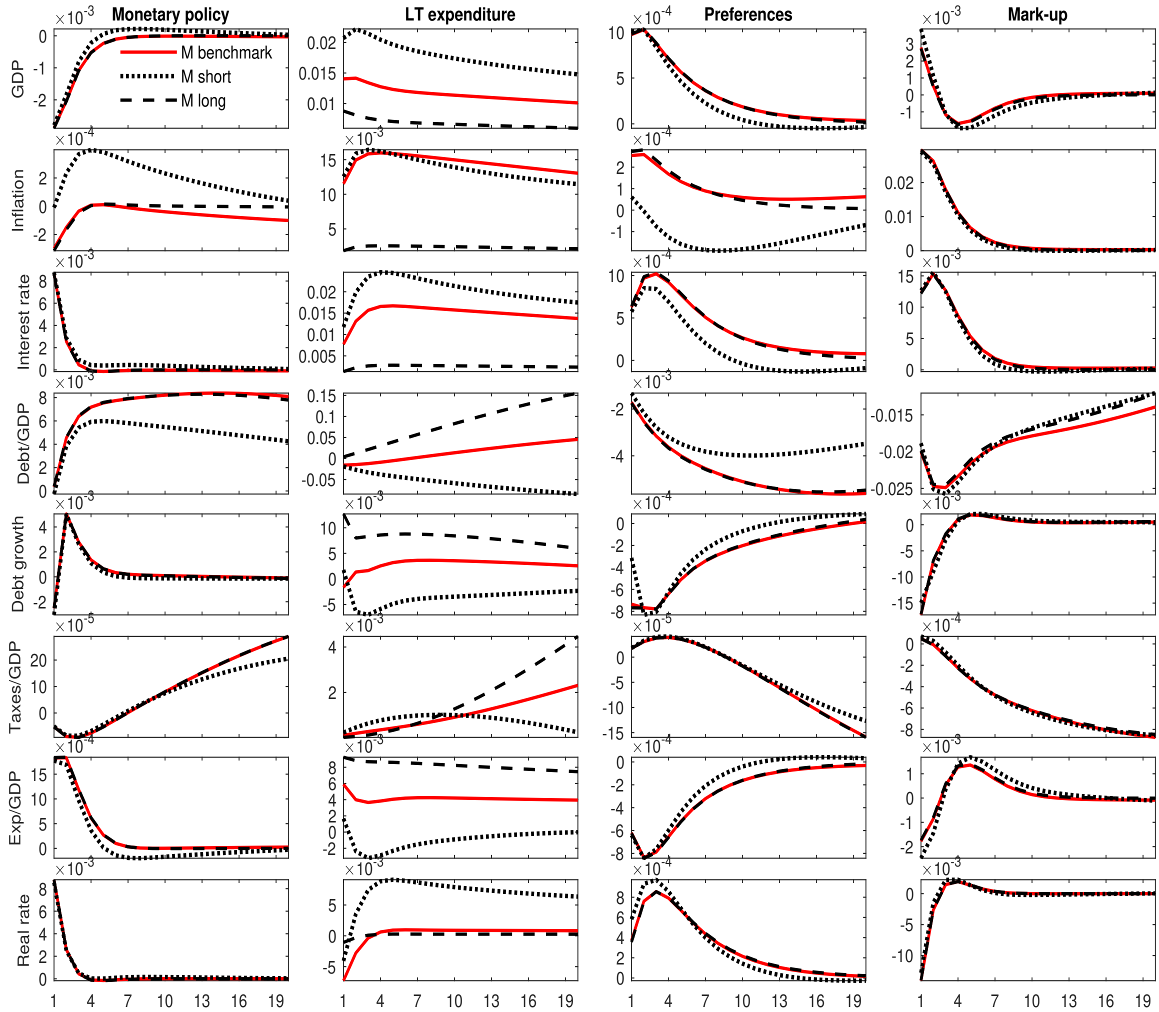
Fiscal imbalances and monetary policy effectiveness at the EA level are central to the macroeconomic policy debate. This study aims to establish empirical regularities concerning debt sustainability and inflation dynamics using the framework for monetary and fiscal policy interactions applied to two European countries: Italy and France. They are solid economies with a history of monetary policy independence, Treasury-Central Bank agreements, exchange rate regimes, and growing fiscal instability.

We analyse post-war data on France and Italy's 1955-2019 and 1950-2019 periods, respectively. We estimate a DSGE model with Markov-switching policy rules for tax revenues and nominal interest rates to identify monetary/fiscal policy mix regimes, accounting for the transition to the monetary union and constrained monetary policy during the ELB period.

The resulting estimated regimes are interpreted as policy narratives as follows. In both countries, a PM/AF regime covers the first period of fiscal inflation and large primary surpluses reflecting the debt monetization operations conducted by the central banks. Since the late 80s/early 90s, the monetary independence, external stability, and the EMU fiscal convergence describe the transition to an active monetary-passive fiscal regime. Finally, in 2009 the ELB triggered an immediate switch back to active fiscal behaviour in France. With the Euro sovereign debt crisis in Italy, the government implemented austerity measures to abate the debt-to-GDP ratios. After that, a reversal in the policy mix determined a switch to active fiscal behaviour, where a vicious cycle of debt inflation, deflation, and output contraction was realised.

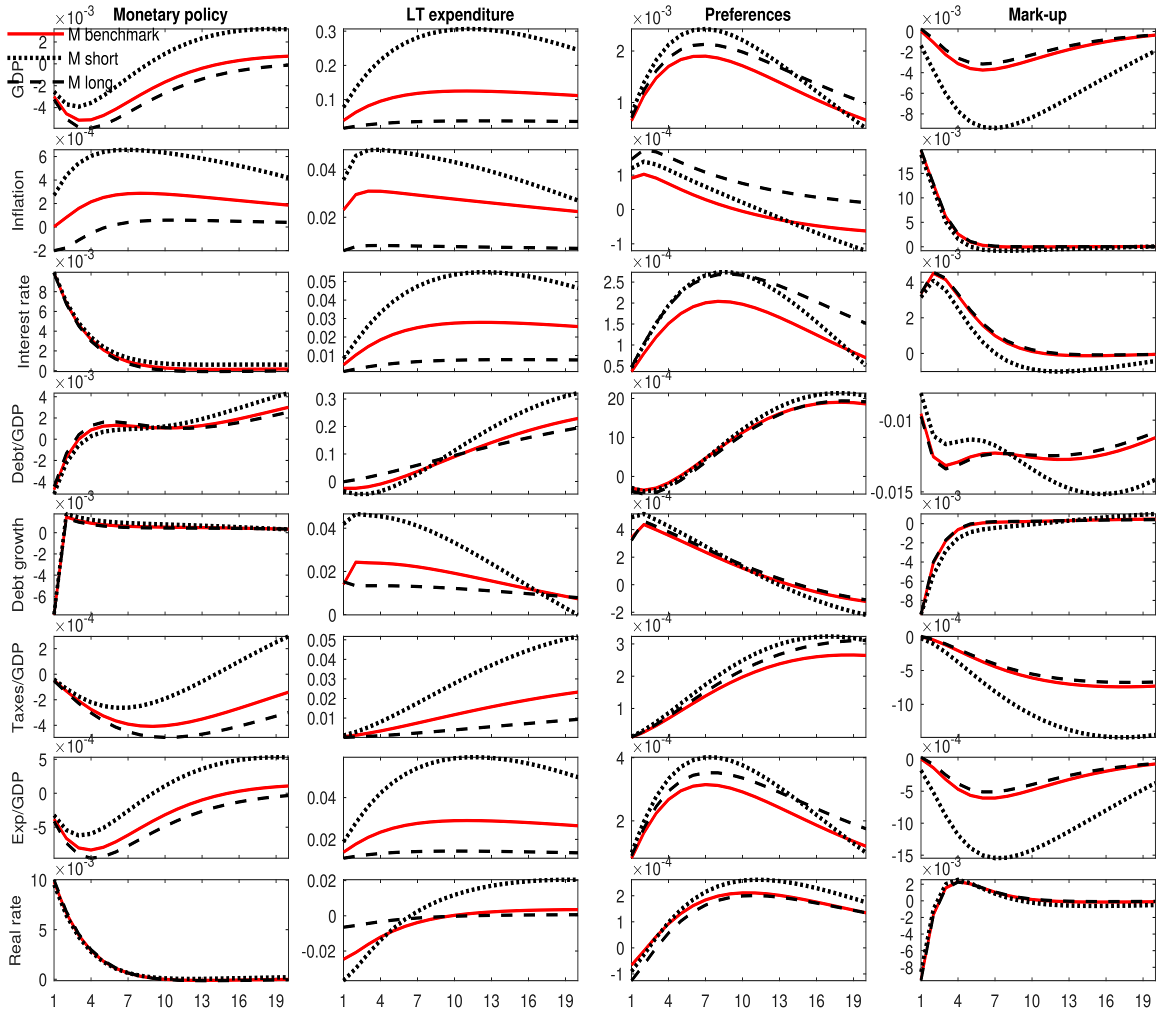
Simulations for France explain price volatility and debt stabilisation under the PM/AF

Figure 8: France. Impulse responses under beliefs' scenarios



Responses are computed by simulating scenarios on the transition probabilities, where the transition matrix is expanded to include a short-lasting and a long-lasting AM/PF regime. Then, a AM/PF-short scenario is generated by setting the probability to go from AM/PF temporary to AM/PF long-lasting to 0.01, and the probability to go from AM/PF temporary to the PM/AF regime to 0.49. A AM/PF-long scenario is simulated by setting the probability to go from AM/PF temporary to AM/PF long-lasting to 0.49 and the probability to go from AM/PF temporary to the PM/AF regime to 0.01. The displayed impulse responses are simulated over a monetary policy shock (ϵ_t^R), a shock to the long-term expenditure ($\epsilon_t^{e^L}$), a preference shock (ϵ_t^d), and a mark-up shock (ϵ_t^μ) The red solid line corresponds to the PM/AF regime, the black dotted one to the confidence scenario, the black dashed one to the credible scenario. Results refer to the estimates on French data.

Figure 9: Italy. Impulse responses under beliefs' scenarios



Responses are computed by simulating scenarios on the transition probabilities, where the transition matrix is expanded to include a short-lasting and a long-lasting AM/PF regime. Then, a AM/PF-short scenario is generated by setting the probability to go from AM/PF temporary to AM/PF long-lasting to 0.01, and the probability to go from AM/PF temporary to the PM/AF regime to 0.49. A AM/PF-long scenario is simulated by setting the probability to go from AM/PF temporary to AM/PF long-lasting to 0.49 and the probability to go from AM/PF temporary to the PM/AF regime to 0.01. The displayed impulse responses are simulated over a monetary policy shock (ϵ_t^R), a shock to the long-term expenditure ($\epsilon_t^{e^L}$), a preference shock (ϵ_t^d), and a mark-up shock (ϵ_t^μ) The red solid line corresponds to the PM/AF regime, the black dotted one to the confidence scenario, the black dashed one to the credible scenario. Results refer to the estimates on Italian data.

regime, deflation, and explosive debt paths under the AM/PF regime. In Italy, a procyclical fiscal policy explains the increasing and persisting imbalances, high aggregate volatility, and low growth.

Simulated scenarios on policy credibility show that the credibility of announcing a different policy can significantly affect the efficacy of the current policy stance. If agents face uncertainty about the duration of regimes, agents gradually adjust to the change in regime after the shift dates.

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Appendices

A Equilibrium Conditions

The model is characterized by the following set of equations in the endogenous variables $Y_t = \{\hat{c}_t, R_t^m, R_t, P_t^m, \pi_t, \varphi_t, h_t, \hat{y}_t, b_t, \tau_t, e_t, e_t^S, \chi_t, g_t, \hat{y}_t^n, v_t\}$, and exogenous variables $z_t = \{a_t, d_t, \mu_t, tp_t, e_t^L, \Pi_{rEA,t}\}$. Detrended variables (normalized by the level of aggregate TFP) are defined as $\hat{X}_t$.

1. Euler Equation: $$1 = \beta \mathbb{E}_t \left\{ e^{d_{t+1}-d_t} \frac{\hat{c}_t - \Phi \hat{c}_{t-1} e^{-(\gamma+a_t)}}{\hat{c}_{t+1} - \Phi \hat{c}_t e^{-(\gamma+a_{t+1})}} e^{-(\gamma+a_{t+1})} \frac{R_{t+1}^m}{\Pi_{t+1}} \right\}$$

2. Long-term Return: $$R_t^m = \frac{1+\rho P_t^m}{P_{t-1}^m}$$

3. Arbitrage condition: $$R_t = \mathbb{E}_t[R_{t+1}^m]$$

4. Real marginal costs: $$\varphi_t = \left[\hat{c}_t - \Phi \hat{c}_{t-1} e^{-(\gamma+a_t)}\right] \frac{h_t^\alpha}{1-\alpha}$$

5. Production function: $$\hat{y}_t = h_t^{1-\alpha}$$

6. Phillips Curve: $$\frac{1}{\nu_t}\Big(1 - \varphi_t(1-\alpha)\Big) = 1 - \psi\left(\Pi_t - \frac{\Pi_{t-1}^\iota}{\Pi^{\iota-1}}\right)\Pi_t - \frac{\psi}{2}\left(\Pi_t - \frac{\Pi_{t-1}^\iota}{\Pi^{\iota-1}}\right)^2 \frac{\nu_t - 1}{\nu_t} +$$ $$+ \beta \mathbb{E}_t \left\{ \frac{\hat{c}_t - \Phi \hat{c}_{t-1} e^{-(\gamma+a_t)}}{\hat{c}_{t+1} - \Phi \hat{c}_t e^{-(\gamma+a_{t+1})}} \psi \left(\Pi_{t+1} - \frac{\Pi_t^\iota}{\Pi^{\iota-1}}\right) \Pi_{t+1} \frac{\hat{y}_{t+1}}{\hat{y}_t} \right\}$$

7. Mark-up shock: $$\frac{\kappa}{1+\iota\beta} \log\left(\frac{1-\nu}{1-\nu_t}\right) = \mu_t; \quad \mu_t = \rho_\mu \mu_{t-1} + \sigma_\mu \varepsilon_t^\mu$$

8. Taylor rule: $$\frac{R_t}{R} = (1 - I_{ELB}) \left\{ \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{\Pi_t^{\omega(I_{EA})} \Pi_{rEA,t}^{(1-\omega(I_{EA}))}}{\Pi} \right)^{\psi_{\pi,\xi_t^p}} \left(\frac{Y_t}{Y_t^n}\right)^{y,\xi_t^p} \right]^{(1-\rho_R)} e^{\sigma_R \varepsilon_t^R} \right\} +$$ $$I_{ELB} \left\{ \left(\frac{R_{t-1}}{R}\right)^{\rho_{R,I}} (1/R)^{(1-\rho_{R,I})\psi_I} e^{\sigma_I \varepsilon_t^R} \right\}$$

9. Budget constraint: $$b_t = b_{t-1} \frac{R_t^m}{\Pi_t} \frac{\hat{y}_{t-1}}{\hat{y}_t} e^{-(\gamma+a_t)} - \tau_t + e_t + tp_t$$

10. Purchases over expenditure: $$\frac{\chi_t}{\chi} = \left(\frac{\chi_{t-1}}{\chi}\right)^{\rho_\chi} e^{\sigma_\chi \varepsilon_t^\chi}; \quad \chi_t = \left(1 - \frac{1}{g_t}\right) e_t^{-1}$$

11. Government expenditure: $$e_t = e_t^S + e_t^L$$

    Short-term component: $$e_t^S = \rho_{e^S} e_{t-1}^S + (1 - \rho_{e^S}) \left[e^S + \phi_y \Big(\hat{y}_t - \hat{y}_t^n\Big) \right] + \sigma_{e^S} \varepsilon_t^{e^S}$$

    Long-term component: $$e_t^L = \rho_{e^L} e_{t-1}^L + \sigma_{e^L} \varepsilon_t^{e^L}$$

12. Tax rule: $$\tau_t = \rho_\tau \tau_{t-1} + (1 - \rho_\tau) \left[\tau + \delta_{b,\xi_t^p}(b_t - b) + \delta_y(y_t - y_t^n) \right] \sigma_\tau \varepsilon_t^\tau$$

13. Government Purchases: $g_t \equiv \left(1 - \frac{\hat{G}_t}{\hat{y}_t}\right)^{-1}$

14. Market clearing: $1 = \frac{\hat{c}_t}{\hat{y}_t} + \frac{g_t - 1}{g_t}$

15. Potential output: $\hat{y}_t^n = \left[\frac{1-\nu_t}{\frac{\hat{y}_t^n}{g_t} - \Phi \frac{\hat{y}_{t-1}^n}{g_{t-1}} e^{-(\gamma + a_t)}}\right]^{\frac{1-\alpha}{\alpha}}$

16. TFP shock: $a_t = \rho_a a_{t-1} + \sigma_a \varepsilon_t^a$

17. Term premium shock: $tp_t = \rho_{tp} tp_{t-1} + \sigma_{tp} \varepsilon_t^{tp}$

18. Preference shock: $d_t = \rho_d d_{t-1} + \sigma_d \varepsilon_t^d$

19. Rest of euro area Inflation shock: $\Pi_{rEA,t} = \rho_{\Pi_{rEA}} \Pi_{rEA,t-1} + \sigma_{\pi_{rEA}} \varepsilon_t^{\Pi_{rEA}}$

B Steady-state System

Given initial data-based calibrations for $\Pi = \Pi^\star$; $g = g^\star$; $b = b^\star$; $\tau = \tau^\star$, the steady state of the model is characterized by the following set of equations:

$$R^m = \frac{\Pi^\star}{\beta} e^\gamma$$

$$P^m = \frac{1}{R^m - \rho}$$

$$R = R^m$$

$$\varphi = \frac{1-\nu}{1-\alpha} = \hat{c}(1 - \Phi e^{-\gamma}) \frac{h^\alpha}{1-\alpha}$$

$$e = \left(1 - \frac{1}{\beta}\right) b^\star + \tau^\star$$

$$e^S = e$$

$$\chi = \left(1 - \frac{1}{g^\star}\right) e^{-1}$$

$$h = \varphi(1-\alpha) \frac{g^\star}{1 - \Phi e^{-\gamma}}$$

$$y = h^{1-\alpha}$$

$$c = \frac{y}{g^\star}$$

$$y^n = y$$

$$a = d = e^L = \mu = tp = \Pi_{rEA} = 0$$

C Linearized model

After de-trending the model, it is then linearized with respect to taxes, government expenditure and debt, and loglinearized with respect to the rest of the variables. Indeed, we use the notation $\tilde{x}_t$ to indicate both linear deviations, ($\tilde{x}_t = X_t - X$), and percentage deviations from the steady-state level ($\tilde{x}_t = \log(\frac{X_t}{X})$, while for de-trended variables $\tilde{x}_t = \log\left(\frac{\hat{X}_t}{\hat{X}}\right) = \log\left(\frac{X_t}{A_t}\frac{A}{X}\right)$).

1. IS curve:

$$\tilde{y}_t = \tilde{g}_t - \frac{1}{1+\Phi e^{-\gamma}}\mathbb{E}_t\{\tilde{g}_{t+1}\} + \frac{\Phi e^{-\gamma}}{1+\Phi e^{-\gamma}}(\tilde{y}_{t-1} - \tilde{g}_{t-1} - a_t) + \\ - \frac{1-\Phi e^{-\gamma}}{1+\Phi e^{-\gamma}}(\tilde{R}_t - \mathbb{E}_t\{\tilde{\pi}_{t+1}\} - (1-\rho_d d_t)) + \frac{1}{1+\Phi e^{-\gamma}}(\mathbb{E}_t\{\tilde{y}_{t+1}\} + \rho_a a_t)$$

2. Phillips Curve:

$$\tilde{\pi}_t = \frac{\kappa(1-\Phi e^{-\gamma})^{-1}}{1+\iota\beta}\left[\left(1 + \frac{\alpha}{1-\alpha}(1-\Phi e^{-\gamma})\right)\tilde{y}_t - \tilde{g}_t - \Phi e^{-\gamma}(\tilde{y}_{t-1} - \tilde{g}_{t-1} - a_t)\right] + \\ + \frac{\iota}{1+\iota\beta}\tilde{\pi}_{t-1} + \frac{\beta}{1+\iota\beta}\mathbb{E}_t\{\tilde{\pi}_{t+1}\} + \mu_t$$

3. Taylor rule:

$$\tilde{R}_t = (1 - I_{ELB})\left\{\rho_R \tilde{R}_{t-1} + (1-\rho_R)\left[\psi_{\pi,\xi_t^p}\left(\omega(I_{EA})\tilde{\pi}_t + (1-\omega(I_{EA}))\tilde{\pi}_{rEA,t}\right) + \psi_{y,\xi_t^p}(\tilde{y}_t - \tilde{y}_t^n)\right] + \sigma_R \varepsilon_t^R\right\} +$$

$$+ I_{ELB}\left\{\rho_{R,I}\tilde{R}_{t-1} - (1-\rho_{R,I})\psi_I \log R + \sigma_I \varepsilon_t^R\right\}$$

4. Government Purchases over expenditure:

$\tilde{\chi}_t = \rho_\chi \tilde{\chi}_{t-1} + \sigma_\chi \epsilon_t^\chi$; $\quad \tilde{\chi}_t = \frac{1}{g^\star - 1}\tilde{g}_t - e^{-1}\tilde{e}_t$

5. Tax rule:

$\tilde{\tau}_t = \rho_\tau \tilde{\tau}_{t-1} + (1-\rho_\tau)[\delta_{b,\xi_t^p}\tilde{b}_{t-1} + \delta_y(\tilde{y}_t - \tilde{y}_t^n)] + \sigma_\tau \epsilon_t^\tau$

6. Debt:

$\tilde{b}_t^m = \beta^{-1}\tilde{b}_{t-1}^m + b^m \beta^{-1}(\tilde{R}_{t-1,t}^m - \tilde{y}_t + \tilde{y}_{t-1} - a_t - \tilde{\pi}_t) - \tilde{\tau}_t + \tilde{e}_t^S + e_t^L + tp_t$

7. Return on portfolio: $\quad \tilde{R}_{t,t+1}^m = R^{-1}\rho \tilde{P}_{t+1}^m - \tilde{P}_t^m$

8. No arbitrage: $\quad \tilde{R}_t = \mathbb{E}_t\{\tilde{R}_{t,t+1}^m\}$

9. Natural output:

$\left[\frac{1}{1-\Phi e^{-\gamma}} + \frac{\alpha}{1-\alpha}\right]\tilde{y}_t^n = (1-\Phi e^{-\gamma})^{-1}\tilde{g}_t + \frac{\Phi e^{-\gamma}}{1-\Phi e^{-\gamma}}(\tilde{y}_{t-1}^n - \tilde{g}_{t-1} - a_t)$

10. Government expenditure: $\tilde{e}_t = \tilde{e}_t^S + e_t^L$

Short-term component: $\tilde{e}_t^S = \rho_{e^S}\tilde{e}_{t-1}^S + (1-\rho_{e^S})\phi_y(\tilde{y}_t - \tilde{y}_t^n) + \sigma_{e^S}\epsilon_t^{e^S}$

Long-term component: $e_t^L = \rho_{e^L} e_{t-1}^L + \sigma_{e^L}\epsilon_t^{e^L}$

11. Term premium shock: $tp_t = \rho_{tp} tp_{t-1} + \sigma_{tp}\epsilon_t^{tp}$

12. Technology shock: $a_t = \rho_a a_{t-1} + \sigma_a \epsilon_t^a$

13. Preference shock: $d_t = \rho_d d_{t-1} + \sigma_d \epsilon_t^d$

14. Mark-up shock: $\mu_t = \rho_\mu \mu_{t-1} + \sigma_\mu \epsilon_t^\mu$

15. Rest of euro area Inflation shock: $\tilde{\pi}_{rEA,t} = \rho_{\pi_{rEA}}\tilde{\pi}_{rEA,t-1} + \sigma_{\pi_{rEA}}\varepsilon_t^{\pi_{rEA}}$

D Solution Methods

The Markov-switching DSGE model is solved using the perturbation method of Foerster et al. (2016). They develop an iterative procedure that approximates the model solution by guessing a set of approximations under each regime. Given a guess, each regime's approximation follows from standard perturbation techniques, and the iterative algorithm stops when obtained approximations equal the guesses. This perturbation approach has two major advantages. First, it provides a flexible environment for models like ours, in which switching dynamics affect the economy's steady state. This is a feature that perturbation handles easily. In addition, perturbation allows for second and higher-order approximations, which improve, on one hand, the solution accuracy and, on the other hand, the ability to capture the role of agents' beliefs over regimes.

We stack the vector of model variables Υ_t into a group of predetermined variables, $\mathbf{x}_t \in \mathbb{R}^{n_x}$, and a group of control variables, $\mathbf{y}_t \in \mathbb{R}^{n_y}$. Then, we define the vector of independent and identically distributed innovations to the exogenous predetermined variables as $\epsilon_t \in \mathbb{R}^{n_\epsilon}$, and the vector of switching parameters as $\theta(\xi_t^p) \in \mathbb{R}^{n_\theta}$. The equilibrium conditions have the following general form:

$$\mathbb{E}_t\mathbf{f}\Big(\mathbf{y}_{t+1}, \mathbf{y}_t, \mathbf{x}_t, \mathbf{x}_{t-1}, \epsilon_{t+1}, \epsilon_t, \theta(\xi_{t+1}^p), \theta(\xi_t^p)\Big) = 0_{n_y+n_x}$$

where $\mathbf{f}$ is a nonlinear function. Then, the algorithm works as an extension of conventional perturbation methods (Judd (1998), Schmitt-Grohé and Uribe (2004)).

Stacking the regime-dependent solutions for $\mathbf{y}_t$ and $\mathbf{x}_t$, the algorithm assumes they are of the form:

$$\mathbf{y}_t = \mathbf{g}_{\xi_t^p}(\mathbf{x}_{t-1}, \epsilon_t, \chi)$$

$$\mathbf{x}_t = \mathbf{h}_{\xi_t^p}(\mathbf{x}_{t-1}, \epsilon_t, \chi)$$

for all ξ_t^p, where $\mathbf{g}_{\xi_t^p} : \mathbb{R}^{n_x+n_\epsilon+1} \rightarrow \mathbb{R}^{n_y}$ and $\mathbf{h}_{\xi_t^p} : \mathbb{R}^{n_x+n_\epsilon+1} \rightarrow \mathbb{R}^{n_x}$ are continuously differentiable regime-dependent functions. Then, $\mathbf{Y}_t = y_t(\mathbf{e}_{\xi_t^p}^T \otimes \mathbf{I}_{n_y})^{-1}$ and $\mathbf{X}_t = x_t(\mathbf{e}_{\xi_t^p}^T \otimes \mathbf{I}_{n_x})^{-1}$, such that approximating a solution to $\mathbf{y}_t$ and $\mathbf{x}_t$ is equivalent to approximating a solution to:

$$\mathbf{Y}_t = \mathbf{G}(\mathbf{x}_{t-1}, \epsilon_t, \chi) = \begin{bmatrix} g_{\xi_t^p=1}(\mathbf{x}_{t-1}, \epsilon_t, \chi) \\ \vdots \\ g_{\xi_t^p=n_\xi}(\mathbf{x}_{t-1}, \epsilon_t, \chi) \end{bmatrix}$$
$$\mathbf{X}_t = \mathbf{H}(\mathbf{x}_{t-1}, \epsilon_t, \chi) = \begin{bmatrix} h_{\xi_t^p=1}(\mathbf{x}_{t-1}, \epsilon_t, \chi) \\ \vdots \\ h_{\xi_t^p=n_\xi}(\mathbf{x}_{t-1}, \epsilon_t, \chi) \end{bmatrix}$$

Given the vector of states $z_t = (x_{t-1},\ \epsilon_t,\ \xi_t^p)$ of dimension $n_x + n_\epsilon + 1$, the first-order approximation of $G(z_t)$ and $H(z_t)$ is:

$$\mathbf{G}(\mathbf{z}_t) \approx Y + D\mathbf{G}(\mathbf{z})(\mathbf{z}_t - \mathbf{z})$$
$$\mathbf{H}(\mathbf{z}_t) \approx X + D\mathbf{H}(\mathbf{z})(\mathbf{z}_t - \mathbf{z})$$

where $D\mathbf{G}(\mathbf{z})$ and $D\mathbf{H}(\mathbf{z})$ can be obtained by solving a system of quadratic polynomial equations and two systems of linear equations.

E Observation Equations

The vector of model solutions S_t is combined with the following system of observation equations:

$$X_t = D + ZS_t \tag{E.15}$$

where $X_t = [\Delta \log(y_t^{\text{obs}}),\ \pi_t^{\text{obs}},\ R_t^{\text{obs}},\ b_t^{\text{obs}},\ \log(g_t^{\text{obs}}),\ \tau_t^{\text{obs}},\ e_t^{\text{obs}}]'$ contains the observables, D the vector of constants and Z_t provides the mapping between the model's solution and the data.

The system of equations reads as follows:

$$\Delta \log(y_t^{\text{obs}}) = \gamma + a_t + \tilde{y}_t - \tilde{y}_{t-1}$$

$$\log(\pi_t^{\text{obs}}) = \log\left(\frac{P_t^{\text{obs}}}{P_{t-1}^{\text{obs}}}\right) = \log(\Pi^\star) + \tilde{\pi}_t$$

$$\log(\pi_{rEA,t}^{\text{obs}}) = \log(\Pi_{rEA}^\star) + \tilde{\pi}_{rEA,t}$$

$$R_t^{\text{obs}} = \left(\log(\Pi^\star) + \left(\frac{e^\gamma}{\beta} - 1\right)\right) + \tilde{R}_t$$

$$b_t^{\text{obs}} = b^\star + \tilde{b}_t$$

$$\log(g_t^{\text{obs}}) = \log(g^\star) + \tilde{g}_t$$

$$\tau_t^{\text{obs}} = \tau^\star + \tilde{\tau}_t$$

$$e_t^{\text{obs}} = e + \tilde{e}_t$$

where the percentage deviation of the de-trended output from its steady state is $\tilde{y}_t = \log\left(\frac{Y_t^{\text{obs}}}{A_t}\frac{y}{A}\right)$ and the percentage deviations for inflation, government purchases, and interest rates are $\tilde{\pi}_t = \log\left(\frac{\Pi_t^{\text{obs}}}{\Pi^\star}\right)$, $g_t = \log\left(\frac{g_t^{\text{obs}}}{g^\star}\right)$ with $g_t^{\text{obs}} = (1 - G_t^{\text{obs}}/Y_t^{\text{obs}})^{-1}$, $\tilde{R}_t = \log\left(\frac{R_t^{\text{obs}}}{R}\right)$. For the variables normalized with respect to GDP the linear deviations are $\tilde{\tau}_t = \tau_t^{\text{obs}} - \tau^\star$, $\tilde{b}_t = b_t^{\text{obs}} - b^\star$ and $\tilde{e}_t = e_t^{\text{obs}} - e$.

F Data

Country: France, Italy.

- Y_t^{obs}: Real GDP.

  France: Database: National accounts. Source: INSEE. Webpage: https://insee.fr/en/information/2868584#titre-bloc-1

  Italy: Database: Baffigi (2013). Source: Bank of Italy, ISTAT. Webpage: https://www.bancaditalia.it/pubblicazioni/collana-storica/pil-storia-italia/index.html

- Π_t^{obs}: GDP deflator inflation.

  France: Database: National accounts. Source: INSEE.

  Italy: Database: Baffigi (2013). Source: Bank of Italy; ISTAT.

- R_t^{obs}: short-term nominal interest rate.

France: Call Money/Interbank Rate: Less than 24 Hours. Database: Main Economic Indicators. Source: OECD. Webpage: http://stats.oecd.org

Italy: Official Discount rate (1950-1992); three-month money market rate (1993-2018). Database: Historical Tables. Monetary and Financial Indicators (Bank of Italy, 2013); Monthly Monetary and Financial statistics (MEI). Source: Bank of Italy, OECD. Webpage: https://www.bancaditalia.it/statistiche/tematiche/stat-storiche/stat-storiche-moneta/BDS_historical_tables.pdf?language_id=1

- b_t^{obs}: Gross General Government debt-to-GDP ratio, Maastricht debt.

  France: Source: INSEE, IMF Historical Public Debt Database. Webpage: https://www.imf.org/en/Publications/WP/Issues/2016/12/31/A-Historical-Public-Debt-Database-24332

  Italy: Database: Baffigi (2013). Source: Banca d'Italia Webpage: https://www.bancaditalia.it/pubblicazioni/qef/2008-0031/index.html

- G_t^{obs}: Government purchases = final consumption expenditure+gross government investment+net purchases of non-produced assets.

  France: Database: National accounts. Source: INSEE.

  Italy: Database: RGS (2011) (1950-1979); Conto Economico consolidato delle Amministrazioni Pubbliche (1980-2018). Source: Italian Ministry of Economy and Finance (MEF). Webpage: http://www.rgs.mef.gov.it; ISTAT. Webpage: https://www.istat.it/it/archivio/11460

- e_t^{obs}: Government Expenditure-to-GDP, where Gov. Expenditure = Gov.Purchases+Transfers, and Transfers=net current transfers+subsidies+net capital transfers.

  France: Database: National accounts. Source: INSEE.

  Italy: RGS (2011) (1950-1979); Conto Economico consolidato delle Amministrazioni Pubbliche (1980-2018). Source: MEF, ISTAT

- t_t^{obs}: Tax revenues-to-GDP ratio, where taxes=current receipts-current tranfer receipts= taxes on production and imports (indirect taxes)+ current taxes on income and wealth (direct taxes)+property income.

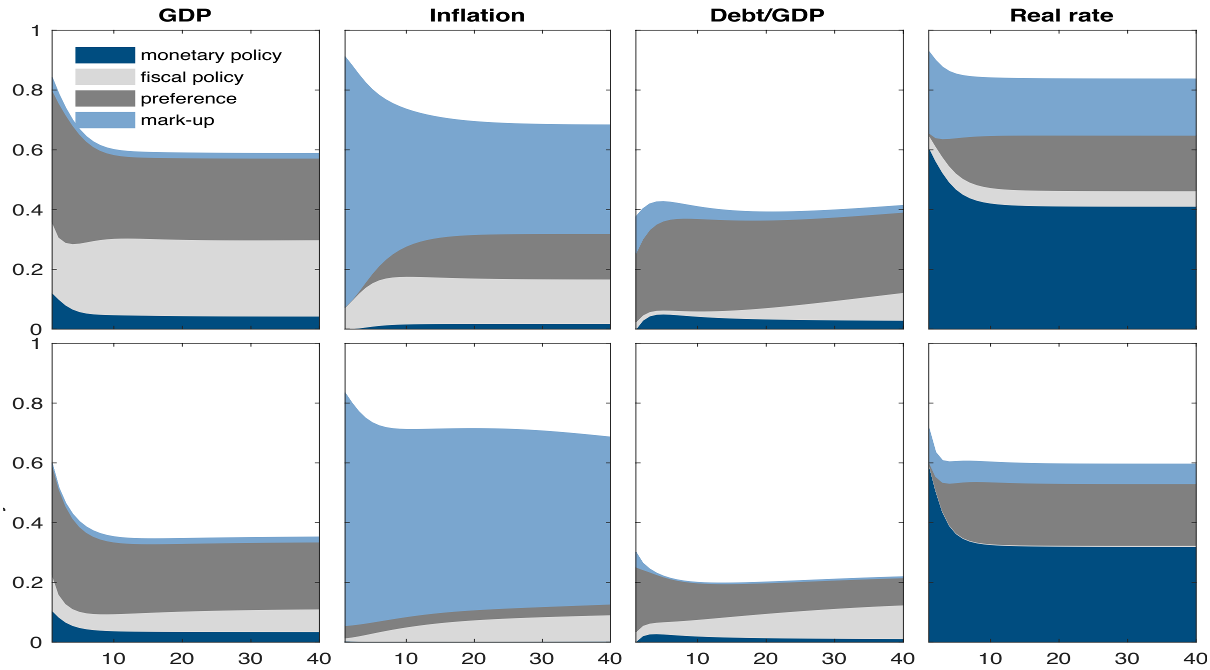
  France: Database: National Households accounts. Source: INSEE.

  Italy: Database: Relazione generale sulla situazione economica del Paese (1950-1979). Conto Economico consolidato delle Amministrazioni Pubbliche (1980-2018). Source: Camera dei Deputati. Webpage: https://storia.camera.it/documenti/doc#nav; ISTAT

G Macroeconomic Volatility

We now analyse the implications of changes in policy behaviour on the volatilities of the main model variables. Figure G.1 and G.2 report the forecast error variance decomposition (FEVD) under France and Italy's AM/PF and PM/AF policy regimes.

Figure G.1: France. FEVD

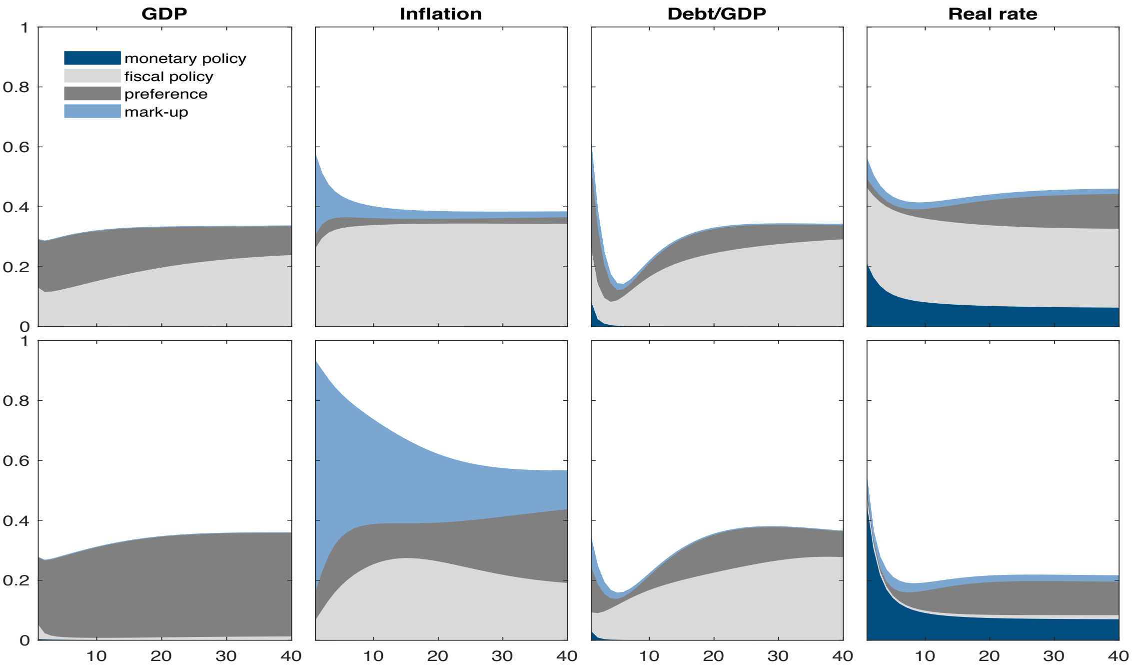


The figure reports the variance decomposition of GDP, inflation, debt-to-GDP, and real rates at different horizons. The decomposition is marked as shades across four shocks: the monetary policy shock, an aggregated measure of fiscal shocks, the preference shock, and the mark-up shock. The white area summarizes the contribution of the remaining shocks, namely shocks to technology, and the rest of EA inflation. Both the standard deviations and variance decompositions take into account the possibility of regime changes. Results are for France, under the PM/AF (top panel) and the AM/PF regime (bottom panel).

Consistently with Bianchi and Ilut (2017), for France, preference shocks explain a large share of output growth volatility under both regimes. This is more relevant under the PM/AF regime, where preference shocks substantially transmit to inflation and debt-to-GDP dynamics. Under the AM/PF regime, instead, interest rates absorb this source of fluctuations. In Italy, this result is not confirmed, and no relevant regime-specific properties can be identified. Regarding mark-up shocks, they cover a large share of inflation volatility in France and Italy under the AM/PF regime. Under the PM/AF regime, instead, fiscal shocks achieve an essential and growing role in inflation dynamics, which in turn crucially contribute to explaining real rates. As for the real interest rates, their volatility is mainly driven by inflation and shocks on preferences under the

AM/PF regime, while the influence of these two sources almost disappears under the PM/AF regime.

Figure G.2: Italy. FEVD

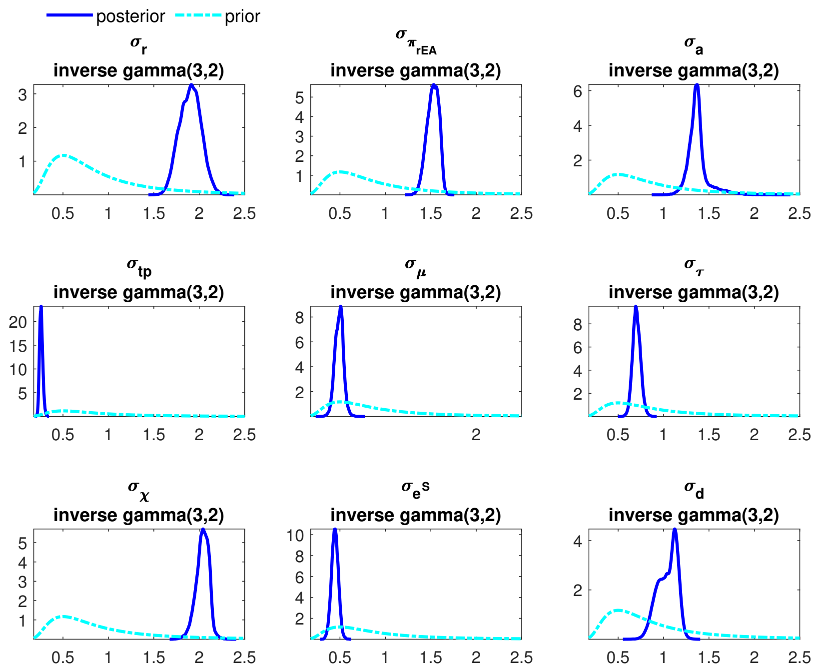


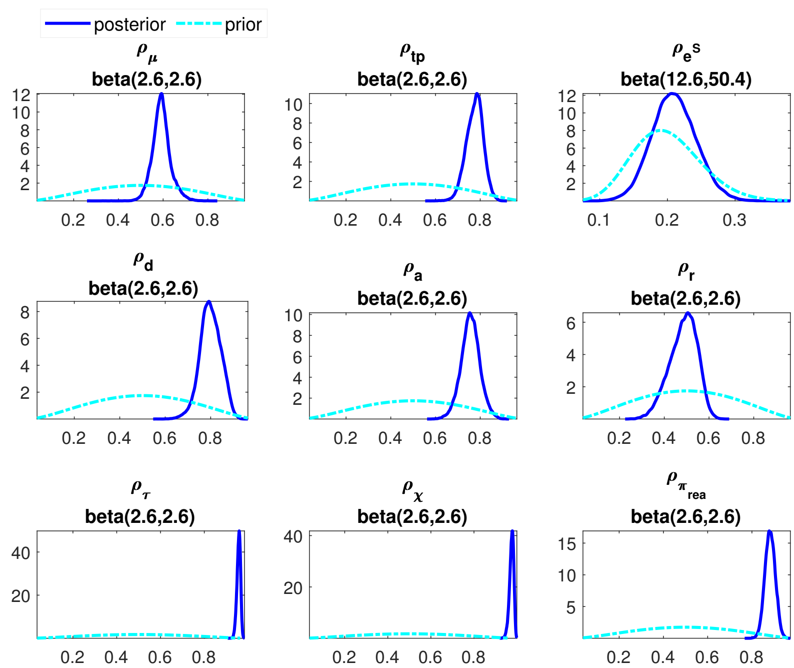
The figure reports the variance decomposition of GDP, inflation, debt-to-GDP, and real rates at different horizons. The decomposition is marked as shades across four shocks: the monetary policy shock, an aggregated measure of fiscal shocks, the preference shock, and the mark-up shock. The white area summarizes the contribution of the remaining shocks, namely shocks to technology, and the rest of EA inflation. Both the standard deviations and variance decompositions take into account the possibility of regime changes. Results are for Italy, under the PM/AF (top panel) and the AM/PF regime (bottom panel).

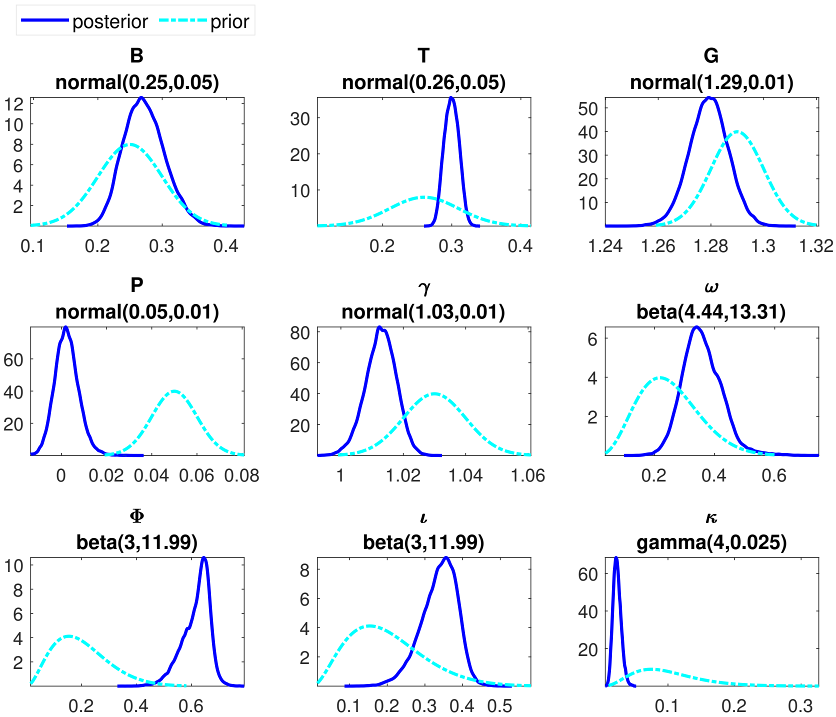
H Model Diagnostics

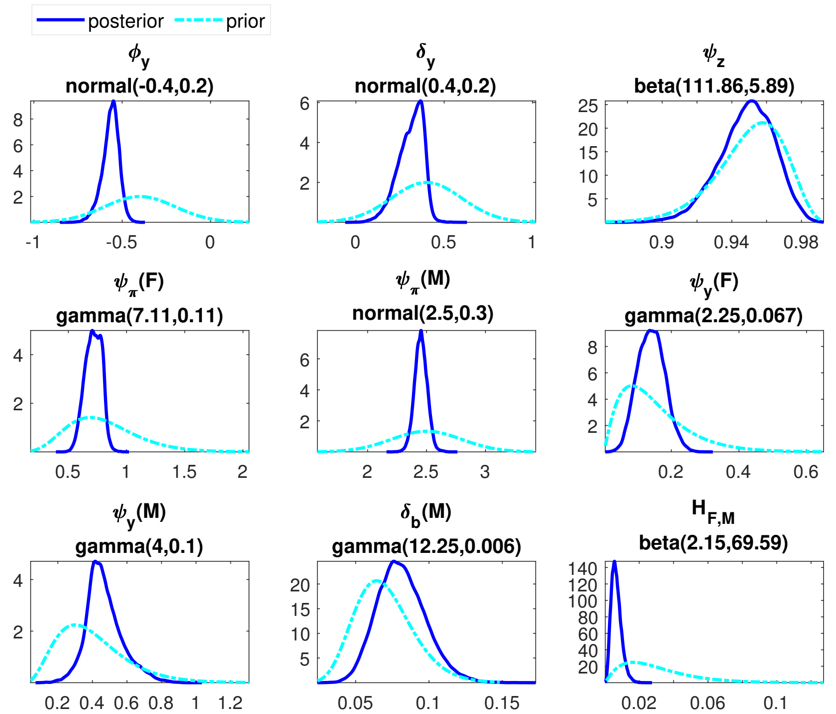
H.1 MCMC Simulation

Figure H.3: France. Posterior and prior densities






posterior
prior
B
normal(0.25,0.05)
T
normal(0.26,0.05)
G
normal(1.29,0.01)
P
normal(0.05,0.01)
γ
normal(1.03,0.01)
ω
beta(4.44,13.31)
Φ
beta(3,11.99)
ι
beta(3,11.99)
κ
gamma(4,0.025)


posterior
prior
ϕ_y
normal(-0.4,0.2)
δ_y
normal(0.4,0.2)
ψ_z
beta(111.86,5.89)
ψ_π(F)
gamma(7.11,0.11)
ψ_π(M)
normal(2.5,0.3)
ψ_y(F)
gamma(2.25,0.067)
ψ_y(M)
gamma(4,0.1)
δ_b(M)
gamma(12.25,0.006)
$H_{F,M}$
beta(2.15,69.59)

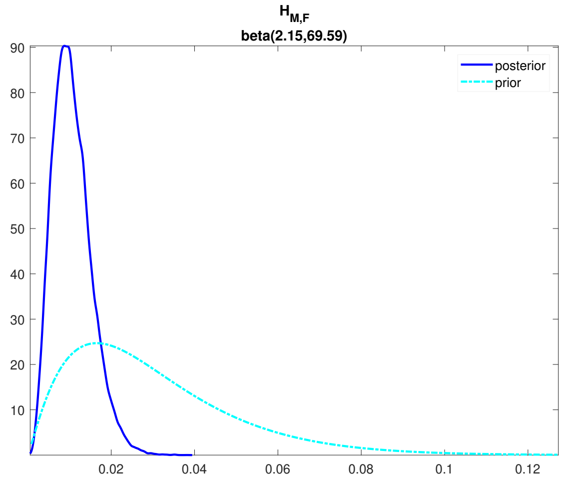
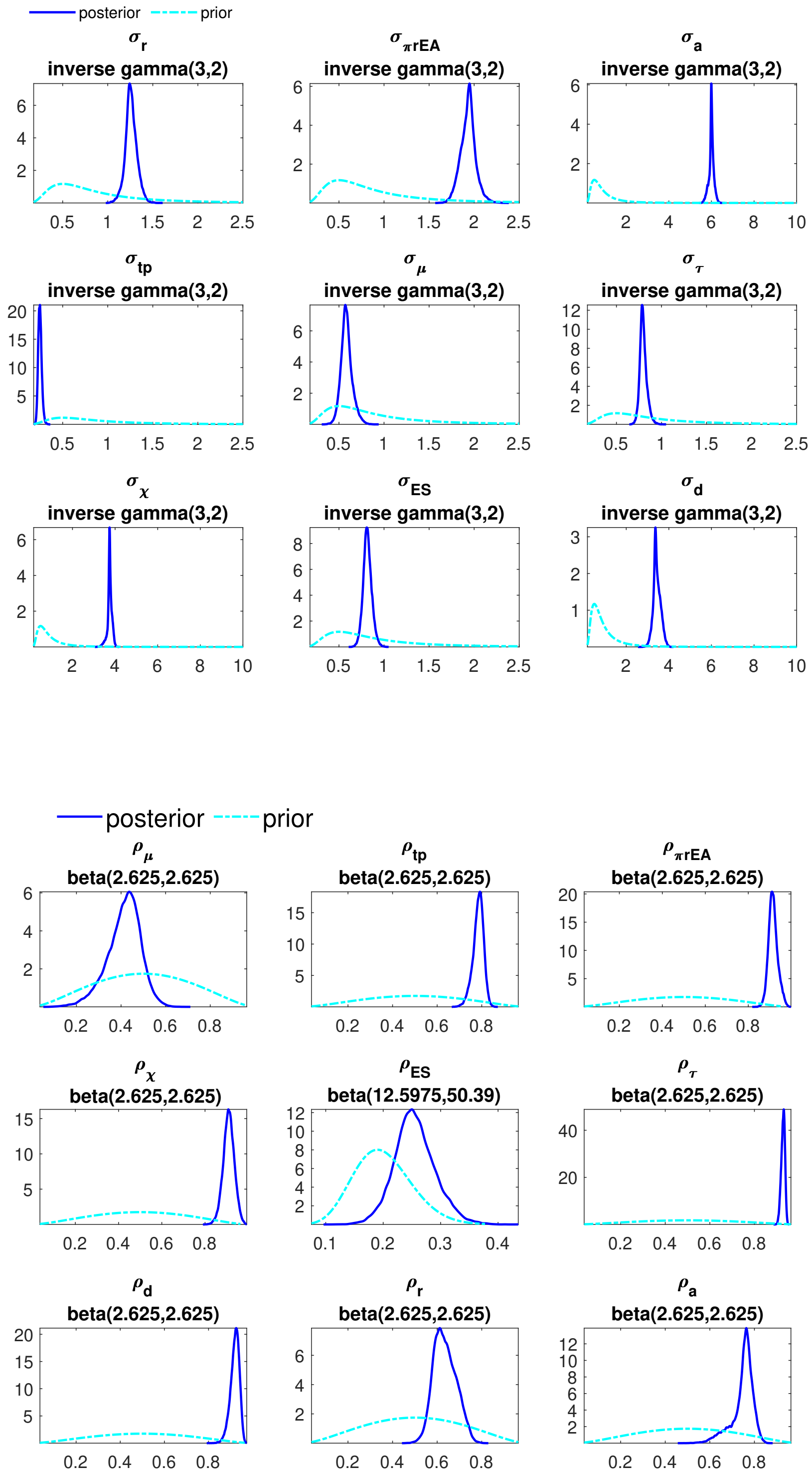
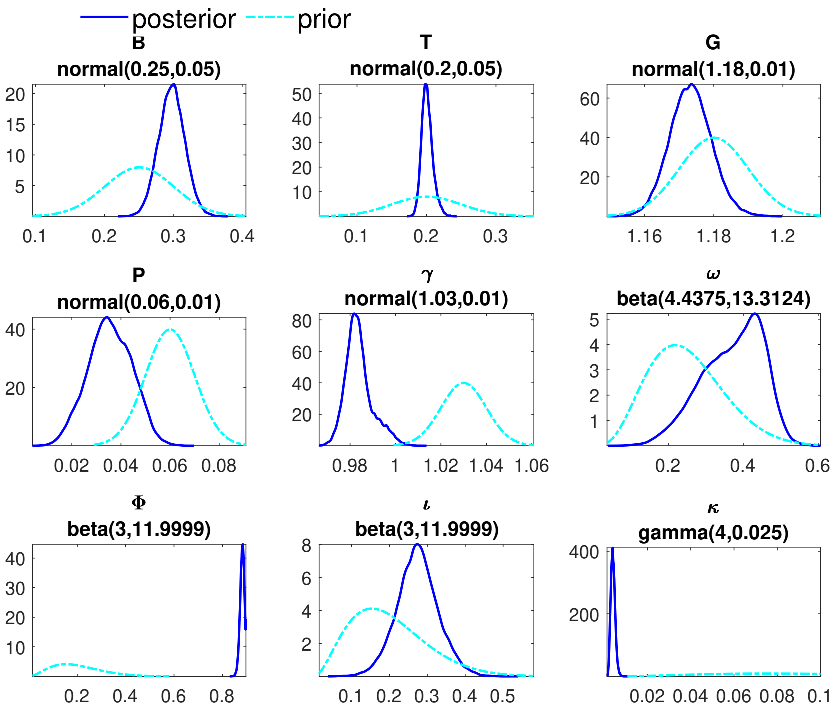
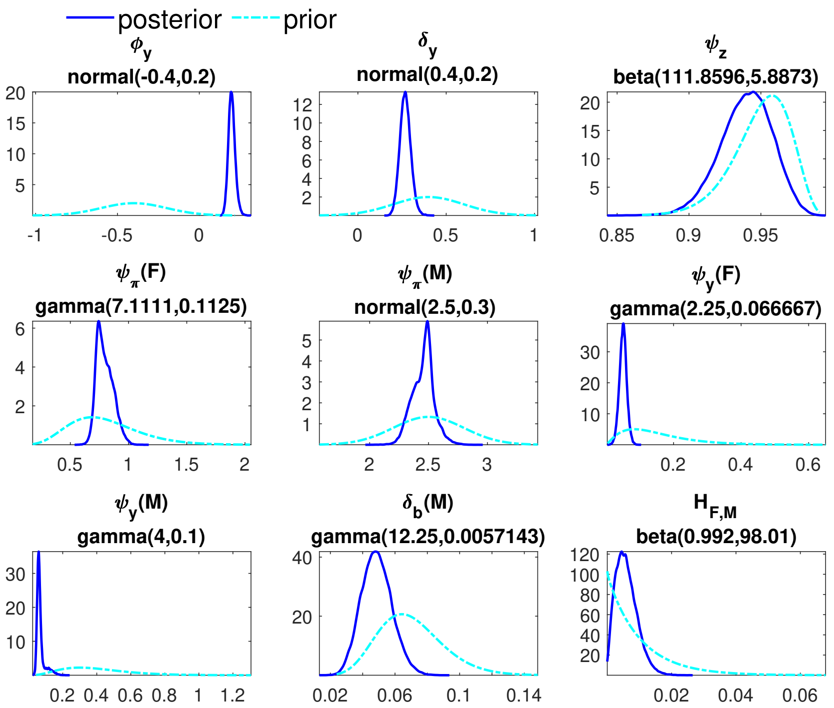
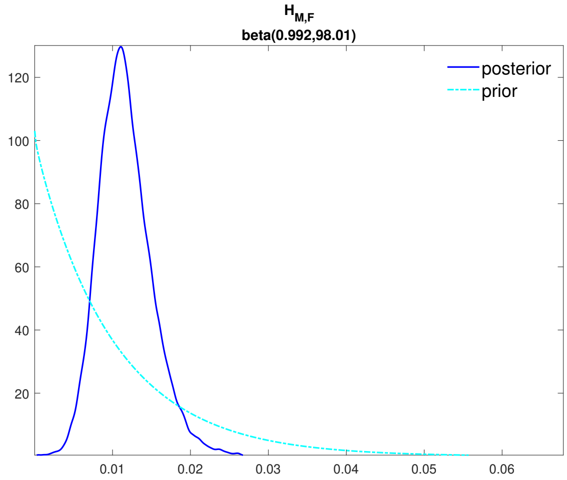

$H_{M,F}$
beta(2.15,69.59)
posterior
prior
90
80
70
60
50
40
30
20
10
0.02
0.04
0.06
0.08
0.1
0.12

Figure H.4: Italy. Posterior and prior densities




posterior
prior
B
normal(0.25,0.05)
T
normal(0.2,0.05)
G
normal(1.18,0.01)
P
normal(0.06,0.01)
γ
normal(1.03,0.01)
ω
beta(4.4375,13.3124)
Φ
beta(3,11.9999)
ι
beta(3,11.9999)
κ
gamma(4,0.025)


posterior
prior
φy
normal(-0.4,0.2)
δy
normal(0.4,0.2)
ψz
beta(111.8596,5.8873)
ψπ(F)
gamma(7.1111,0.1125)
ψπ(M)
normal(2.5,0.3)
ψy(F)
gamma(2.25,0.066667)
ψy(M)
gamma(4,0.1)
δb(M)
gamma(12.25,0.0057143)
HF,M
beta(0.992,98.01)


$H_{M,F}$
beta(0.992,98.01)
posterior
prior
120
100
80
60
40
20
0.01
0.02
0.03
0.04
0.05
0.06

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Othman Bouabdallah
European Central Bank, Frankfurt am Main, Germany; email: Othman.Bouabdallah@ecb.europa.eu

Pascal Jacquinot
European Central Bank, Frankfurt am Main, Germany; email: pascal.jacquinot@ecb.int

Valeria Patella
Sapienza University Rome, Rome, Italy; email: valeria.patella@uniroma1.it

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu

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