DOCUMENTOS DE TRABAJO

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N° 896 Diciembre 2020
BANCO CENTRAL DE CHILE

BANCO CENTRAL DE CHILE

CENTRAL BANK OF CHILE

Documentos de Trabajo del Banco Central de Chile
Working Papers of the Central Bank of Chile
Agustinas 1180, Santiago, Chile
Teléfono: (56-2) 3882475; Fax: (56-2) 3882231

Documento de Trabajo
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Sovereign Default Risk, Macroeconomic Fluctuations and Monetary-Fiscal Stabilization*

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Abstract

This paper examines the role of sovereign default beliefs for macroeconomic fluctuations and stabilization policy in a small open economy where fiscal solvency is a critical problem. We set up and estimate a DSGE model on Turkish data and show that accounting for sovereign risk significantly improves the fit of the model through an endogenous amplification between default beliefs, exchange rate and inflation movements. We then use the estimated model to study the implications of sovereign risk for stability, fiscal and monetary policy, and their interaction. We find that a relatively strong fiscal feedback from deficits to taxes, some exchange rate targeting, or a monetary response to default premia are more effective and efficient stabilization tools than hawkish inflation targeting.

Resumen

Este trabajo examina el impacto del riesgo de impago soberano para las fluctuaciones macroeconómicas y sus implicancias para la política de estabilización para el caso de una economía pequeña y abierta donde la solvencia fiscal no está bien establecida. Desarrollamos y estimamos un modelo dinámico y estocástico de equilibrio general con datos para Turquía. Mostramos que la incorporación de riesgo soberano mejora significativamente el ajuste del modelo, a través de un mecanismo de amplificación endógeno entre las creencias de los agentes sobre el impago soberano y los movimientos del tipo de cambio y la inflación. Luego utilizamos el modelo estimado para estudiar las implicancias del riesgo soberano para la estabilidad macroeconómica, la política fiscal y monetaria, y su interacción. Encontramos que una retroalimentación fiscal relativamente fuerte entre déficits e impuestos, cierta estabilización del tipo de cambio o una respuesta monetaria a los premios por riesgo son herramientas de estabilización más efectivas y eficientes en comparación con una respuesta muy agresiva de política monetaria a movimientos en la inflación.

* The authors would like to thank Fabio Canova, Giancarlo Corsetti, Wouter den Haan, Javier García-Cicco, Markus Hormann, Falko Juessen, Michael Krause, Alexander Kriwoluzky, Ludger Linnemann, Wolfram Richter, Andreas Schabert, Frank Schorfheide, Sweder van Wijnbergen, and participants at various seminars and conferences for valuable comments. Rieth was partly financially supported by the Collaborative Research Center of the German Research Foundation (DFG) [grant SFB 823]. The views and conclusions presented in this paper are exclusively those of the authors and do not necessarily reflect the position of the Central Bank of Chile or its Board members. Email addresses: mkirchner@bcentral.cl (Markus Kirchner), mrieth@diw.de (Malte Rieth).

1. Introduction

Sovereign default risk is a long-standing phenomenon of emerging market economies. Since the global financial and the European debt crisis, it has also become an important policy issue for many advanced economies. In this paper, we analyze the implications of sovereign risk for small open economies from two viewpoints. First, from a modeling perspective, we ask whether and how accounting for sovereign default beliefs helps a quantitative DSGE model with new open-economy macroeconomic (NOEM) foundations to better explain aggregate fluctuations. Second, from a policy perspective, we use the model as a laboratory to study the implications of sovereign risk for fiscal and monetary stabilization.

The first question is motivated by a large literature which analyzes business cycles and economic policy in advanced open economies using quantitative NOEM models (see, for instance, Adolfson et al., 2007; Coenen et al., 2012). Several studies have attempted to extend such models to emerging markets (see Malakhovskaya and Minabutdinov, 2014; de Menezes Linardi, 2016). However, these models are prone to the problem that emerging markets tend to be characterized by fluctuations that are difficult to explain with standard NOEM models. In this paper, we show that investors' beliefs on sovereign debt default are a key ingredient to be able to explain and analyze such fluctuations.

The use of the estimated model as a laboratory is motivated by a set of policy questions about monetary and exchange rate regimes that arise in the presence of sovereign risk. Inflation targeting has become the preferred modus operandi for central banks around the globe (see Ball, 2010). It is praised for its success in bringing down inflation and inflation volatility. However, Blanchard (2005) and Schabert and van Wijnbergen (2014) point out that active monetary policy can actually be destabilizing when fiscal solvency is at risk. When higher sovereign default premia generate an exchange rate depreciation and the following increase in inflation triggers policy-induced higher real rates, this can lead to a further deterioration in the fiscal position, higher default fears and eventually higher inflation. Is hawkish monetary policy under flexible exchange rate thus self-defeating? What is the best stabilization policy in such a situation? In contrast, Krugman (2014) argues that higher sovereign risk is expansionary under flexible exchange rates because the associated depreciation stimulates demand for domestic goods. How does this potential channel depend on monetary policy parameters and structural country characteristics?

To answer these questions, we set up a New Keynesian model of a small open economy with sovereign default risk. In our model, the government borrows in domestic currency at home and in foreign currency abroad. With some probability it is expected to default on (part of) its outstanding debt. There is no strategic default. Default premia are instead determined by a stochastic fiscal limit, similar to Corsetti et al. (2013, 2014). The default beliefs introduce an endogenous risk premium, which depends on government debt and deficits, into the households' Euler equations and into the uncovered interest rate parity condition. In addition, we allow for a pass-through friction from sovereign to private credit conditions, following Uribe and Yue (2006), through a possible dependence of the private external borrowing rate on the government's foreign borrowing rate. Monetary policy is conducted by an inflation-targeting central bank that steers the domestic nominal interest rate and takes into account sovereign risk but is unable to perfectly offset the latter.

To provide a plausible description of the empirical transmission of sovereign risk, the model further incorporates several standard features from existing empirical NOEM models, including incomplete international asset markets, a debt-elastic interest rate premium on private borrowing from abroad and a working capital constraint for firms, while the rest is a medium-scale DSGE framework with capital and a standard set of shocks and rigidities such as sticky wages, habit formation in consumption and investment adjustment costs, as in Christiano et al. (2005) and Smets and Wouters (2007). The model thereby extends the basic frameworks used in related, theoretical studies of the role of sovereign risk in small open economies such as Corsetti et al. (2013) or Schabert and van Wijnbergen (2014) that have used smaller-scale calibrated NOEM models closer to Galí and Monacelli (2005).

We estimate two variants of the model on quarterly Turkish data using a Bayesian approach. The variants differ only with respect to the presence of sovereign default beliefs. We use Turkey as a prototype small, commercially and financially open economy that has adopted an inflation-targeting framework although fiscal solvency is not well established. This country has historically been characterized by large output and exchange rate fluctuations and persistent and volatile inflation, along with significant fluctuations in sovereign risk premia (see Figure 1). It was hit by a financial crisis in 2000/01 when the currency depreciated sharply and interest rates skyrocketed, accompanied by a downgrading of government debt to below investment grade and a spike of sovereign CDS spreads. The crisis in 2018/19 also involved a loss of international investors' confidence, a strong exchange rate depreciation and rapidly rising inflation, although at lower levels than during the first crisis and with a less dramatic fiscal situation. The historical and recent developments indicate that fears of sovereign debt default played a relevant role although a default did not actually occur.

The paper makes two contributions. First, we study the transmission of sovereign risk empirically

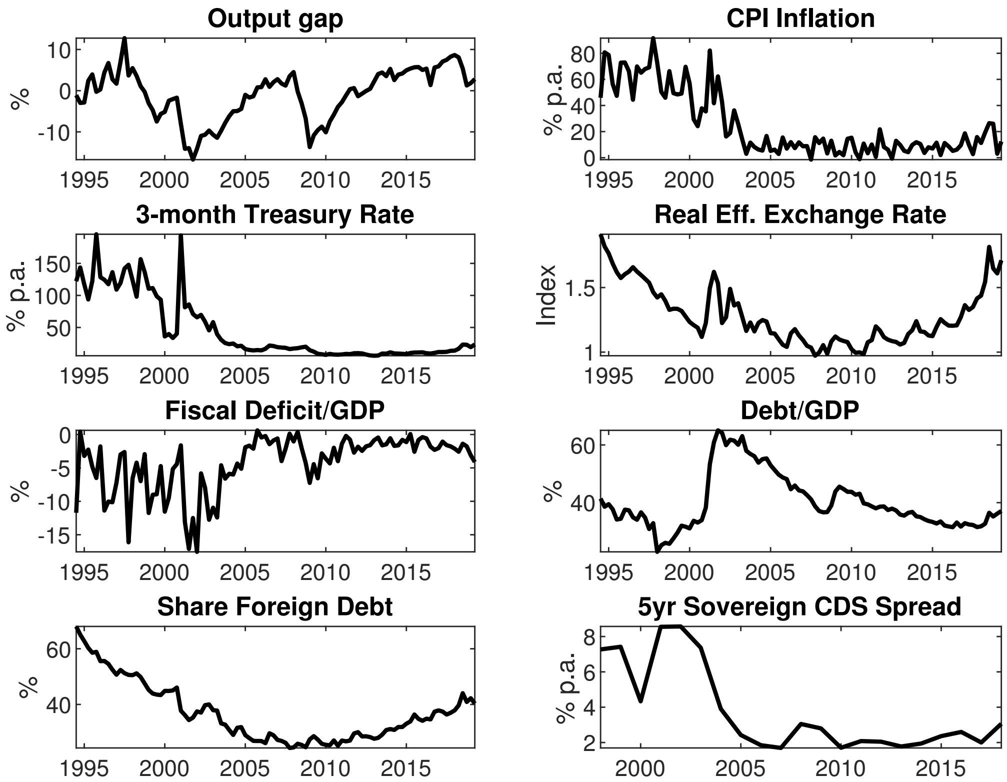

Figure 1: Evolution of macroeconomic variables in Turkey. *Notes.* Period 1994Q3-2019Q2.

and show that accounting for default beliefs significantly improves the fit of the NOEM model. The latter requires smaller shocks and less *ad hoc*, extrinsic persistence and smoothing features to match the data than the version of the model without sovereign risk. Shocks are instead amplified through an endogenous feedback loop from government finances and default premia on the exchange rate, inflation and interest rates, and back to the fiscal position, as well as pass-through effects from sovereign to private credit conditions. Accounting for sovereign risk improves in particular the empirical fit of the consumption and investment equations, as well as the uncovered interest rate parity condition. A formal Bayesian model comparison clearly prefers the model with sovereign risk. We therefore conclude that modeling investors' beliefs on sovereign default can lead to a better understanding of macroeconomic fluctuations in small open economies where fiscal solvency is a relevant concern.

As a second contribution, we use the estimated model as a laboratory to address a number of policy questions about the effects of sovereign risk in inflation-targeting small open economies. In several counterfactuals, we first show that the theoretical argument of Blanchard (2005) and Schabert and van Wijnbergen (2014) on the impact of hawkish monetary policy when fiscal solvency problems exist is an empirically relevant concern. Simulating the estimated model under alternative monetary and fiscal reaction functions, we document that the parameter space which leads to instability is substantially larger with sovereign risk relative to a situation where default beliefs are absent. If the central bank raises nominal rates more than one-for-one with inflation, the feedback coefficient in the tax rule needs to be more than doubled to yield determinacy. We also find that hawkish monetary policy leads to a rejection of Krugman's (2014) dictum in our estimated model, where higher sovereign default beliefs are contractionary even with a flexible exchange rate. Although output rises on impact in response to a sovereign risk shock due to the devaluation, the effect turns contractionary after a few quarters. A counterfactual analysis shows that the size of this contraction depends critically on the monetary policy reaction function: a more aggressive response to inflation generates a stronger contraction, while a weaker response can lead to an output expansion. The effect of sovereign risk on output also depends on structural characteristics and financial frictions, in particular, the size of the import share and the pass-through from sovereign to private credit conditions.

In the same line, we show that a more hawkish monetary policy is both ineffective and inefficient for reducing inflation volatility due to the adverse effect of fluctuations in real rates on the fiscal position, default expectations and the real exchange rate. Fiscal policy, in contrast, by stabilizing deficits, has a strong lever on inflation and is the most efficient tool for reducing inflation volatility. In the limit, a balanced budget rule eliminates the unpleasant amplification of exchange rate and inflation movements due to sovereign risk and replicates the no-default expectations outcome. The second preferred option is exchange rate targeting, which essentially implies 'importing' the international risk-free rate (Schabert, 2011). Finally, we show that lowering the inflation target, whose level is a key determinant of estimated default rates in our model, is the most efficient policy option for reducing observed fluctuations, as it stabilizes both inflation and the currency. All in all, our results underscore the importance of sound fiscal policies and a careful design of monetary rules for the success of inflation-targeting frameworks.

This paper is also related to other recent articles that analyze the interaction between sovereign risk on the one hand and monetary, exchange rate or fiscal policy on the other hand. In a closed economy model, Bocola (2016) examines the transmission of sovereign risk through banks' balance sheets. He shows that higher sovereign risk adversely affects bank funding conditions and raises the riskiness of lending to the productive sector. He then studies monetary policy in form of subsidized loans to banks and shows that such a policy has only limited stabilizing effects. We view our work as complementary as we examine the external channel of sovereign risk, while Bocola (2016) focuses on the domestic pass-through. Corsetti et al. (2013, 2014) also analyze how sovereign risk may affect private credit conditions, assuming that private credit spreads rise with sovereign risk, in calibrated closed economy and two-country models, respectively. In particular, Corsetti et al. (2013) show that, if monetary policy cannot offset increased credit spreads because it is constrained by the zero lower bound or otherwise, the sovereign risk pass-through channel exacerbates indeterminacy problems.[1] In our model, we allow for a potential domestic pass-through from sovereign to private credit conditions through a possible dependence of the private external borrowing rate on the government's foreign borrowing rate. In this sense, compared to the above studies our paper is closer to the literature that emphasizes the relevance of the so-called 'original sin', foreign currency borrowing and currency mismatch in emerging markets, including Céspedes et al. (2004) and Uribe and Yue (2006).

Na et al. (2018) study exchange rate policy and actual defaults. They propose a model with downward nominal wage rigidity that can account for the empirical regularity that defaults are accompanied by large nominal devaluations, which are the outcome of optimal policy decisions. Bianchi et al. (2019) assess optimal fiscal policy under sovereign risk. They show that high levels of debt and sovereign risk premia can rationalize the observed procyclicality of fiscal policy in emerging markets as governments face a trade-off between debt-financed output stabilization and countercyclical sovereign spreads. Finally, Arellano et al. (2020) analyze the relations between strategic sovereign default, monetary policy and debt levels. They show that sovereign risk amplifies inflation volatility, as we do, but then focus on the disciplining effect of this friction on sovereign debt and the experience of Brazil.

The remainder of the paper is organized as follows. Section 2 lays out the model and Section 3 describes its estimation. Section 4 contains the results, and Section 5 concludes.

2. Model

We derive and estimate a New Keynesian DSGE model of a small open economy with sovereign default risk and pass-through to private credit conditions. The model incorporates several standard features of empirical NOEM models including incomplete international asset markets, a debt-elastic interest rate premium on private borrowing from abroad and a working capital constraint for firms. The rest is a medium-scale DSGE framework with capital and a standard set of shocks and rigidities

[1] Corsetti et al. (2014) show that a combination of sovereign risk in one region of a monetary union and procyclical fiscal policy at the aggregate level exacerbates the risk of belief-driven downturns.

such as sticky wages, habit formation in consumption, and investment adjustment costs. This section outlines the basic model ingredients and the main features and assumptions relevant for our analysis of sovereign risk. A complete derivation of the model is provided in the appendix.

2.1. Overall setup

The model has a public and a private sector. In the public sector, a government issues domestic and foreign currency debt. The issuance of debt in foreign currency is motivated by the well-known 'original sin' phenomenon (Eichengreen et al., 2007). This phenomenon describes a situation where a limited internal market for debt generates a need for external financing, but a history of inflation and devaluations makes international investors reluctant to hold domestic currency debt, as in Turkey.

Following Corsetti et al. (2013, 2014) and Schabert and van Wijnbergen (2014), the model considers expectations of sovereign default, which play a central role in the pricing of public debt in emerging market economies and in many advanced economies more recently.[2] In these articles, default premia depend either on the level of government debt or the fiscal deficit. In our specification we allow default expectations to depend on both the level of debt and the deficit. Whether debt or deficits matter for sovereign yields is an open question (see Laubach, 2009), so we let the data decide on the importance of each argument. A common feature across models, including ours, is that the time path of government debt matters for the equilibrium allocation of non-fiscal variables. There is also a monetary authority or central bank that steers the short-term interest rate according to a generalized Taylor-type monetary policy rule.

The private sector consists of households and goods-producing firms, as well as specialized financial intermediaries that channel foreign funds to domestic households and to domestic firms which finance working capital expenditure. Due to a private borrowing premium, the model is stationary (see Schmitt-Grohé and Uribe, 2003). We now describe in more detail the structure of the model.

2.2. Public sector

The public sector consists of a government that conducts fiscal policy and a monetary authority that is in charge of monetary policy.

[2]See Hilscher and Nosbusch (2010).

2.2.1. Fiscal policy

The government issues one-period discount bonds denominated in domestic and foreign currency, $B_{H,t}$ and $B_{F,t}$, respectively.[3] Domestic currency denominated debt is assumed to be held entirely by domestic households, while foreign households hold all foreign currency denominated debt. The government levies lump-sum taxes $P_t\tilde{\tau}_t$ on domestic households and it purchases domestic goods $P_{H,t}g_t$, where P_t and $P_{H,t}$ denote the consumer price level and the price of domestically produced goods, respectively.[4] The monetary authority sets the domestic currency price $1/R_{H,t}$ of domestic bonds, whereas the foreign currency price $1/R_{F,t}$ of foreign currency bonds is determined endogenously in equilibrium. The government follows the (linearized) tax feedback rule

$$\widehat{\tilde{\tau}}_t = \kappa_\tau \widehat{\tilde{\tau}}_{t-1} + (1-\kappa_\tau)\left(\kappa_d \hat{d}_t + \kappa_y \hat{y}_{H,t}\right) + \varepsilon_{\tau,t}, \qquad \kappa_\tau \in [0,1), \tag{1}$$

adjusting lump-sum taxes in response to real fiscal deficit fluctuations $\hat{d}_t$ to ensure long-run debt stability, that is, $\kappa_d > 0$, and to output changes $\hat{y}_{H,t}$. A hat over a variable denotes log deviations from its steady state, and $\varepsilon_{\tau,t} \sim N(0,\sigma_\tau^2)$ is a scaled tax shock.

Following Corsetti et al. (2013, 2014) and Schabert and van Wijnbergen (2014), according to investors' beliefs, the government defaults when fiscal financing would exceed a so-called fiscal limit. Investors do not know the exact value of the fiscal limit, which is determined stochastically, reflecting the uncertainty of the underlying political process. The limit may depend on both the real value of debt, b_t, and the fiscal deficit. We assume that each period the maximum tolerable debt and deficit, $\bar{b}$ and $\bar{d}$, respectively, are drawn from a joint probability density function $f_{\bar{b},\bar{d}}(b_t, d_t)$. The probability of default is then determined by the joint likelihood that $b_t \geq \bar{b}$ or $d_t \geq \bar{d}$, which is given by:

$$\mathfrak{p}_t = F_{\bar{b}}(b_t) + F_{\bar{d}}(d_t) - F_{\bar{b},\bar{d}}(b_t, d_t),$$

where $F_{\bar{b}}(b_t)$ and $F_{\bar{d}}(d_t)$ denotes the marginal cumulative distribution function (cdf) of $\bar{b}$ and $\bar{d}$, respectively, and $F_{\bar{b},\bar{d}}(b_t, d_t)$ is their joint cdf. In case of a default, there is a haircut of size $\omega \in [0,1]$.

[3] Throughout, nominal (real) variables are denoted by capital (lower) letters, asterisks denote foreign variables and variables without time subscript (and bars) denote non-stochastic steady state values.

[4] The assumption that government purchases are fully allocated to domestically produced goods is motivated by empirical evidence for OECD countries of a strong home bias in government procurement, over and above that observed in private consumption .

The default rate is

$$\delta_t = \begin{cases} \omega & \text{with probability } \mathfrak{p}_t, \\ 0 & \text{with probability } 1 - \mathfrak{p}_t. \end{cases}$$

For the local analysis, we obtain $(\delta/(1-\delta))\hat{\delta}_t = \omega\left(\Phi_b \hat{b}_t + \Phi_d \hat{d}_t\right)$. We treat Φ_b and Φ_d as structural parameters capturing the sensitivity of the default rate with respect to the level of debt and the deficit, respectively.[5]

To determine the division of total government debt among domestic and foreign debt, we assume that the government issues foreign debt as a time-varying fraction $f_t \geq 0$ of domestic debt, $X_t B_{F,t}/R_{F,t} = f_t B_{H,t}/R_{H,t}$, which follows $\log(f_t/f) = \rho_f \log(f_{t-1}/f) + \varepsilon_{f,t}$ with $\rho_f \in [0,1)$ and $\varepsilon_{f,t} \sim N(0, \sigma_f^2)$. X_t denotes the domestic currency price of one unit of foreign currency. Shocks to the foreign debt share f_t could be interpreted as changes in risk sentiment in international markets, which are exogenous to a small open economy like Turkey. In addition, on the supply side they capture the government's decision on debt denomination (which we do not endogenize for simplicity). We assume further that savings through default, $\delta_t(B_{H,t-1} + X_t B_{F,t-1})$, are handed out in a lump-sum fashion to domestic and foreign households, through transfers equal to $\delta_t B_{H,t-1}$ and $\delta_t X_t B_{F,t-1}$, respectively.[6] The period-by-period expected government budget constraint for any period t reads

$$B_{H,t}/R_{H,t} + X_t B_{F,t}/R_{F,t} + P_t \tau_t + P_t \tau_t^* = P_{H,t} g_t + (1-\delta_t)(B_{H,t-1} + X_t B_{F,t-1}), \tag{2}$$

where $P_t \tau_t = P_t \tilde{\tau}_t - \delta_t B_{H,t-1}$, $P_t \tilde{\tau}_t^* = -\delta_t X_t B_{F,t-1}$, and g_t follows an autoregressive process in logs: $\log(g_t/\bar{g}) = \rho_g \log(g_{t-1}/\bar{g}) + \varepsilon_{g,t}$ with $\rho_g \in [0,1)$ and $\varepsilon_{g,t} \sim N(0, \sigma_g^2)$.

2.2.2. Monetary policy

In line with the actual behavior of the Central Bank of the Republic of Turkey (CBRT), the main objective of monetary policy is the stabilization of consumer price index (CPI) inflation. We further include an interest smoothing term and we allow for a reaction to output and the expected default rate. This yields the following reaction function:

$$\hat{R}_{H,t} = \alpha_R \hat{R}_{H,t-1} + (1-\alpha_R)\left[\widehat{\breve{\pi}}_t + \alpha_\pi(\hat{\pi}_t - \widehat{\breve{\pi}}_t) + \alpha_y \hat{y}_{H,t} + \frac{\alpha_\delta \delta}{1-\delta} E_t \hat{\delta}_{t+1}\right] + \varepsilon_{R,t}, \ \alpha_R \in [0,1), \tag{3}$$

[5]These satisfy $\Phi_b = \left(f_{\bar{b}}(b) - \frac{\partial F_{\bar{b},\bar{d}}(b,d)}{\partial \bar{b}}\right) b/(1-\delta)$ and $\Phi_d = \left(f_{\bar{d}}(d) - \frac{\partial F_{\bar{b},\bar{d}}(b,d)}{\partial \bar{d}}\right) d/(1-\delta)$.

[6]This assumption is made for technical reasons to prevent the discontinuity due to the resource transfer from foreign to domestic agents in the event of a default that would prohibit the use of local approximation methods.

where $\pi_t \equiv P_t/P_{t-1}$ is home CPI inflation, $\widehat{\breve{\pi}}_t$ is the central bank's inflation objective which follows an exogenous process $\widehat{\breve{\pi}}_t = \rho_{\breve{\pi}} \widehat{\breve{\pi}}_{t-1} + \varepsilon_{\breve{\pi},t}$ with $\rho_{\breve{\pi}} \in [0, 1)$ and $\varepsilon_{\breve{\pi},t} \sim N(0, \sigma^2_{\breve{\pi}})$, while $\varepsilon_{R,t} \sim N(0, \sigma^2_R)$ is an i.i.d. shock to the monetary policy reaction function.

According to (3), the monetary authority targets the headline nominal interest rate and may take into account default expectations. However, because of the interest rate smoothing term, and because in practice it is difficult to construct timely and stable measures of risk premia that can be used to estimate short-term rates net of default reliably, it is unlikely to be able to perfectly offset fluctuations in default premia such that it effectively steers an interest rate that contains a compensation for counterparty risk. Indeed, as argued by Loyo (2005), even an overnight rate contains the sovereign risk premium to the extent that commercial banks hold risky government debt.

2.3. Private sector

The private sector consists of sets of households, financial intermediaries, goods-producing firms and labor market agencies.

2.3.1. Domestic households

There is a continuum of infinitely lived domestic households with identical preferences and asset endowments. A representative household chooses consumption c_t, hours worked n_t, investment i_t, and the asset portfolio described below, to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t z_t [(1-\sigma)^{-1} c_t^{1-\sigma} - \varsigma_{w,t} (1+\eta)^{-1} n_t^{1+\eta}], \quad \beta \in (0,1), \quad \sigma > 0, \quad \eta \geq 0. \tag{4}$$

There are two exogenous preference shifters as in Smets and Wouters (2007): a consumption preference shock z_t and a labor supply/wage markup shock $\varsigma_{w,t}$, with $\hat{z}_t = \rho_z \hat{z}_{t-1} + \varepsilon_{z,t}$, $\rho_z \in [0, 1)$ and $\varepsilon_{z,t} \sim N(0, \sigma^2_z)$, and $\hat{\varsigma}_{w,t} = \rho_w \hat{\varsigma}_{w,t-1} + \varepsilon_{w,t}$, $\rho_w \in [0, 1)$ and $\varepsilon_{w,t} \sim N(0, \sigma^2_w)$. We assume that domestic households invest in domestic but not in foreign currency denominated government bonds, and in foreign currency denominated deposits at financial intermediaries, M_t, at the nominal gross interest rate R_t. Furthermore, they are the owners of domestic capital and choose k_{t+1}, which they rent out to intermediate goods firms at the nominal rental rate R^k_t. The flow budget constraint, which takes into account default beliefs, is then:

$$P_t(c_t + i_t + \tau_t) + B_{H,t}/R_{H,t} + X_t M_t/R_t \leq (1-\delta_t) B_{H,t-1} + X_t M_{t-1} + W^h_t n_t + R^k_t k_t + \Sigma_t, \tag{5}$$

for given initial wealth endowments $B_{H,-1}$, M_{-1} and k_0. Here, W_t^h is the nominal wage rate paid by labor unions and Σ_t collects dividend payouts from ownership of firms, labor unions and financial intermediaries. Following Christiano et al. (2005), the physical stock of capital evolves according to the law of motion

$$k_{t+1} = \mu_t[1 - S(i_t/i_{t-1})]i_t + (1 - \varpi)k_t, \qquad \varpi \in (0, 1], \tag{6}$$

where $S(1) = S'(1) = 0$ and $S''(1) > 0$ and μ_t is an investment efficiency shock with $\hat{\mu}_t = \rho_\mu \hat{\mu}_{t-1} + \varepsilon_{\mu,t}$, $\rho_\mu \in [0, 1)$ and $\varepsilon_{\mu,t} \sim N(0, \sigma_\mu^2)$.

The first-order conditions to the household's problem (see the appendix) include the Euler equation

$$\lambda_t = R_{H,t}\beta E_t[(1 - \delta_{t+1})\lambda_{t+1}\pi_{t+1}^{-1}], \tag{7}$$

where λ_t denotes the Lagrangian multiplier associated with (5). It follows from (7) that, all else equal, a higher expected default rate leads households to demand in return a higher interest rate $R_{H,t}$. From (7) and the first-order condition for foreign assets a real uncovered interest rate parity (UIP) condition can be derived according to which, up to a first-order approximation, the real exchange rate satisfies

$$\hat{R}_{H,t} - E_t[\hat{\pi}_{t+1} + \delta(1 - \delta)^{-1}\hat{\delta}_{t+1}] = \hat{R}_t - E_t[\hat{\pi}_{t+1}^* - \hat{q}_{t+1}] - \hat{q}_t, \tag{8}$$

where $q_t \equiv X_t P_t^*/P_t$ the real exchange rate and $\pi_t^* \equiv P_t^*/P_{t-1}^*$ is foreign CPI inflation. Hence, all else equal, an increase in the expected default rate generates an exchange rate depreciation due to a lower expected return on domestic financial investments.

2.3.2. Foreign households

There is a continuum of infinitely lived foreign households with the same preference structure as domestic households. Analogous to the case of domestic demand described below, a representative foreign household's demand for domestically produced goods satisfies[7]

$$x_{H,t}^* = \vartheta^*(P_{H,t}^*/P_t^*)^{-\gamma^*}y_t^*, \qquad \vartheta^* \in [0, 1], \qquad \gamma^* > 0, \tag{9}$$

[7] In what follows, demanded and supplied quantities are denoted by the letters x and y, respectively.

where $P^*_{H,t}$ is the price of domestic goods expressed in foreign currency and y^*_t denotes aggregate foreign demand. Foreign households also invest in foreign currency denominated bonds issued by the domestic government and have an opportunity cost of funds R^*_t. Therefore, they require that

$$R^*_t = R_{F,t}E_t(1-\delta_{t+1}). \tag{10}$$

According to (10), given R^*_t, an increase in the expected default rate leads foreign households to demand from the domestic government in return a higher interest rate $R_{F,t}$.

Since the foreign economy is exogenous to the domestic economy we assume that foreign variables follow independent AR(1) processes: $\hat{j}_t = \rho_j \hat{j}_{t-1} + \varepsilon_{j,t}$ with $\rho_j \in [0,1)$ and $\varepsilon_{j,t} \sim N(0,\sigma^2_j)$, where $j = y^*, \pi^*, R^*$. Aggregate foreign demand is assumed to satisfy $y^*_t = c^*_t + i^*_t$, where c^*_t and i^*_t are foreign consumption and investment, respectively.

2.3.3. Financial intermediaries

There is a set of perfectly competitive specialized domestic financial intermediaries that receive funds denominated in foreign currency, V_t, from foreign financial intermediaries. The domestic intermediaries use some share of those funds to provide loans for working capital, L_t, to domestic goods-producing firms. The remaining share, M_t, is lent to domestic households. The profits from intermediation are distributed lump-sum to domestic households. The presence of financial intermediaries is motivated by the need for specialist knowledge and monitoring capacity for credit intermediation.

Foreign intermediaries charge an interest rate $R_{v,t}\Upsilon_t$ on the funds they provide, where Υ_t is a borrowing premium that depends on the (real) ratio of *private* foreign debt to domestic output, as follows:

$$\Upsilon_t = \exp[\varphi(v_t - v)/y_H + (\psi_t - \psi)/\psi], \qquad \varphi > 0, \qquad \bar{v} \geq 0, \tag{11}$$

with $v_t \equiv V_t/P_t$. The variable ψ_t is a shock to the premium that satisfies $\hat{\psi}_t = \rho_\psi \hat{\psi}_{t-1} + \varepsilon_{\psi,t}$, $\rho_\psi \in [0,1)$ and $\varepsilon_{\psi,t} \sim N(0,\sigma^2_\psi)$. In addition, we allow for a pass-through of *sovereign* risk to private credit conditions. We assume that the spread between the private borrowing rate without the borrowing premium and R^*_t may depend on the sovereign foreign borrowing spread:

$$R_{v,t}/R^*_t = v_1(R_{F,t}/R^*_t)^{v_2}, \tag{12}$$

where v_1 is used to scale R_v/R^* in steady state and v_2 measures the strength of pass-through.

When $v_1 = v_2 = 1$, the private foreign borrowing rate equals the sovereign rate multiplied by Υ_t. This is the case of full pass-through analyzed by Uribe and Yue (2006). Otherwise, if $v_2 > 0$ there is partial positive pass-through of sovereign risk, similarly as in Corsetti et al. (2013, 2014), and there is no direct effect of sovereign risk on the private foreign borrowing rate when $v_2 = 0$. While the existence of the sovereign risk pass-through channel is not derived in a formal way, it can be motivated by the possibility that in case of a sovereign default the government may divert funds from the repayments made by borrowers (see Mendoza and Yue, 2012). If $v_2 < 0$, private external borrowing occurs at more favorable conditions than public borrowing. For simplicity, we also do not explicitly model the lending spread that foreign intermediaries require in return for their funds, and use instead a reduced-form approach following most of the literature.

The first-order conditions for profit maximization of the financial intermediaries imply

$$R_t = R_{v,t}\Upsilon_t. \tag{13}$$

Hence, the relevant foreign borrowing rate for domestic households and firms increases with $R_{v,t}$ which in turn, according to (12), increases one-for-one with the risk-free foreign interest rate R_t^* and, through the relation $R_{F,t}/R_t^* = 1/[E_t(1-\delta_{t+1})]$, may increase or decrease with the expected sovereign default rate as measured by the pass-through parameter v_2. Using the linearized versions of (12) and (13) in the UIP condition (8) yields

$$\hat{R}_{H,t} - E_t[\hat{\pi}_{t+1} + \delta(1-\delta)^{-1}\hat{\delta}_{t+1}] = \hat{R}_t^* + v_2\delta(1-\delta)^{-1}E_t\hat{\delta}_{t+1} + \hat{\Upsilon}_t - E_t[\hat{\pi}_{t+1}^* - \hat{q}_{t+1}] - \hat{q}_t. \tag{14}$$

All else equal, an increase in the expected default rate generates an additional exchange rate depreciation if sovereign risk is positively passed through ($v_2 > 0$) due to higher required interest on private foreign debt, or attenuates the devaluation if sovereign risk is less than fully transmitted to domestic lending conditions ($v_2 < 0$), reflecting that not all domestic financial assets might be affected by sovereign risk.

2.3.4. Labor market, production and pricing

The labor market is described by the sticky-wage model of Smets and Wouters (2007). A complete characterization of this part of the model is provided in the appendix.

The production sector consists of intermediate, home composite and final goods firms. Final goods are produced by a set of perfectly competitive firms that demand home composite goods, $x_{H,t}$, and foreign goods, $x_{F,t}$, which are combined with the CES technology $y_t = [(1-\vartheta)^{1/\gamma} x_{H,t}^{(\gamma-1)/\gamma} + \vartheta^{1/\gamma} x_{F,t}^{(\gamma-1)/\gamma}]^{\gamma/(\gamma-1)}$, with share parameter $\vartheta \in [0,1]$ and elasticity of substitution between home and foreign goods $\gamma > 0$. The associated profit maximization problem yields demand functions for $x_{H,t}$ and $x_{F,t}$ and an expression for the aggregate price index P_t (see the appendix).

The home composite good $y_{H,t}$ is assembled by a different set of perfectly competitive firms that demand intermediate goods in quantities $x_{H,t}^i$, with $i \in [0,1]$, through the CES technology $y_{H,t} = [\int_0^1 (x_{H,t}^i)^{(\epsilon-1)/\epsilon} di]^{\epsilon/(\epsilon-1)}$, where $\epsilon > 1$ denotes the elasticity of substitution among intermediate goods. Profit maximization by home composite goods producers yields input demand functions for all $x_{H,t}^i$ and an expression for the price index for home composite goods $P_{H,t}$ (see again the appendix).

Intermediate goods production is conducted by a continuum of monopolistically competitive firms. Each firm i uses the technology

$$y_{H,t}^i = a_t k_{it}^{\alpha} (n_{it}^d)^{1-\alpha}, \qquad \alpha \in (0,1), \tag{15}$$

where n_{it}^d and k_{it} is the firm's demand for labor and capital, respectively, and a_t is common factor productivity which follows an autoregressive process: $\hat{a}_t = \rho_a \hat{a}_{t-1} + \varepsilon_{a,t}$ with $\rho_a \in [0,1)$ and $\varepsilon_{a,t} \sim N(0, \sigma_a^2)$. In addition, each firm finances a share $\zeta^w \geq 0$ of the wage bill in advance using intra-period loans L_{it} obtained from financial intermediaries:

$$X_t L_{it}/R_t \geq \zeta^w W_t n_{it}^d. \tag{16}$$

The role of working capital in amplifying business cycle fluctuations in emerging economies has been studied extensively (see, for example, Chang and Fernández, 2013). We analyze its role for shock amplification due to sovereign default beliefs. Intermediate goods producers set their prices $P_{H,t}^i$ to maximize dividend payouts to households. We allow for Calvo-type staggered price setting following Yun (1996). Each period a fraction $1-\phi$ of randomly selected firms is allowed to set a new optimal price $\check{P}_{H,t}^i$. The remaining firms adjust their prices according to the indexation scheme $P_{H,t}^i = (\pi_{H,t-1})^{\iota} (\breve{\pi}_t)^{1-\iota} P_{H,t-1}^i$, where $\iota \in [0,1]$ and $1-\iota$ measure the degree of indexation to past producer price inflation and the current inflation target, respectively.

2.4. Market clearing

Factor, goods and asset markets clear. The small open economy assumption implies that the foreign producer price level, $P^*_{F,t}$, is identical to the foreign CPI, P^*_t. Furthermore, the law of one price is assumed to hold separately for each good (H and F). As the appendix shows, these assumptions allow to derive equations for aggregate supply $y_{H,t}$ and the CPI inflation rate π_t in terms of producer price inflation $\pi_{H,t}$. In addition, an equation describing the evolution of net foreign assets can be derived by combining the household and government budget constraints and substituting out aggregate payouts Σ_t, which gives

$$-X_t[V_t/(R_{v,t}\Upsilon_t) + B_{F,t}/R_{F,t}] = X_t\vartheta^* y^*_t - \vartheta y_t - X_t(V_{t-1} + B_{F,t-1}). \quad (17)$$

The borrowing premium Υ_t ensures that private net foreign assets $-V_t$ are stationary under incomplete international asset markets (see Schmitt-Grohé and Uribe, 2003), while the fiscal rule ensures stationarity of public net foreign assets $-B_{F,t}$. [8]

3. Estimation

We employ a log-linear approximation to the model's equilibrium conditions around the non-stochastic steady state and estimate it by Bayesian methods. Details on the steady state, log-linearization, estimation and data sources and construction are provided in the appendix.

3.1. Data

We use quarterly Turkish data on real GDP, real private consumption, real gross fixed capital formation, real wages, the annualized consumer price inflation rate, the annualized nominal rate on 3-month Turkish lira denominated treasury bills, the real effective exchange rate, real government consumption, the deficit-to-GDP ratio, real foreign GDP, the annualized nominal rate on emerging market dollar denominated sovereign debt, the ratio of foreign currency over domestic currency government debt, and the annualized foreign consumer price inflation rate. The sample period is 1994Q3-2013Q3. Foreign output and inflation are computed as trade-weighted averages of data

[8] Note that the trajectory of government debt has an impact on the private allocation when $f > 0$ through the effect of $B_{F,t}$ through V_t on the private borrowing premium Υ_t. This is because (17) determines V_t while $B_{F,t}$ is determined by $X_t B_{F,t}/R_{F,t} = f_t B_{H,t}/R_{H,t}$ given total government debt which is determined by the government budget constraint (2). That is, Ricardian equivalence does not hold, independently of whether there is sovereign default risk or not. If Υ_t depended instead on the sum of private and public foreign debt, then Ricardian equivalence would hold in the absence of sovereign risk.

for the U.S. and the euro area, which are Turkey's main trading partners. Nominal variables are demeaned consistent with their steady state values. Real variables are in natural logarithms and they are linearly detrended.[9] Finally, we include measurement errors for all domestic observables, following Adolfson et al. (2007), as Turkish data are likely to be measured with noise.[10]

3.2. Calibration

Several steady state values are calibrated consistent with sample averages, while other parameters are calibrated following related studies or normalized to standard values. Specifically, we set $\delta = 1 - \pi/(\beta R_H) = 0.013$ in accordance with an average annual J.P. Morgan Emerging Market Bond Index Global (EMBIG) spread on Turkish government bonds of five percent. Further, we treat the time up to 2002Q4, when the monetary reforms became effective, as a disinflationary period and use the subsequent observations to calibrate the steady state level of inflation and the domestic interest rate. In particular, to match the average annual Turkish inflation rate of 8.9 percent we set $\pi = 1.022$. The average annualized 3-month treasury bill rate was 16 percent, so we set $R_H = 1.04$. We calibrate the steady state foreign interest rate to $R^* = 1.018$ to match an average annual interest rate of 7.0 percent. We set $v_1 = 1$ so that for the case of no pass-through ($v_2 = 0$), the private interest rate equals $R_v = R^*$. Further, the steady state values of the real exchange rate and real private external debt are set to $q = 1$ and $v = 0$, respectively. The elasticities of substitution are $\epsilon = 10$ and $\epsilon_w = 21$ for intermediate goods and labor services, respectively. Regarding the exogenous processes, we set $a = z = \mu = \Upsilon = 1$. We calibrate the AR(1) coefficient of the inflation target process to $\rho_{\breve{\pi}} = 0.975$ and the rate of depreciation to $\varpi = 0.013$, following Adolfson et al. (2007). Given ϖ, we choose a share of capital in production of $\alpha = 0.32$ to roughly match the investment-to-output ratio of 0.21 in the data. We normalize the share of working time to 30 percent. The shares of government consumption and imports in GDP and the ratios of domestic currency and foreign currency debt to annual GDP are set to their empirical counterparts, that is, $s_g = 0.108$, $\vartheta = 0.25$, $s_{b_H} = 1.08$, and $s_{b_F} = 0.60$. We calibrate the import share since including it in the estimation yielded counterfactually low values of this parameter. Finally, we set the Frisch elasticity of labor supply to $\eta = 2$ and for the estimation introduce external habits, setting the degree of habit formation to $h = 0.7$ following Adolfson et al. (2007). The appendix contains a full

[9] We have verified that our main results are robust when estimating the model on data that was detrended using linear-quadratic and Hodrick-Prescott filtered trends.

[10] We calibrate the variances of the measurement errors to five percent of the sample variances of the corresponding data series. The measurement errors then mainly capture high-frequency movements in the data which the model cannot explain through the structural shocks.

table of the calibrated (and implied) parameters and steady state values.

3.3. Priors

We largely follow Adolfson et al. (2007) and Smets and Wouters (2007) in our choice of priors which are documented in Table 1. We elicit beta distributions for the Calvo probabilities ϕ and ϕ_w, the price indexation parameters ι and ι_w, the share of working capital ζ^w, the size of the haircut ω, the policy smoothing coefficients α_R and κ_τ, as well as for the AR(1) coefficients of the stochastic processes, restricting these parameters to their feasible range between 0 and 1. Relatively diffuse gamma priors centered around the Cobb-Douglas case are used for the substitution elasticities of the CES demand functions, γ and γ^*. We also use fairly diffuse gamma priors for the standard deviations of the innovations.[11] The priors for the domestic innovations have larger means and standard deviations than the priors for the foreign innovations. We choose normal distributions for the investment adjustment cost parameter S'' and for the policy reaction coefficients α_π, α_y, α_δ, and κ_y. For the degree of risk aversion, σ, and for the fiscal response to the deficit, κ_d, we use gamma priors. The degree of sovereign risk pass-through, υ_2, obtains a normal distribution centered around zero. For the elasticities of the default rate with respect to debt and deficit, Φ_b and Φ_d, and for the private risk premium elasticity, φ, we use an inverse gamma with infinite standard deviation. These priors are sufficiently diffuse so that the associated mechanisms may 'compete'.

4. Results

The discussion of the results is organized as follows. Section 4.1 analyzes the main mechanisms associated to sovereign risk in a calibrated version of the model. Section 4.2 compares the models with and without sovereign risk according to the estimated parameters and marginal data densities. Section 4.3 highlights the role of sovereign risk for savings and investment decisions. Section 4.4 discusses the transmission channels of sovereign risk based on estimated impulse responses and variance decompositions. Finally, Section 4.5 studies the policy implications of sovereign risk. Additional results and an extensive sensitivity analysis are provided in the appendix.

4.1. Model mechanics

Before analyzing the estimated model, we highlight the main mechanisms focusing on the effects of sovereign default risk on inflation, exchange rate depreciation and domestic output and demand.

[11] We use gamma priors since under inverse gamma priors with fatter tails, the version of the model without sovereign risk relied upon a priori implausibly large shocks to match the data.

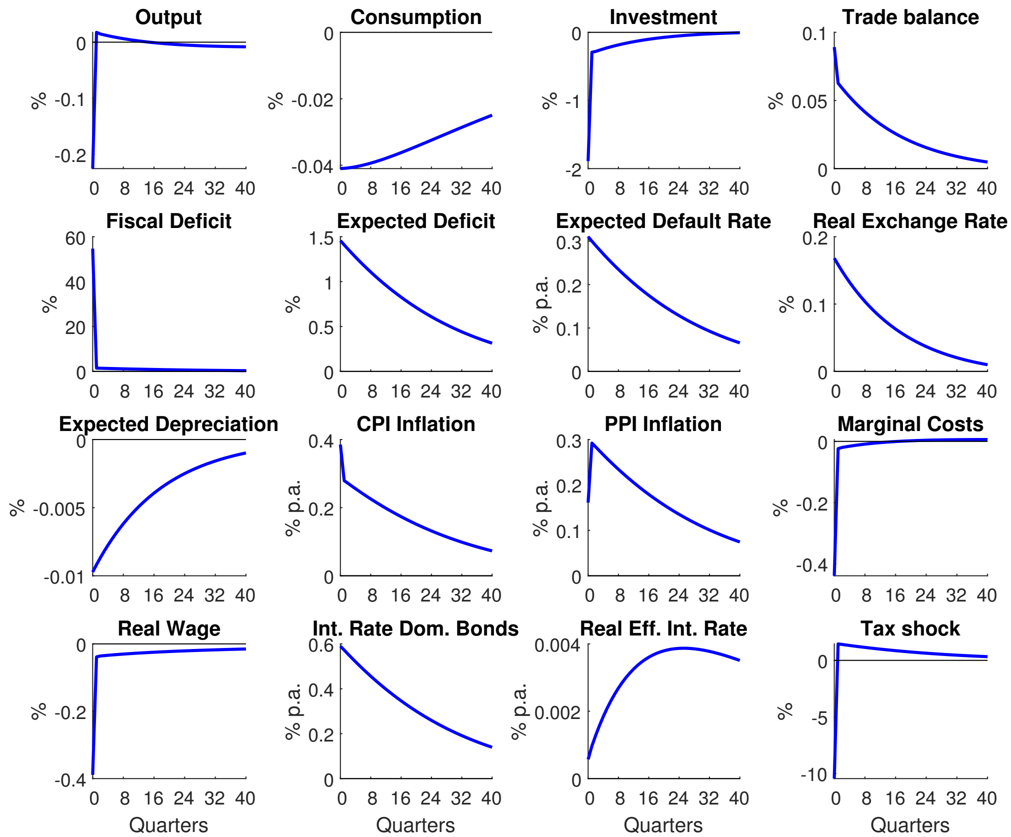

Figure 2: Simulated impulse responses to a negative lump-sum tax shock based on a simplified model with sovereign risk (M_1). *Notes.* The shock is scaled to -10%. Nominal variables and the real effective interest rate are measured in absolute (annual) percentage deviations from steady state, other real variables in relative percentage deviations from steady state.

For this, we show the effects of an 'exogenous' increase in sovereign risk, which is most easily simulated through a negative lump-sum tax shock. To isolate the impact of sovereign risk from other model elements, we eliminate the main extrinsic persistence mechanisms and other model elements by setting $S'' = i_w = i_p = 0$, $\phi_w = 0.01$, $\zeta = 0$, and $\alpha_R = \alpha_y = \alpha_\delta = \kappa_\tau = \kappa_y = 0$. Furthermore, we set $\sigma = 2$, $\gamma = \gamma^* = 1$, $\vartheta = 0.25$, $\Phi_b = 0.01$, $\Phi_d = 0.1$, $\omega = 0.5$, $\upsilon_2 = 0.2$, $\alpha_\pi = 2$, and $\kappa_d = 1$.

Figure 2 shows the impact of a negative tax shock of 10%. The current and expected real fiscal deficits increase sharply as public debt jumps up immediately and returns to trend only slowly. So does the expected default rate. As investors expect a lower effective return on domestic government bonds, they require a future appreciation of the currency. The real exchange rate therefore sharply depreciates upon impact, and then gradually appreciates. The depreciation up front mechanically feeds into consumer price inflation through the composition of the price index as import prices increase. The persistently higher real exchange rate and the associated expenditure switching of domestic and foreign households towards domestic goods induces domestic producers to raise prices, along with the path of the currency. From period 2 onwards, the dynamics of the CPI inflation rate follow the evolution of the producer price index (PPI) inflation rate. The slower initial rise in producer prices reflects the decline in marginal costs due to lower real wages and rental rates on capital.

Domestic households decrease their consumption as the real wage falls, and partly try to offset the increase in marginal utility by drastically reducing investment. Despite the improvement of the trade balance following the real depreciation, output drops on impact, driven by the decline in investment. Thereafter, it overshoots slightly as the higher trade balance outweighs depressed domestic absorption. The central bank responds to the strong increase in inflation by raising the interest rate. The real effective interest rate on domestic government bonds net of default risk hardly moves upon impact, however, as higher nominal rates, inflation and expected default rates offset each other. Thereafter, it increases, contributing to lower consumption, but quantitatively its response is small.

4.2. Model comparison

Table 1 reports the posterior means of the estimated parameters and their 95% highest posterior density intervals for the model with sovereign risk (M_1) and without sovereign risk (M_2). Especially for M_1, most of the estimated values are in line with existing studies of small open economies and Turkey. The autocorrelations of the shock processes are similar to García-Cicco et al. (2010). The reaction coefficients of monetary policy are in line with GMM estimates for the CBRT by Berument and Malatyali (2000) and Yazgan and Yilmazkuday (2007), which indicate a relatively large response to inflation. These studies find no monetary response to fiscal deficit measures or the exchange rate. We investigate this issue in the sensitivity analysis and confirm the first but not the second finding, which may be due to different samples. Moreover, Yazgan and Yilmazkuday (2007) present strong empirical support for a specification with a time-varying inflation target. Regarding fiscal policy, our estimates are in line with Çebi (2012), who finds a similar degree of tax smoothing and that taxes stabilize debt. Also, our result of a strongly active monetary and a relatively passive fiscal authority confirms the analysis of policy interaction of Oktayer and Oktayer (2016).

With $\Phi_b = 0.01$, $\Phi_d = 0.13$, and $\omega = 0.55$ the expected default rate does not respond much to debt but is highly deficit-elastic. An increase in the deficit by 1 percentage point of GDP leads to an increase in expected default risk by about 1.5 percentage points. This result squares with the

				With sov. risk (M_1)		*No sov. risk (M_2)*	
	Parameter	Dom.	Prior	Post.	95% HPDI	Post.	95% HPDI
σ	Risk aversion	$\mathbb{R}^+$	$G(2, 0.5)$	1.82	[1.19, 2.53]	2.37	[1.47, 3.37]
ϕ	Price stickiness	[0,1]	$B(0.75, 0.15)$	0.84	[0.77, 0.91]	0.94	[0.90, 0.99]
ι	Price indexation	[0,1]	$B(0.5, 0.15)$	0.49	[0.24, 0.73]	0.36	[0.16, 0.56]
ϕ_w	Wage stickiness	[0,1]	$B(0.75, 0.15)$	0.86	[0.76, 0.94]	0.84	[0.75, 0.93]
ι_w	Wage indexation	[0,1]	$B(0.5, 0.15)$	0.46	[0.19, 0.75]	0.45	[0.18, 0.72]
ζ^w	Working capital share	[0,1]	$B(0.66, 0.238)$	0.77	[0.50, 0.99]	0.75	[0.46, 0.99]
S''	Inv. adj. cost elast.	$\mathbb{R}$	$N(8, 1.5)$	5.41	[3.19, 7.71]	7.02	[4.50, 9.46]
γ	Subst. elast., home	$\mathbb{R}^+$	$G(1, 0.5)$	0.44	[0.21, 0.67]	0.47	[0.27, 0.65]
γ^*	Subst. elast., foreign	$\mathbb{R}^+$	$G(1, 0.5)$	0.17	[0.04, 0.31]	0.16	[0.04, 0.30]
Φ_b	Default elasticity debt	$\mathbb{R}^+$	IG(0.01)	0.008	[0.00, 0.02]	–	–
Φ_d	Default elasticity deficit	$\mathbb{R}^+$	IG(0.05)	0.133	[0.06, 0.23]	–	–
ω	Haircut	[0,1]	$B(0.5, 0.15)$	0.551	[0.29, 0.83]	–	–
υ_2	Sov. risk pass-through	[0,1]	$N(0, 0.5)$	0.178	[-0.08, 0.41]	–	–
φ	Priv. risk premium elast.	$\mathbb{R}^+$	IG(0.01)	0.004	[0.00, 0.01]	0.004	[0.00, 0.01]
α_R	Int. rate smoothing	[0,1]	$B(0.5, 0.15)$	0.24	[0.08, 0.40]	0.35	[0.19, 0.50]
α_π	Mon. inflation resp.	$\mathbb{R}$	$N(1.5, 0.25, 1)$	2.70	[2.03, 3.37]	1.84	[1.00, 2.70]
α_y	Mon. output resp.	$\mathbb{R}$	$G(0.125, 0.075)$	0.15	[0.02, 0.31]	0.24	[0.09, 0.41]
α_δ	Mon. def. rate resp.	$\mathbb{R}$	$N(0, 0.5)$	0.24	[-0.43, 0.91]	–	–
κ_τ	Tax rate smoothing	[0,1]	$B(0.5, 0.15)$	0.47	[0.28, 0.64]	0.73	[0.57, 0.88]
κ_d	Tax deficit resp.	$\mathbb{R}^+$	$G(1.5, 0.25)$	1.38	[1.04, 1.72]	1.29	[0.87, 1.73]
κ_y	Tax output resp.	$\mathbb{R}$	$N(0.5, 0.25)$	0.56	[0.08, 1.05]	0.52	[0.04, 1.03]
ρ_z	AR(1) cons. preference	[0,1]	$B(0.6, 0.2)$	0.35	[0.08, 0.65]	0.64	[0.45, 0.81]
ρ_μ	AR(1) inv. efficiency	[0,1]	$B(0.6, 0.2)$	0.58	[0.26, 0.87]	0.77	[0.67, 0.88]
ρ_a	AR(1) productivity	[0,1]	$B(0.6, 0.2)$	0.85	[0.74, 0.95]	0.57	[0.22, 0.91]
ρ_w	AR(1) wage markup	[0,1]	$B(0.6, 0.2)$	0.43	[0.20, 0.66]	0.43	[0.18, 0.68]
ρ_g	AR(1) gov. cons.	[0,1]	$B(0.6, 0.2)$	0.62	[0.45, 0.79]	0.62	[0.46, 0.78]
ρ_ψ	AR(1) int. rate parity	[0,1]	$B(0.6, 0.2)$	0.93	[0.85, 0.99]	0.77	[0.61, 0.92]
ρ_f	AR(1) foreign debt share	[0,1]	$B(0.6, 0.2)$	0.95	[0.89, 0.99]	0.95	[0.89, 0.99]
ρ_{y^*}	AR(1) for. demand	[0,1]	$B(0.6, 0.2)$	0.97	[0.94, 1.00]	0.97	[0.94, 1.00]
ρ_{π^*}	AR(1) for. inflation	[0,1]	$B(0.6, 0.2)$	0.35	[0.16, 0.54]	0.35	[0.15, 0.53]
ρ_{R^*}	AR(1) for. int. rate	[0,1]	$B(0.6, 0.2)$	0.88	[0.83, 0.93]	0.87	[0.82, 0.91]
σ_z	Std. cons. pref. inn.	$\mathbb{R}^+$	$G(0.05, 0.025)$	0.092	[0.047, 0.144]	0.177	[0.113, 0.241]
σ_μ	Std. inv. eff. inn.	$\mathbb{R}^+$	$G(0.05, 0.025)$	0.061	[0.012, 0.115]	0.156	[0.099, 0.215]
σ_a	Std. prod. inn.	$\mathbb{R}^+$	$G(0.05, 0.025)$	0.055	[0.024, 0.095]	0.045	[0.009, 0.087]
σ_w	Std. wage markup inn.	$\mathbb{R}^+$	$G(0.05, 0.025)$	0.034	[0.020, 0.050]	0.029	[0.015, 0.044]
σ_g	Std. gov. cons. inn.	$\mathbb{R}^+$	$G(0.05, 0.025)$	0.043	[0.037, 0.051]	0.044	[0.037, 0.050]
σ_τ	Std. tax inn.	$\mathbb{R}^+$	$G(0.05, 0.025)$	0.214	[0.149, 0.283]	0.132	[0.088, 0.181]
σ_f	Std. debt share inn.	$\mathbb{R}^+$	$G(0.05, 0.025)$	0.068	[0.053, 0.083]	0.068	[0.054, 0.083]
σ_R	Std. int. rate inn.	$\mathbb{R}^+$	$G(0.05, 0.025)$	0.038	[0.025, 0.051]	0.054	[0.041, 0.068]
σ_ψ	Std. int. rate parity inn.	$\mathbb{R}^+$	$G(0.05, 0.025)$	0.012	[0.004, 0.020]	0.019	[0.008, 0.031]
$\sigma_{\bar{\pi}}$	Std. infl. target inn.	$\mathbb{R}^+$	$G(0.05, 0.025)$	0.016	[0.011, 0.021]	0.019	[0.013, 0.026]
σ_{y^*}	Std. for. dem. inn.	$\mathbb{R}^+$	$G(0.01, 0.005)$	0.006	[0.005, 0.007]	0.006	[0.005, 0.007]
σ_{π^*}	Std. for. infl. inn.	$\mathbb{R}^+$	$G(0.01, 0.005)$	0.004	[0.003, 0.004]	0.004	[0.003, 0.004]
σ_{R^*}	Std. for. int. rate inn.	$\mathbb{R}^+$	$G(0.01, 0.005)$	0.005	[0.004, 0.005]	0.005	[0.004, 0.005]

Table 1: Prior distributions and posterior estimates of model parameters. *Notes.* The results are based on 750,000 draws from the Metropolis-Hastings (MH) algorithm, dropping the first 250,000 draws and an average acceptance rate of approximately 25%. Posterior mean estimates are reported with their 95% highest posterior density interval (HPDI). $U(a, b)$ refers to the continuous uniform distribution with lower bound a and upper bound b; $B(a, b)$ refers to the beta distribution on the open interval (0,1) with mean a and standard deviation (s.d.) b; $N(a, b, c)$ refers to the normal distribution with mean a and s.d. b, truncated at c; $G(a, b)$ refers to the gamma distribution with mean a and s.d. b; $IG(a)$ refers to the inverse gamma distribution with mean a and infinite s.d.

finding of García-Cicco et al. (2010) for Argentina where the elasticity of the country risk premium with respect to external debt is about one third of our estimate. The difference can be rationalized by the fact that deficits are persistent. If they were uncorrelated then the effect of a higher deficit

	DSGE model		BVAR			
	With sov. risk (M_1)	No sov. risk (M_2)	Lag 1	Lag 2	Lag 3	Lag 4
Log data density	1693.52	1669.90	1080.26	1239.34	1282.18	1332.55

Table 2: Marginal data densities of estimated DSGE model and benchmark BVAR. *Notes.* For the DSGE model, the estimation results are based on 750,000 draws from the MH algorithm, dropping the first 250,000 draws and an average acceptance rate of approximately 25%. Minnesota priors were specified for the BVAR.

or an increase of the debt level on expected future debt would be the same. But since deficits are highly autocorrelated the effect of a higher deficit on the expected debt level in subsequent years is larger than the impact of current increases in debt on future debt. Therefore, estimated elasticities of sovereign yields are larger for deficits than for debt, as shown by Laubach (2009). The estimated expected investor loss in case of a default is 55%. This is the same value as the calibrated haircut in Corsetti et al. (2014) and Bocola (2016), and is close to the empirical estimates of Cruces and Trebesch (2013) who report average haircuts of about 50% in the 1990s and 2000s.

To gauge the plausibility of the implied dynamics of sovereign risk, we compare the smoothed expected default rate with the EMBIG spreads on (i) U.S. dollar denominated Turkish bonds over U.S. treasury bonds and (ii) Euro denominated Turkish bonds over German bunds. The correlation between the model-implied default rate and (i) and (ii) is 0.67 and 0.59, respectively. The default premium implied by our model thus shows similar dynamics as these marked-based measures.[12] In addition, we find some sovereign risk pass-through ($\upsilon_2 = 0.18$), but the estimate is below the calibrated value of 0.55 in Corsetti et al. (2013, 2014) based on estimates by Harjes (2011). The estimated private risk premium elasticity φ, on the other hand, is small in both models. Therefore, that possible alternative financial friction does not seem to be important. We return to this point below.

Overall, M_1 relies less on smoothing and extrinsic persistence mechanisms to match the data. The degree of risk aversion σ, the investment adjustment cost elasticity S'' and the Calvo parameter ϕ are all smaller than in M_2. The serial correlations of the consumption preference shock (ρ_z) and of the investment efficiency shock (ρ_μ) are also markedly lower. Moreover, several innovation standard deviations are smaller, in particular of the consumption preference shock (σ_z) and of the investment efficiency shock (σ_μ).

According to Table 2, a formal model comparison clearly supports the model with sovereign

[12]There is a fairly strong co-movement, although the EMBIG indicates smaller default premia before 2000 and during the mid-2000s (see appendix).

risk. The Bayes factor is $p(Y^T|M_1)/p(Y^T|M_2) = \exp(23.62)$ or 1.81×10^{10}, indicating strong support for M_1 over M_2 conditional on the observed data. Finally, to evaluate whether either of the model variants provides a reasonable description of the data we compare them to a non-structural alternative in form of a Bayesian VAR. Table 2 shows that both variants perform better than BVARs with up to four lags in terms of the estimated data densities, indicating strong support for the specified DSGE model as an empirical device to study macroeconomic fluctuations and sovereign risk in the small open economy at hand.

4.3. Default premia and intertemporal margins

Why does M_1 fit the data better? To provide an intuition we write the consumption Euler equation, including habits as in the estimation, as

$$\frac{\sigma}{1-h}(E_t\hat{c}_{t+1} - \hat{c}_t) = \hat{R}_{H,t} - E_t\hat{\pi}_{t+1} - \frac{\delta}{1-\delta}E_t\hat{\delta}_{t+1} - (1-\rho)\hat{z}_t + \frac{\sigma h}{1-h}(\hat{c}_t - \hat{c}_{t-1}). \quad (18)$$

Suppose that expected consumption growth $E_t\hat{c}_{t+1} - \hat{c}_t$ shows 'different' dynamics than the ex ante real interest rate $\hat{R}_{H,t} - E_t\hat{\pi}_{t+1}$. For example, according to both models, estimated expected consumption growth was low in the first half of the sample whereas the real interest rate was high. There are two channels through which M_2 can reconcile this: through consumption preference shocks (z_t) or a high degree of risk aversion (σ), for given habit formation (h). In the first case households have a preference for temporarily higher or lower consumption, while in the second case they dislike consumption fluctuations more. Both channels generate a smooth consumption path even if the real interest rate is not smooth. In M_1, there is a third channel due to sovereign risk: a positive expected default rate can balance (18) with relatively small demand shocks and lower values of σ. Households would then invest less in domestic bonds when the real interest rate is high due to stronger default fears, and vice versa, as reflected by the effective real interest rate net of default risk, $\hat{R}_{H,t} - E_t\hat{\pi}_{t+1} - \delta/(1-\delta)E_t\delta_{t+1}$. These arguments also explain part of the estimation results: smaller preference shocks occur in M_1 and the degree of risk aversion is lower.

To illustrate these points, the top panel of Figure 3 plots the estimated contributions of consumption preference shocks to the observed evolution of domestic consumption for both models, obtained from historical decompositions. In M_1 (right bars) smaller shocks are inferred than in M_2 (left bars), in particular before and during the financial crises in 2000/01 and 2008/09. This leaves

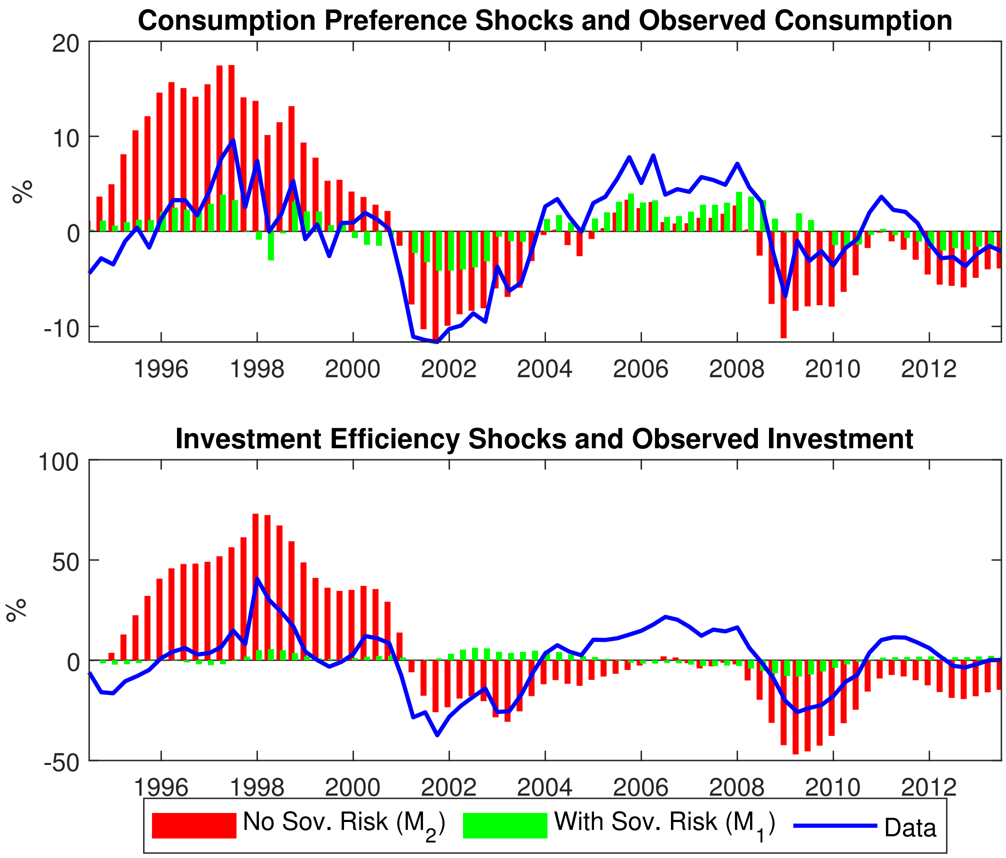

Figure 3: Contribution of consumption preference shocks to observed consumption and contribution of investment efficiency shocks to observed investment. *Notes.* Estimated contributions for the period 1994Q3-2013Q3.

more room for other shocks to drive consumption through internal model propagation.[13]

Similar reasoning applies to investment dynamics. Combining (18) with the Euler equation for investment yields a relation that links the interest rate differential between the (net) rates of return on domestic government bonds and physical investment to the dynamics of investment growth:

$$\hat{R}_{H,t} - E_t\left[\hat{\pi}_{t+1} + \beta r^k \hat{r}^k_{t+1} + \frac{\delta}{1-\delta}\hat{\delta}_{t+1}\right] = S''(\hat{\imath}_t - \hat{\imath}_{t-1}) - \beta\omega S''\left(\hat{\imath}_{t+1} - \hat{\imath}_t\right) - \beta^2(1-\omega)S''\left(\hat{\imath}_{t+2} - \hat{\imath}_{t+1}\right) - (1+\rho_\mu)\beta(1-\omega)\hat{\mu}_t. \quad (19)$$

Without sovereign risk, large fluctuations in the interest rate differential can be matched with smooth investment growth through high adjustment costs S'', large efficiency shocks μ_t, or a high

[13]The better performance of M_1 is corroborated when comparing the ability of both models to match selected moments especially of domestic consumption and investment. It comes closer to the data in terms of the standard deviations relative to output, correlations with output, as well as several standard deviations and auto-correlation coefficients. Moreover, the one-step ahead mean and mean squared forecast errors for most domestic variables is smaller in M_1. These results are provided in the appendix.

autocorrelation ρ_μ of these shocks. With sovereign risk, there is another channel, as changes in the expected default rate can balance (19) for lower values of S'' and smaller as well as less autocorrelated investment efficiency shocks. This is what we find in the estimation. As an illustration, the bottom panel of Figure 3 shows that M_1 requires substantially smaller efficiency shocks to explain observed investment than M_2.

Finally, we examine the importance of sovereign vis-à-vis private risk in explaining macroeconomic fluctuations using the uncovered interest rate parity condition, which is given by

$$\hat{R}_{H,t} - E_t\left[\hat{\pi}_{t+1} + \frac{(1+\upsilon_2)\delta}{1-\delta}\hat{\delta}_{t+1}\right] = \hat{R}^*_t - E_t[\hat{\pi}^*_{t+1} - \hat{q}_{t+1}] - \hat{q}_t + \frac{\varphi}{y_H}\tilde{\upsilon}_t + \psi_t. \tag{20}$$

Eq. (20) shows that the private risk premium represents an alternative channel that–through (18) and (19)–can potentially reconcile observed changes in interest rates, inflation and the exchange rate with the evolution of domestic demand. Moreover, changes in private risk premia could be an alternative source of model-endogenous fluctuations as they affect domestic production through the cost of working capital. However, the estimation results show that the private risk channel plays only a minor role in driving cyclical fluctuations. The estimated elasticity φ is close to zero, whereas the default elasticitiy Φ_d is large and the degree of sovereign risk pass-through υ_2 is positive. Finally, the model without sovereign risk relies on larger risk premium innovations to balance (20).

4.4. Sovereign risk transmission and monetary policy

We now discuss in detail the transmission of sovereign risk in the estimated model and the role of monetary policy in the transmission mechanism.

4.4.1. Determinants of pass-through and monetary policy

We now present the impulse responses to a negative tax shock of 10%, as before, but including all persistence mechanisms as estimated in M_1. The solid lines in Figure 4 show that, qualitatively, the responses are similar to the simplified version but more persistent. Due to habit formation and adjustment costs, both consumption and investment show a hump-shaped response. This is reflected in the evolution of the real exchange rate which, as before, sharply depreciates upon impact. But now, the depreciation is much stronger as the estimated default elasticity is higher such that output increases shortly, before dropping persistently below trend in line with the evolution of domestic demand. Due to the larger depreciation, CPI inflation jumps up by more. Afterwards, it reverts and converges towards its long-run trend following the dynamics of PPI inflation. The latter is

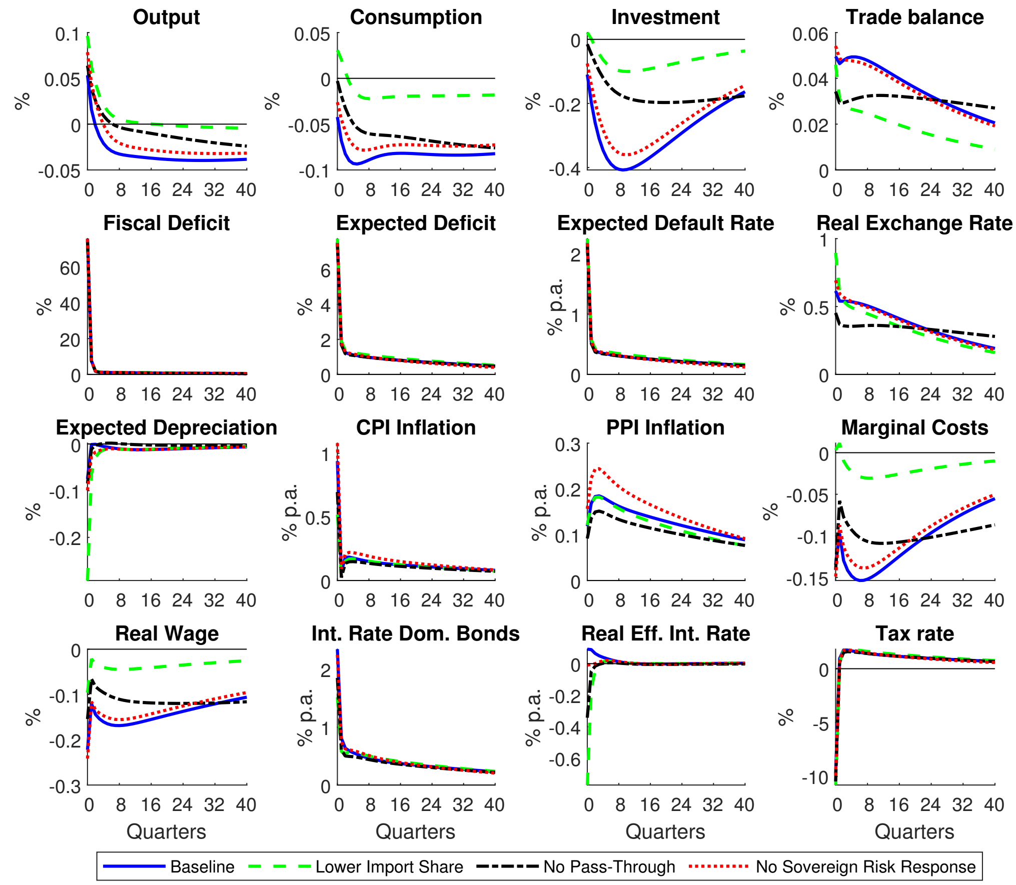

Figure 4: Counterfactual impulse responses to a negative tax shock of 10% based on the model with sovereign risk (M_1). *Notes.* Counterfactual impulse responses are calculated at the posterior mean (blue solid line), and setting $\vartheta = 0.1$ (green dashed lines), $v_2 = 0$ (black dash-dotted lines), or $\alpha_\delta = 0$ (red dotted lines).

more hump-shaped now due to indexation. The central bank responds to higher CPI inflation by tightening monetary policy and the real effective interest rate increases.

We add several counterfactuals to the figure to illustrate how selected model elements affect these dynamics. First, we focus on two parameters that determine the strength of the transmission of sovereign risk to the domestic economy: the import share and the pass-through of sovereign risk to private credit conditions. The dashed line shows a case where the import share is lowered from $\vartheta = 0.25$ in the baseline to $\vartheta = 0.10$. While the depreciation is similar as in the baseline model, its impact on domestic consumption and investment is substantially smaller as the effect of falling imports weighs less on demand. Accordingly, the increase in the trade balance is more muted and wages as well as marginal costs fall by less. Output and consumption actually rise for several quarters. The pass-through channel has qualitatively similar implications. When setting $v_2 = 0$ (dash-dotted lines), the responses of both quantities and prices are more muted. As now the relevant private foreign borrowing rate is not subject to default risk, the initial depreciation is smaller. So are the associated increase in CPI inflation and the response of monetary policy.

To further study the role of monetary policy in the transmission of sovereign risk, we set $\alpha_\delta = 0$ (dotted lines). Relative to the baseline dynamics, quantities tend to respond less while prices react more. This asymmetry suggest a policy trade-off to which we return below. As the central bank does not aim at offsetting the increase in expected sovereign risk, the real depreciation needs to be stronger in order to generate a larger expected appreciation subsequently. The additional depreciation pushes up consumer and producer price inflation further. At the same time, it raises foreign and domestic demand for home goods such that output and labor now both increase by more. Accordingly, consumption and investment fall less.

4.4.2. Krugman's (2014) dictum

Another important element of monetary policy for the transmission and effects of sovereign risk is the central bank's response to inflation. Krugman (2014) argues that sovereign risk may be expansionary in open economies with floating exchange rates because, in contrast to a fixed exchange rate regime, it produces a real depreciation and thereby boosts foreign demand for home goods. We use M_1 to evaluate this argument and show that its validity critically depends on the response of monetary policy to inflation.

Figure 5 repeats the baseline responses following a surprise increase in sovereign risk (simulated as before as a negative tax shock), which is contractionary from the second quarter onwards. The dashed lines show a case with a weaker inflation response of the monetary authority ($\alpha_\pi = 1.5$). Now, output increases persistently. A more dovish central bank allows the currency to depreciate more, which leads to a larger increase in the trade balance. Moreover, the depreciation raises external borrowing costs and increases the default rate further. The real effective interest rate is therefore lower than in the baseline and the drop in domestic consumption and investment is attenuated. In contrast, under more hawkish monetary policy (dotted lines, $\alpha_\pi = 5.0$), the effective interest rate is higher, the exchange rate depreciates less, the trade balance improves less, and consumption, investment as well as output fall by more than under the baseline.[14]

The effects are similar if the central bank targets (changes in) the nominal exchange rate ($\alpha_{\Delta X} =$

[14] Krugman (2014) also discusses the role of monetary policy. He argues that a strong increase in the policy rate in the U.S. and the U.K. is unlikely as both monetary authorities are stuck at the effective lower bound (at the time of his writing). He allows, however, for the possibility that sovereign risk can be contractionary if the central banks aggressively raise rates in an attempt to maintain inflation and inflation expectations. This is what we find in our analysis. Whether higher sovereign risk is expansionary or contractionary also depends on structural characteristics and financial frictions, in particular, the size of the import share and the feedback from sovereign risk to private credit conditions (see Figure 4).

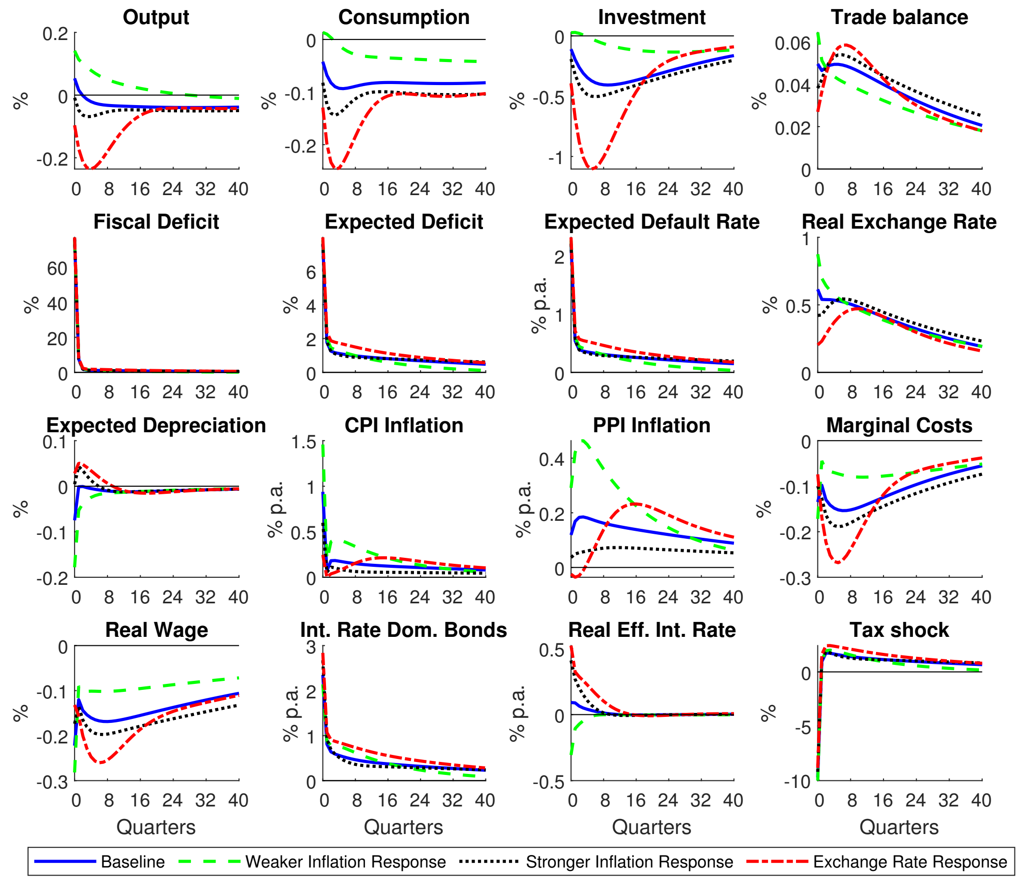

Figure 5: The role of monetary policy's inflation and exchange rate response. *Notes.* The tax shock is –10%. Impulse responses are calculated at the posterior mean of the baseline model M_1 (blue solid line), and setting $\alpha_\pi = 1.5$ (green dashed lines), $\alpha_\pi = 5$ (black dotted lines) or $\alpha_{\Delta X} = 3$ (red dash-dotted lines).

3, dash-dotted line). The decline in capital inflows following the shock drives up the interest rate until the point where investors are indifferent between domestic and foreign assets. Domestic demand collapses and prices rise less so that net exports increase. This is what Krugman calls the 'Greek-style scenario'. Output of countries with fixed exchange rate regimes, such as in a currency union, is more exposed to sovereign risk shocks as the current account change needs to be achieved via import compression. Under flexible exchange rates, such shocks are instead partially absorbed through a depreciation and an increase in exports.

4.4.3. Drivers of fluctuations

We now examine the importance of different shocks for the dynamics of the endogenous variables in both versions of the model. Table 3 contains the estimated unconditional variance decomposi-

	With sov. risk (M_1)									*No sov. risk (M_2)*							
	Output	Cons.	Inv.	Infl.	Int. rate	Real wage	RE-ER	Def./GDP	Def. rate	Output	Cons.	Inv.	Infl.	Int. rate	Real wage	RE-ER	Def./GDP
									$h = 0$								
Cons. pref. ε_z	0.8	3.8	0.4	0.0	0.1	0.2	0.0	0.0	0.0	12.1	52.3	5.1	0.2	0.8	7.6	1.1	0.1
Inv. eff. ε_μ	0.9	0.2	2.2	0.0	0.0	0.0	0.4	0.0	0.0	48.0	8.2	81.8	0.2	0.4	2.8	18.7	0.0
Productivity ε_a	53.7	14.4	35.1	7.4	12.8	1.3	21.2	3.1	2.5	0.3	0.1	0.0	0.0	0.1	2.4	0.1	0.0
Wage markup ε_w	15.1	4.2	9.7	2.6	4.8	30.5	5.6	1.1	0.9	1.5	0.4	0.2	0.1	0.2	54.2	0.5	0.0
Gov. cons. ε_g	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
For. debt share ε_g	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lump-sum tax ε_f	0.4	1.6	0.9	0.9	2.3	1.6	2.1	68.0	69.6	0.1	0.3	0.1	0.0	0.0	0.2	0.3	81.6
Int. rate ε_R	1.2	0.7	0.3	1.9	3.1	0.2	0.6	0.8	0.8	16.9	3.8	1.6	5.1	16.0	1.7	7.6	6.3
Infl. targ $\varepsilon_{\bar{\pi}}$	18.9	59.5	21.0	78.2	60.6	46.5	34.3	22.7	22.6	11.5	30.4	9.6	90.1	75.5	25.6	42.4	8.6
For. demand ε_{y^*}	0.5	0.7	0.2	0.0	0.1	0.9	1.1	0.0	0.0	1.7	2.4	0.8	0.1	0.1	2.4	5.7	0.0
For. inflation ε_{π^*}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
For. int. rate ε_{R^*}	0.2	0.9	1.2	1.1	2.0	1.1	2.2	0.7	0.6	0.5	0.7	0.3	0.6	1.2	0.6	6.5	0.7
Int. rate parity ε_ψ	8.1	13.9	29.0	7.9	14.2	17.8	32.4	3.6	2.9	6.4	1.4	0.5	3.5	5.7	2.4	17.0	2.5

Table 3: Unconditional posterior variance decomposition. *Notes.* Table entries refer to the contribution to the unconditional variance (in percent) at the posterior mean. Some of the totals may not sum up to 100% due to rounding errors.

tions of selected variables.[15] In line with the results above, the presence of sovereign risk strongly reduces the role of preference and efficiency shocks as drivers of consumption, investment and output dynamics, compared to the model without sovereign risk. Those variables are instead mainly explained by productivity and inflation target shocks.

The expected default rate is primarily driven by tax and inflation target shocks. The latter are important for most variables. In the following, we first explain the transmission of target shocks and then why they are so important at long horizons. Positive target shocks trigger similar dynamics as negative tax shocks. They induce domestic producers to leads to higher prices which also raises consumer prices. The monetary authority responds by strongly raising rates. This increases real interest rates, the real government deficit and the expected default rate. The latter implies a depreciation up front followed by an expected appreciation for investors to hold domestic currency denominated government bonds. The depreciation feeds back into inflation, amplifying and prolonging its initial increase. At the same time, the higher default rate offsets the increase in the real rate, such that the real effective interest rate actually declines for several quarters. This adds to the improvement of the trade balance induced by the depreciation and leads to overall higher output.

Inflation target shocks are important because they are very persistent and directly affect domestic variables, as opposed to foreign demand shocks which are similarly persistent. This implies strong increases in PPI inflation according to the forward-looking component of the Phillips curve,

[15]The appendix contains the conditional variance decomposition at horizons of 1, 4, 12 and 40 quarters.

and hence CPI inflation, as well as large increases in policy rates, real interest rates and fiscal deficits.[16] Finally, we note that productivity shocks are also an important driver of many variables up to medium-term forecast horizons (see appendix).

4.5. Policy implications of sovereign risk

Our sample is characterized by a gradual move by the Turkish central bank towards an inflation targeting framework with a flexible exchange rate, similarly as in many other emerging markets like Brazil, Mexico, or Russia. At the same time, the findings of the previous sections suggest that sovereign default risk can be a key determinant of macroeconomic fluctuations in a small open economy. What could be done in such a situation to keep inflation in check? What are the associated policy risks and trade-offs? In this section, we use our model to provide answers to these questions.

4.5.1. Is hawkish monetary policy self-defeating?

One option to stabilize inflation is a tough stance of monetary policy towards it. However, Blanchard (2005) argues and Schabert and van Wijnbergen (2014) formally show that this gives rise to the possibility that fiscal credibility may be impaired because of higher debt servicing costs in the face of inflationary surprises. In an extreme case, the argument goes, hawkish monetary policy can be self-defeating through adverse feedback dynamics from monetary-policy induced higher real rates on fiscal deficits, default expectations, exchange rate depreciation, and an eventual further increase in inflation. Aggressive monetary policy would then generate unstable dynamics. We now use our estimated model as a laboratory to study under which circumstances this is the case and why.

The black area in Figure 6 shows the region where the model has a unique stable equilibrium as a function of the monetary response to the inflation gap, α_π, and of the fiscal reaction to the deficit, κ_d. We compare the determinacy regions of the estimated model with sovereign risk and of a version where $\Phi_b = \Phi_d = 0$. The gray area with circles shows the parameter space that is added to the region of instability due to the existence of sovereign default beliefs. Here, unstable dynamics arise in which higher real interest rates imply such a deterioration in the fiscal position and corresponding default expectations that capital outflows and the depreciation of the currency lead to additional inflation and instability. If monetary policy is active, that is, if it responds to

[16] We use the persistence to distinguish these shocks empirically from i.i.d. domestic interest rate shocks.

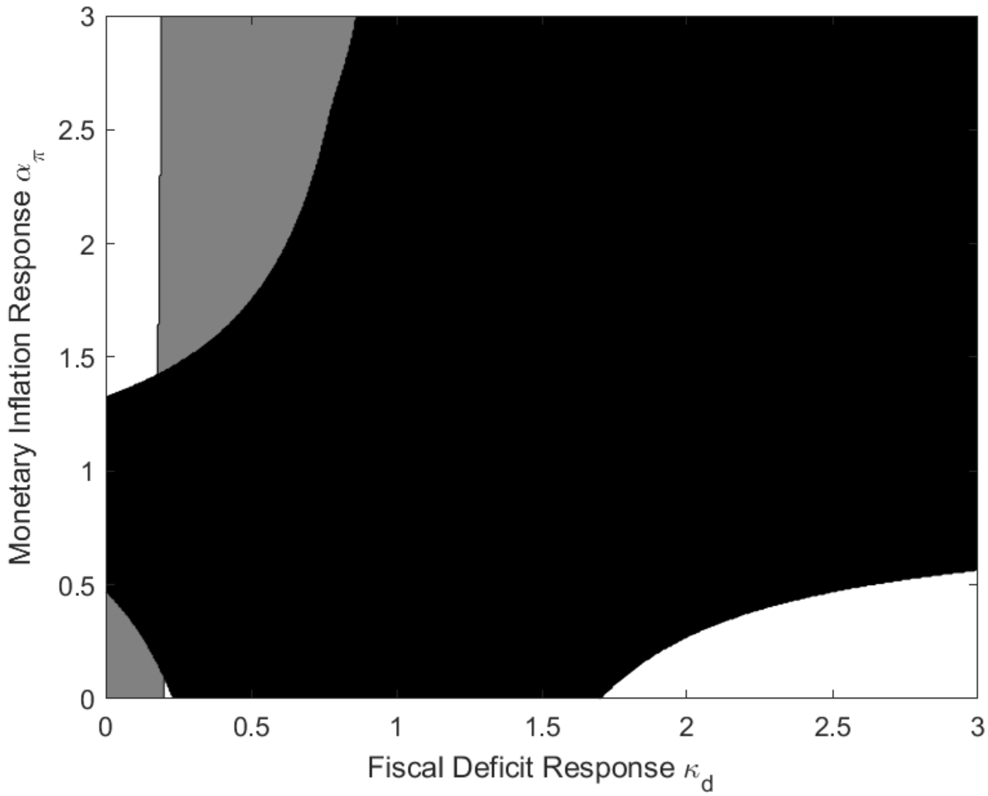

Figure 6: Determinacy and stability region. *Notes.* Black - unique and stable equilibria in estimated model with sovereign risk; gray - additional unique and stable equilibria region when setting $\Phi_b = \Phi_d = 0$; white - regions of indeterminacy/ instability in both models.

deviations of inflation from its target by more than one-for-one, the fiscal feedback needs to be doubled to yield determinacy. Similarly, the determinacy region shrinks with sovereign default beliefs if monetary policy is passive. Then, the fiscal feedback needs to be strictly larger than zero and higher than without sovereign risk to yield stable and unique equilibria.[17] From these findings we conclude that the argument of Blanchard (2005) is an empirically relevant concern. At the same time, inflation targeting is not necessarily destabilizing in an economy plagued with high levels of sovereign risk if it is coupled with a sufficiently strong fiscal feedback.

4.5.2. Policy trade-offs

We now focus on the case where the monetary-fiscal rules ensure determinacy and study alternative policies that can be used to reduce inflation volatility, and the implied trade-offs. For this,

[17]On the other hand, the indeterminacy region, implied by a high fiscal response and a low monetary feedback (white area in lower right corner), is not affected by the presence of sovereign default beliefs.

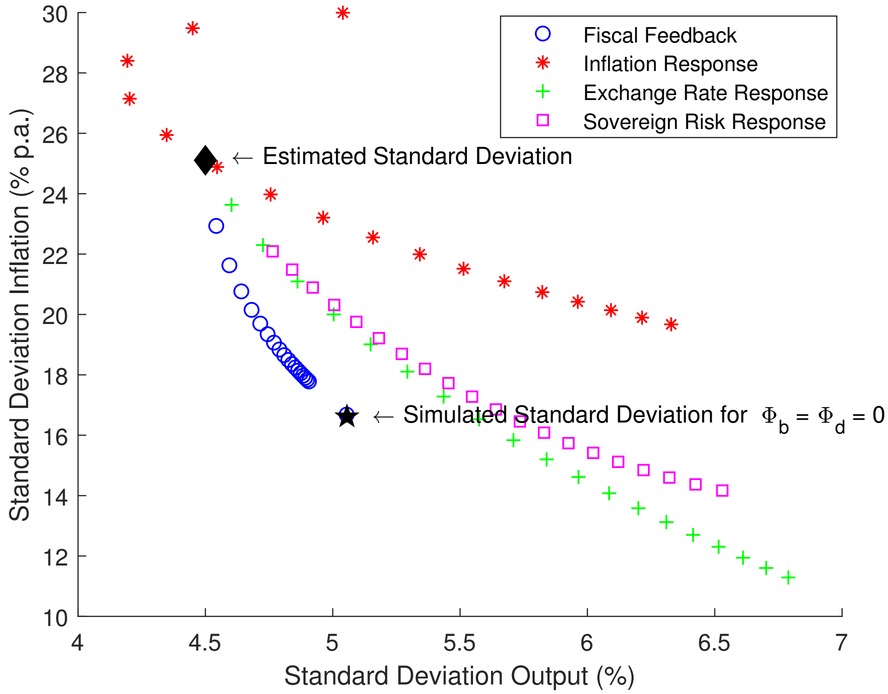

Figure 7: Variance frontier. *Notes.* Simulations are based on the inferred initial state and the inferred shocks. The latter are obtained from the Kalman smoother using the posterior mean of the estimated parameters. The circles, asterisks, crosses, and boxes correspond to simulations with $\kappa \in [1.37, 5.00]$, $\alpha_\pi \in [1.1, 5.0]$, $\alpha_{\Delta X} \in [0, 2]$, and $\alpha_\delta \in [0.5, 1.5]$, respectively, using the posterior mean for the remaining parameters.

we simulate the estimated baseline model with sovereign risk, using the inferred shocks, and change selected policy coefficients one at a time. Figure 7 shows the simulated standard deviations of output and annualized inflation. The black diamond marks the volatilities implied by the estimated policy coefficients. The points closest to the origin form the variance frontier and contain the most favorable policy trade-offs.

There are asterisks northwest of the estimated variances with smaller output fluctuations and only mildly higher inflation volatility. These points correspond to lower than estimated values for the monetary inflation response. They reflect the argument of Blanchard (2005) that less aggressive inflation targeting can entail stabilizing elements because it dampens fluctuations in default rates, real exchange rates, and output. Reversely, the asterisks to the right of the estimated variances show that more hawkish monetary policy is a relatively ineffective tool. There is only a small decline in the standard deviation of inflation when increasing the inflation response. Moreover, this strategy is coupled with strong increases in output volatility, rendering this policy option inefficient.

A stronger fiscal feedback (blue circles) allows moving southeast. This is the most efficient policy option. In the event of adverse shocks, such a policy is akin to a stabilization of expected default rates, which prevents sharp exchange rate movements and corresponding volatility in PPI and CPI inflation. Marginal costs and the interest rate on working capital also fluctuate less. A second element relevant for understanding the strong lever of fiscal policy on inflation is the transmission of inflation target shocks, which are a main driver of inflation (see Table 3). These shocks have much smaller price effects when sovereign risk is less sensitive to them. Target shocks lead domestic producers to change prices. This feeds into consumer prices. The CPI targeting central bank responds by strongly adjusting policy rates, such that real rates fluctuate as well. The latter, in turn, lead to movements in the real fiscal deficit, the expected default rate, and the real exchange rate, which ultimately feeds back into inflation. A fiscal authority with a large feedback coefficient is able to prevent part of these adverse dynamics. In the limit such a policy implies a balanced budget regime. The fiscal authority then eliminates fluctuations in sovereign risk and thereby replicates the point in the variance space which corresponds to $\Phi_b = \Phi_d = 0$ (compare last circle where $\kappa = 1000$ and black pentagram). This result underscores the importance of strong fiscal rules for countries operating under inflation targeting.

The same reduction in inflation volatility, but at the cost of higher output fluctuations, can be reached by increasing the monetary reaction to either expected sovereign risk (squares) or nominal exchange rate movements (crosses), with the former policy dominated by the latter. Responding more to default expectations addresses the problem of setting a risky interest rate and the associated unpleasant amplification of exogenous disturbances on inflation. The policy coefficient has an upper limit, however, beyond which the model yields unstable equilibria. If the monetary authority's aim is to reduce inflation volatility further, the only tool left is aggressive nominal exchange rate targeting. In line with Schabert (2011), such a policy has strong effects on the volatility of inflation as it helps 'import' the international risk-free rate and thereby also partly offsets the problem of steering a rate that contains a risk premium in equilibrium. In the limit, this policy implies a fixed exchange rate regime. However, while such a regime can partly shield against the amplification effect of sovereign risk on inflation, this comes at the cost of higher output volatility (see also Section 4.4.2). Again, the preferred option would be more fiscal stabilization.

4.5.3. Sovereign risk and inflation targets

In this section, we assess how the inflation target can be reduced to engineer a disinflation. We employ the inferred shocks except those for the smoothed inflation target and feed M_1 with j alternative target paths. Specifically, we set the first innovation to the target to $\varepsilon^{j}_{\breve{\pi},1} \in [-0.05; 0]$

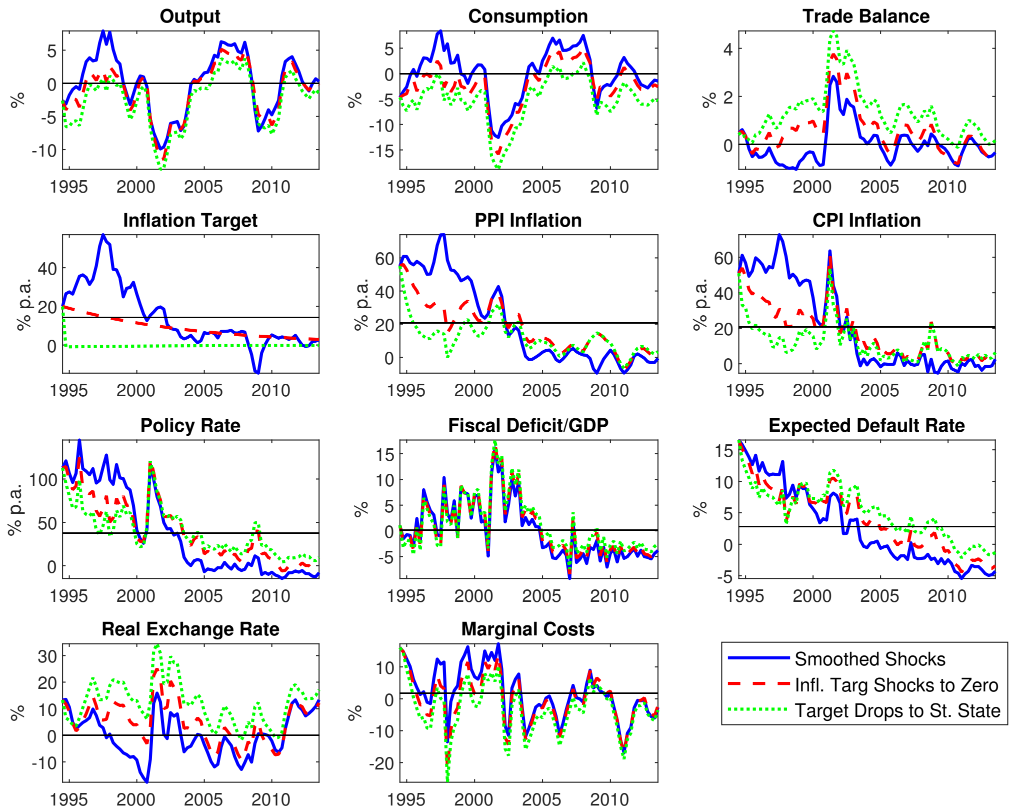

Figure 8: Simulated dynamics under alternative inflation target paths. *Notes.* The solid lines correspond to the simulation based on the inferred initial state and all inferred shocks from 1994Q3 to 2013Q3. The dashed line shows a case when all innovations to the inflation target are set to zero. The dotted line refers to the initial innovation to the inflation target being equal to minus the difference between the initial state and the steady state value of the inflation target.

and $\varepsilon^{j}_{\breve{\pi},t} = 0 \ \forall \ t \geq 2$. The first value of the range for $\varepsilon^{j}_{\breve{\pi},1}$ implies that the target drops to its long-run level immediately. The last value implies that it starts at its inferred initial state and then smoothly converges to its steady state without further disturbances. The speed of convergence is dictated by the autocorrelation of the target. The smoothed path of $\hat{\breve{\pi}}_t$ and the two polar cases with no and full initial drop are shown in Figure 8, together with the implied trajectories of other variables.

The faster reduction in the inflation target in the counterfactuals (dashed and dotted lines) during the first part of the sample leads domestic producers to drastically reduce prices. This feeds directly into lower consumer prices. As the central bank responds by more than one-for-one to the decline in CPI inflation, the real rate falls. This lowers public financing costs, the real fiscal deficit falls as well, and the expected default rate declines sharply. This decline is so strong that the real effective interest rate actually increases, and private consumption falls. The exchange rate, on the other hand, appreciates due to higher expected returns on sovereign debt and lower domestic inflation. This lowers net exports which, together with reduced domestic demand, depresses output. Marginal costs fall as well, adding to the disinflationary impulse: the relevant borrowing rate for firms financing working capital declines due to the pass-through from lower sovereign risk to private credit conditions and this offsets a small increase in the real wage following the decline in consumer price inflation. When the counterfactual target path exceeds its smoothed value during most of the second half of the sample, these dynamics are reversed. Moreover, the effects are stronger the larger is the initial drop in the target. These results show that a credible low-inflation policy can substantially reduce sovereign risk premia.

4.6. Efficient crisis response

Finally, we compare the crisis in 2000/01 to that in 2018/19 and evaluate alternative policy responses. As Figure 1 shows, there are commonalities but also important differences between the two crises. The main common feature is the sharp depreciation of the currency during both episodes, reflecting a sudden drop in investors' confidence. The fiscal situations, however, were different. During the 1990s the government ran large and persistent deficits and actual and expected bank bailouts questioned fiscal solvency at the beginning of the 2000s. Interest rates on government debt skyrocketed–way in excess of inflation–, CDS spreads shot up, and government debt surged dramatically. In contrast, in the 2018/19 crisis, fiscal deficits were moderate and public debt, Treasury rates and CDS spreads were low. Nevertheless, the successive pruning of the central bank's independence let to a loss of its credibility in the eyes of domestic firms and international investors. Turkish companies were setting higher wages and prices, the Lira's value declined against the Euro by around 50 percent and the inflation rate doubled from 10 to 20 percent.

What can domestic authorities and international institutions do to counter the dramatic currency erosion and price increases? To answer this questions, we evaluate the effectiveness and efficiency of the following three policy interventions:

1. fiscal consolidation
2. contractionary monetary policy
3. restoring central bank independence

To quantify the three measures, we simulate the effects of a reduction of government spending by 10 percent, an increase in the domestic policy rate by 10 percentage points, and a lowering of the inflation target by 5 percentage points. We interpret the third measure as restoring central bank independence and thereby the credibility of the inflation target.

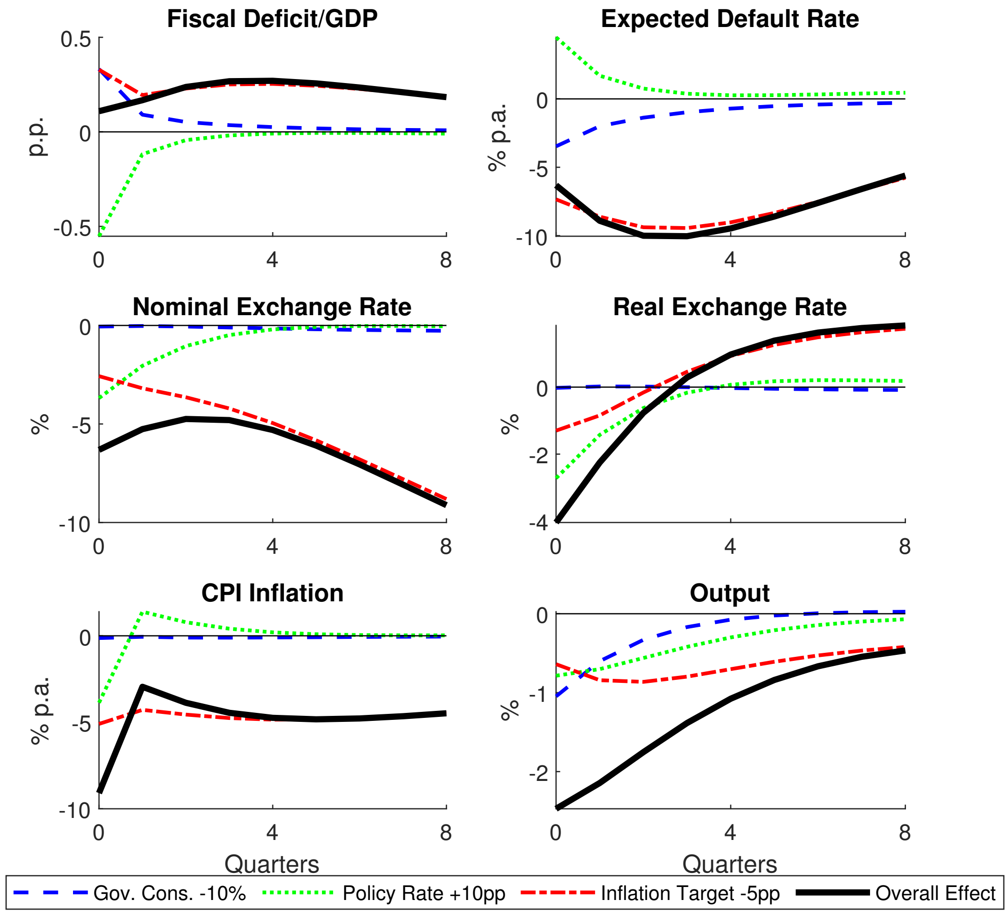

Figure 9: Dynamic effects of policy interventions. *Notes.* The figure shows the impulse responses of selected variables to four alternative shocks and the overall effect (thick black line).

Figure 9 shows that all three measures stabilize the currency. Although lowering public spending only results in a slight revaluation due to confidence effects, raising the policy rate leads to an appreciation by around four percent in the first quarter. A long stabilization phase follows as a consequence of lowering the inflation target. The overall effect of the measures is an almost 10-percent increase in the Lira's value after two years. This primarily reflects foreign investors' resurgent confidence in the domestic currency. Sovereign risk decreases by more than five percentage points as the budget balance increases. Fiscal consolidation and lowering the inflation target contribute most to this improvement, while raising the interest rate increases public financing costs. Along with the nominal appreciation the real exchange rate also rises, and inflation falls by around 10 percent initially. At the same time, output drops by more than 2 percent, before completely recovering after two years.

We apply two criteria in order to assess which measure is most efficient. The first is the 'sacrifice

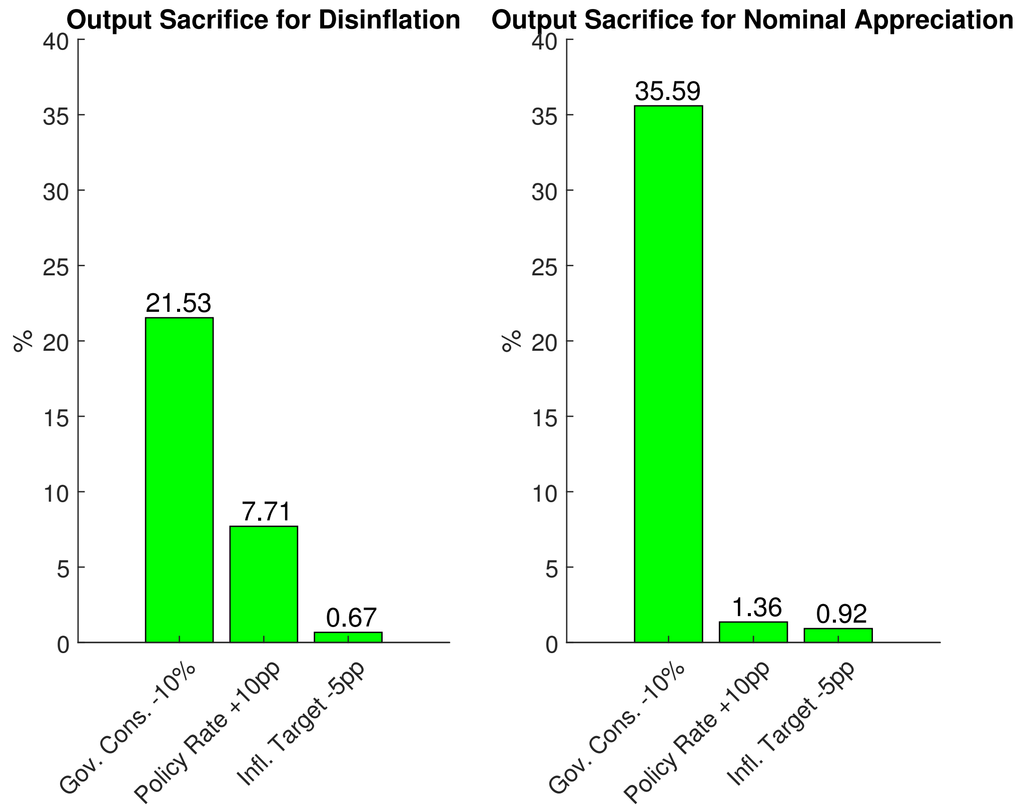

Figure 10: Sacrifice ratios. *Notes.* The upper and lower panel shows the sacrifice ratio for disinflations and the for nominal appreciations defined as the ouput loss per percentage point reduction in the inflation level and per percent nominal appreciation in the first year following the policy shock, respectively.

ratio' and defined as the cumulative production loss (relative to trend output) over the inflation reduction. Because Turkey's recent crisis primarily affected its currency, we also compute the ratio of cumulative production losses to nominal appreciation and use it as a second criterion. We calculate both measures for the first year after the policy interventions; a smaller number means higher efficiency. Figure 10 shows that reducing the inflation target is most efficient in both fighting inflation and stabilizing the currency, followed by raising interest rates and by cutting government consumption.[18]

[18]Note that the sacrifice ratios in Figure 9 are by far the highest for a cut in government consumption, while we learned from Figure 7 in Section 4.5.2 that fiscal consolidation through a stronger tax feedback is most effective for reducing inflation volatility without sacrificing much in output volatility. This is due to two main forces. First, a feedback rule entails credible future commitment in response to all shocks hitting the economy, which is absent in a one-off cut in government spending. Second, as government consumption is biased towards domestic goods, a spending cut generates a relatively large fall in output and depreciation pressure which compensates the effect of the fiscal consolidation on the real exchange rate and inflation.

5. Conclusions

We study the role of sovereign risk for macroeconomic fluctuations and stabilization policy in a small open economy. We first set up a quantitative DSGE model with new open-economy macroeconomic foundations where a perceived risk of sovereign debt default leads to a time-varying default premium on government bonds linked to the fiscal position. We estimated the model on Turkish time series data showing remarkable fluctuations in interest and exchange rates, inflation, as well as in fiscal deficits. Our results show that the introduction of sovereign default risk strongly improves the ability of the model to explain such fluctuations. The underlying mechanisms rely on a feedback loop from government debt and deficits on sovereign risk premia, the exchange rate, inflation and interest rates and back to deficits, as well as pass-through from sovereign to private credit conditions. These mechanisms are also critical to understanding the improved empirical fit of the consumption and investment Euler equations that we detect, and of the interest rate parity condition. Overall, accounting for sovereign risk implies smaller shocks and less need for extrinsic persistence mechanisms as it instead generates more intrinsic shock propagation.

We then use the model to analyze the policy implications of sovereign default risk. Our findings show that hawkish monetary policy requires substantially higher tax feedback coefficients to stabilize the economy when government solvency is at risk. At the same time, hawkish inflation targeting implies that increases in sovereign default risk themselves are contractionary despite their weakening effect on the exchange rate which stimulates demand for domestic goods. Furthermore, our results suggest that sound fiscal policy is a key condition to stabilize inflation, while more hawkish monetary policy is a relatively ineffective tool. Finally, we use the model to assess several policy options to reduce observed fluctuations in Turkey. We find that a reduction of the inflation target would be the preferred policy option for stabilizing the currency and curbing inflation. All in all, our results highlight the importance of interaction effects between monetary and fiscal policy for macroeconomic stability in small open economies where sovereign risk is a relevant concern.

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Appendix

This appendix contains a detailed derivation of the model, as well as details on the estimation methodology, the data used and some additional results. Appendix A provides the derivation of the model's equations, Appendix B the non-linear equilibrium conditions, Appendix C the steady state solution, Appendix D the log-linearization and Appendix E a compact representation of the linear equilibrium conditions. Appendix F discusses some details on the estimation including data sources, definitions and the construction of foreign variables. Appendix G describes the changes to the model's equations considered in the sensitivity analysis. Finally, Appendix H contains the additional results.

Appendix A. Model equations

Appendix A.1. Fiscal policy

The government budget constraint is

$$\frac{B_{H,t}}{R_{H,t}} + X_t \frac{B_{F,t}}{R_{F,t}} + P_t \tau_t + P_t \tau_t^* = P_{H,t} g_t + (1-\delta_t)(B_{H,t-1} + X_t B_{F,t-1}), \tag{A.1}$$

or, dividing by P_t and defining $b_{H,t} \equiv B_{H,t}/P_t$, $b_{F,t} \equiv B_{F,t}/P_t^*$, $q_t \equiv X_t P_t^*/P_t$ and $p_{H,t} \equiv P_{H,t}/P_t$,

$$\frac{b_{H,t}}{R_{H,t}} + q_t \frac{b_{F,t}}{R_{F,t}} + \tau_t + \tau_t^* = p_{H,t} g_t + (1-\delta_t)(b_{H,t-1}\pi_t^{-1} + q_t b_{F,t-1}\pi_t^{*-1}),$$

where

$$\begin{aligned}
\tau_t &= \tilde{\tau}_t - \delta_t b_{H,t-1}\pi_t^{-1}, \\
\tau_t^* &= -\delta_t q_t b_{F,t-1}\pi_t^{*-1}, \\
\frac{\tilde{\tau}_t}{\tau} &= \left(\frac{\tilde{\tau}_{t-1}}{\tau}\right)^{\kappa_\tau} \left[\left(\frac{d_t}{d}\right)^{\kappa_d} \left(\frac{y_{H,t}}{y_H}\right)^{\kappa_y}\right]^{1-\kappa_\tau} \exp(\varepsilon_{\tau,t}), \\
d_t &= b_{H,t} - b_{H,t-1}\pi_t^{-1} + q_t(b_{F,t} - b_{F,t-1}\pi_t^{*-1}), \\
q_t \frac{b_{F,t}}{R_{F,t}} &= f_t \frac{b_{H,t}}{R_{H,t}}.
\end{aligned} \tag{A.2}$$

Combining (A.1) with (A.2) yields

$$b_{H,t} + q_t b_{F,t}/R_{F,t} + \tilde{\tau}_t = p_{H,t} g_t + b_{H,t-1}\pi_t^{-1} + q_t b_{F,t-1}\pi_t^{*-1}. \tag{A.3}$$

The default probability is

$$\mathfrak{p}_t = F_{\bar{b}}(b_t) + F_{\bar{d}}(d_t) - F_{\bar{b},\bar{d}}(b_t, d_t), \tag{A.4}$$

where $F_{\bar{b}}(b_t)$ and $F_{\bar{d}}(d_t)$ denotes the marginal cumulative distribution function (cdf) of $\bar{b}$ and $\bar{d}$, respectively, and $F_{\bar{b},\bar{d}}(b_t, d_t)$ is their joint cdf.

The default rate is

$$\delta_t = \begin{cases} \omega & \text{with probability } \mathfrak{p}_t, \\ 0 & \text{with probability } 1-\mathfrak{p}_t. \end{cases}$$

Appendix A.2. Monetary policy

The monetary policy rule is

$$\frac{R_{H,t}}{R_H} = \left(\frac{R_{H,t-1}}{R_H}\right)^{\alpha_R} \left[\frac{\breve{\pi}_t}{\bar{\pi}} \left(\frac{\pi_t}{\breve{\pi}_t}\right)^{\alpha_\pi} \left(\frac{y_{H,t}}{y_H}\right)^{\alpha_y} E_t \left(\frac{\delta_{t+1}}{\delta}\right)^{\frac{\alpha_\delta \delta}{1-\delta}}\right]^{1-\alpha_R} \exp(\varepsilon_{R,t}).$$

Appendix A.3. Domestic households

Maximize

$$E_t \sum_{s=0}^{\infty} \beta^s z_{t+s} \left[\frac{1}{1-\sigma}(c_{t+s} - h\breve{c}_{t+s-1})^{1-\sigma} - \varsigma_{w,t+s} \frac{n_{t+s}^{1+\eta}}{1+\eta}\right],$$

where

$$P_t(c_t + i_t + \tau_t) + \frac{B_{H,t}}{R_{H,t}} + X_t \frac{M_t}{R_t} \leq (1-\delta_t) B_{H,t-1} + X_t M_{t-1} + W_t^h n_t + R_t^k k_t + \Sigma_t, \tag{A.5}$$

or, dividing by P_t and defining $m_t \equiv M_t/P_t^*$, $w_t^h \equiv W_t^h/P_t$ and $r_t^k \equiv R_t^k/P_t$,

$$c_t + i_t + \tau_t + \frac{b_{H,t}}{R_{H,t}} + q_t \frac{m_t}{R_t} \leq (1-\delta_t) \frac{b_{H,t-1}}{\pi_t} + q_t \frac{m_{t-1}}{\pi_t^*} + w_t^h n_t + r_t^k k_t + \frac{\Sigma_t}{P_t}, \tag{A.6}$$

and where

$$k_{t+1} = \mu_t \left[1 - S\left(\frac{i_t}{i_{t-1}}\right)\right] i_t + (1-\varpi) k_t, \tag{A.7}$$

taking prices, wages, interest rates, aggregate consumption $\breve{c}_t$, payouts Σ_t, taxes τ_t and initial wealth endowments as given. The Lagrangian is

$$\mathcal{L}_t = E_t \sum_{s=0}^{\infty} \beta^s \left\{ \begin{array}{c} z_{t+s}\left[\frac{1}{1-\sigma}(c_{t+s} - h\breve{c}_{t+s-1})^{1-\sigma} - \varsigma_{w,t+s}\frac{n_{t+s}^{1+\eta}}{1+\eta}\right] \\ +\lambda_{t+s}\left[\begin{array}{c} (1-\delta_{t+s})\frac{b_{H,t+s-1}}{\pi_{t+s}} + q_{t+s}\frac{m_{t+s-1}}{\pi_{t+s}^*} + w_{t+s}^h n_{t+s} + r_{t+s}^k k_{t+s} + \frac{\Sigma_{t+s}}{P_{t+s}} \\ -\left(c_{t+s} + i_{t+s} + \tau_{t+s} + \frac{b_{H,t+s}}{R_{H,t+s}} + q_{t+s}\frac{m_{t+s}}{R_{t+s}}\right) \end{array}\right] \\ +\lambda_{t+s}\lambda_{t+s}^k\left[\mu_{t+s}\left(1 - S\left(\frac{i_{t+s}}{i_{t+s-1}}\right)\right) i_{t+s} + (1-\varpi) k_{t+s} - k_{t+s+1}\right] \end{array} \right\},$$

where λ_t and $\lambda_t \lambda_t^k$ denote the Lagrangian multipliers associated with (A.6) and (A.7), respectively. The first-order conditions (FOCs) are

$$\begin{aligned} c_t &: \lambda_t = z_t(c_t - h\breve{c}_{t-1})^{-\sigma}, \\ n_t &: \lambda_t w_t^h = z_t \varsigma_{w,t} n_t^\eta, \\ k_{t+1} &: \lambda_t \lambda_t^k = \beta E_t[\lambda_{t+1} r_{t+1}^k + \lambda_{t+1}\lambda_{t+1}^k (1-\varpi)], \\ i_t &: \lambda_t = \lambda_t \lambda_t^k \mu_t [1 - S(\iota_t) - S'(\iota_t)\iota_t] + \beta E_t[\lambda_{t+1}\lambda_{t+1}^k \mu_{t+1} S'(\iota_{t+1})\iota_{t+1}^2], \\ b_{H,t} &: \lambda_t = R_{H,t}\beta E_t[(1-\delta_{t+1})\lambda_{t+1}\pi_{t+1}^{-1}], \\ m_t &: \lambda_t q_t = R_t \beta E_t[\lambda_{t+1} q_{t+1} \pi_{t+1}^{*-1}], \end{aligned} \tag{A.8}$$

with $\iota_t \equiv i_t/i_{t-1}$, and the no-Ponzi-game condition is satisfied. The first condition shows that $\lambda_t > 0$ in a local neighborhood of the steady state such that the budget constraint holds with equality.

Appendix A.4. Foreign households

Analogous to the domestic case described in Appendix A.7.1, demand for domestic goods by foreign households is

$$x^*_{H,t} = \vartheta^* \left(\frac{P^*_{H,t}}{P^*_t} \right)^{-\gamma^*} y^*_t. \tag{A.9}$$

In addition, foreign households have an opportunity cost of funds R^*_t. Therefore, they require that

$$R^*_t = R_{F,t} E_t (1 - \delta_{t+1}).$$

Appendix A.5. Financial intermediaries

Maximize

$$E_t \sum_{s=0}^{\infty} \beta^s \frac{\lambda_{t+s}}{\lambda_t} \left[q_{t+s} \left(\frac{v_{t+s}}{R_{v,t+s} \Upsilon_{t+s}} + \frac{m_{t+s}}{R_{t+s}} + \frac{l_{t+s}}{R_{t+s}} \right) - q_{t+s} \left(\frac{v_{t+s-1}}{\pi^*_{t+s}} + \frac{m_{t+s-1}}{\pi^*_{t+s}} + \frac{l_{t+s-1}}{\pi^*_{t+s}} \right) \right],$$

taking prices, interest rates and initial wealth endowments as given, and where

$$\Upsilon_t = \exp \left[\varphi \left(\frac{v_t - \bar{v}}{y_H} \right) + \frac{\psi_t - \psi}{\psi} \right],$$

and

$$\frac{R_{v,t}}{R^*_t} = v_1 \left(\frac{R_{F,t}}{R^*_t} \right)^{v_2}.$$

The FOCs are

$$v_t \quad : \quad \lambda_t q_t = R_{v,t} \Upsilon_t \beta E_t [\lambda_{t+1} q_{t+1} \pi^{*-1}_{t+1}], \tag{A.10}$$

$$m_t, l_t \quad : \quad \lambda_t q_t = R_t \beta E_t [\lambda_{t+1} q_{t+1} \pi^{*-1}_{t+1}], \tag{A.11}$$

and the no-Ponzi-game condition is satisfied. Combining (A.10) and (A.11) yields

$$R_t = R_{v,t} \Upsilon_t.$$

Appendix A.6. Labor market

The labor market is described by the sticky-wage model of Erceg et al. (2000) and Smets and Wouters (2007). Accordingly, households supply their homogenous labor n_t to monopolistically competitive intermediate labor unions that differentiate the labor services setting wages in a staggered way. A set of perfectly competitive profit-maximizing labor packers buy and package the differentiated labor services n^l_t, with $l \in [0, 1]$, into an aggregate labor service unit n^d_t through a constant elasticity of substitution (CES) technology $n^d_t = [\int_0^1 (n^l_t)^{(\epsilon_w - 1)/\epsilon_w} dl]^{\epsilon_w/(\epsilon_w - 1)}$, where $\epsilon_w > 1$ denotes the elasticity of substitution among intermediate labor services. The aggregate labor service is demanded by goods producers at the aggregate wage W_t. Labor unions maximize dividend payouts to households taking as given the wage desired by households, W^h_t (which is taken as the cost of the homogeneous labor supplied by households), and aggregate wages, prices and labor demand. Wage setting is subject to Calvo-type frictions. Each period a fraction $1 - \phi_w$ of randomly selected unions is allowed to set a new optimal wage $\check{W}^l_t$. The remaining unions adjust wages according to the indexation scheme $W^l_t = (\pi_{t-1})^{\iota_w} (\breve{\pi}_t)^{1-\iota_w} W^l_{t-1}$, where $\iota_w \in [0, 1]$ and $1 - \iota$ measure the degree of indexation to past CPI inflation and the monetary authority's current inflation target, respectively. The following provides a complete description of the labor packers' and unions' problems and the derivation of the first-order conditions.

Appendix A.6.1. Labor packers

Maximize

$$w_t n_t^d - \int_0^1 \frac{W_t^l}{P_t} n_t^l dl, \tag{A.12}$$

subject to

$$n_t^d = \left[\int_0^1 (n_t^l)^{\frac{\epsilon_w - 1}{\epsilon_w}} dl\right]^{\frac{\epsilon_w}{\epsilon_w - 1}}, \tag{A.13}$$

taking prices and wages as given. Substituting out (A.13) in (A.12), the FOCs for all l are

$$n_t^l \quad : \quad w_t (n_t^l)^{-\frac{1}{\epsilon}} (n_t^d)^{\frac{1}{\epsilon_w}} = \frac{W_t^l}{P_t},$$

or

$$n_t^l = \left(\frac{W_t^l}{W_t}\right)^{-\epsilon_w} n_t^d. \tag{A.14}$$

Combining (A.13) with (A.14) yields the aggregate wage index:

$$W_t = \left[\int_0^1 (W_t^l)^{1-\epsilon_w} dl\right]^{\frac{1}{1-\epsilon_w}}. \tag{A.15}$$

Appendix A.6.2. Intermediate labor unions

Maximize

$$\max_{\breve{W}_t^l} E_t \sum_{s=0}^{\infty} (\phi_w \beta)^s \frac{\lambda_{t+s} P_t}{\lambda_t P_{t+s}} \left(\breve{W}_t^l Z_{t,s}^w - W_{t+s}^h\right) n_{t+s}^l, \tag{A.16}$$

subject to

$$n_{t+s}^l = \left(\frac{\breve{W}_t^l Z_{t,s}^w}{W_{t+s}}\right)^{-\epsilon_w} n_{t+s}^d, \tag{A.17}$$

where $Z_{t,s}^w = 1$ for $s = 0$ and $Z_{t,s}^w = \Pi_{l=1}^s (\pi_{t+l-1})^{\iota_w} (\breve{\pi}_{t+l})^{1-\iota_w} = (P_{t+s-1}/P_{t-1})^{\iota_w} (\breve{P}_{t+s}/\breve{P}_t)^{1-\iota_w}$ for $s = 1, 2, \ldots, \infty$, taking λ_{t+s}, P_{t+s}, W_{t+s}, W_{t+s}^h and n_{t+s}^d as given. Substituting out (A.17) in (A.16) and using (A.8) yields

$$\begin{aligned} &\max_{\breve{W}_t^l} E_t \sum_{s=0}^{\infty} (\phi_w \beta)^s \frac{\lambda_{t+s} P_t}{\lambda_t P_{t+s}} \left[\frac{\left(\breve{W}_t^l Z_{t,s}^w\right)^{1-\epsilon_w}}{W_{t+s}^{-\epsilon_w}} n_{t+s}^d - \frac{P_{t+s} z_{t+s} \varsigma_{w,t+s} n_{t+s}^{\eta}}{\lambda_{t+s}} \left(\frac{\breve{W}_t^l Z_{t,s}^w}{W_{t+s}}\right)^{-\epsilon_w} n_{t+s}^d\right] \\ = \; &\max_{\breve{W}_t^l} E_t \sum_{s=0}^{\infty} (\phi_w \beta)^s \frac{P_t}{\lambda_t} \left[\frac{\lambda_{t+s}}{P_{t+s}} W_{t+s} \left(\frac{\breve{W}_t^l Z_{t,s}^w}{W_{t+s}}\right)^{1-\epsilon_w} n_{t+s}^d - z_{t+s} \varsigma_{w,t+s} n_{t+s}^{\eta} \left(\frac{\breve{W}_t^l Z_{t,s}^w}{W_{t+s}}\right)^{-\epsilon_w} n_{t+s}^d\right]. \end{aligned}$$

The FOC is

$$\breve{W}_t^l \quad : \quad 0 = E_t \sum_{s=0}^{\infty} (\phi_w \beta)^s \frac{P_t}{\lambda_t} \left[\begin{array}{c} \frac{\lambda_{t+s}}{P_{t+s}} W_{t+s} (1-\epsilon_w) \left(\breve{W}_t^l\right)^{-\epsilon_w} \left(\frac{Z_{t,s}^w}{W_{t+s}}\right)^{1-\epsilon_w} n_{t+s}^d \\ + z_{t+s} \varsigma_{w,t+s} n_{t+s}^{\eta} \epsilon_w \left(\breve{W}_t^l\right)^{-\epsilon_w - 1} \left(\frac{Z_{t,s}^w}{W_{t+s}}\right)^{-\epsilon_w} n_{t+s}^d \end{array}\right].$$

This shows that $\breve{W}_t^l = \breve{W}_t$ for all l. Multiplying through by $\breve{W}_t / W_t$ yields

$$0 = E_t \sum_{s=0}^{\infty} (\phi_w \beta)^s \frac{P_t}{\lambda_t} \left[\begin{array}{c} \frac{\lambda_{t+s}}{P_{t+s}} \frac{W_{t+s}}{W_t} (1-\epsilon_w) \breve{W}_t^{1-\epsilon_w} \left(\frac{Z_{t,s}^w}{W_{t+s}} \right)^{1-\epsilon_w} n_{t+s}^d \\ + \frac{z_{t+s} \varsigma_{w,t+s} n_{t+s}^\eta}{W_t} \epsilon_w \breve{W}_t^{-\epsilon_w} \left(\frac{Z_{t,s}^w}{W_{t+s}} \right)^{-\epsilon_w} n_{t+s}^d \end{array} \right]. \tag{A.18}$$

Rearranging (A.18) using $w_t \equiv W_t / P_t$ gives

$$\begin{aligned} & E_t \sum_{s=0}^{\infty} (\phi_w \beta)^s \frac{z_{t+s} \varsigma_{w,t+s} n_{t+s}^\eta}{\lambda_t w_t} n_{t+s}^d \epsilon_w \breve{W}_t^{-\epsilon_w} \left(\frac{Z_{t,s}^w}{W_{t+s}} \right)^{-\epsilon_w} \\ = \quad & E_t \sum_{s=0}^{\infty} (\phi_w \beta)^s \frac{\lambda_{t+s}}{\lambda_t} \frac{P_t}{P_{t+s}} \frac{W_{t+s}}{W_t} n_{t+s}^d (\epsilon_w - 1) \breve{W}_t^{1-\epsilon_w} \left(\frac{Z_{t,s}^w}{W_{t+s}} \right)^{1-\epsilon_w}. \end{aligned}$$

Defining $\mu_t^w \equiv \lambda_t w_t / (z \varsigma_{w,t} n_t^\eta)$, $\breve{w}_t \equiv \breve{W}_t / W_t$ and $\pi_{w,t} \equiv W_t / W_{t-1}$, this expression can be re-written recursively as follows:

$$\epsilon_w E_t \Gamma_{w,t}^1 = (\epsilon_w - 1) E_t \Gamma_{w,t}^2,$$

where

$$\begin{aligned} \Gamma_{w,t}^1 &= \sum_{s=0}^{\infty} (\phi_w \beta)^s \frac{z_{t+s} \varsigma_{w,t+s} n_{t+s}^\eta}{\lambda_t w_t} n_{t+s}^d \breve{W}_t^{-\epsilon_w} \left(\frac{Z_{t,s}^w}{W_{t+s}} \right)^{-\epsilon_w} \\ &= \left(\frac{\breve{W}_t}{W_t} \right)^{-\epsilon_w} \frac{z_t \varsigma_{w,t} n_t^\eta}{\lambda_t w_t} n_t^d + \sum_{s=1}^{\infty} (\phi_w \beta)^s \frac{z_{t+s} \varsigma_{t+s} n_{t+s}^\eta}{\lambda_t w_t} n_{t+s}^d \breve{W}_t^{-\epsilon_w} \left(\frac{Z_{t,s}^w}{W_{t+s}} \right)^{-\epsilon_w} \\ &= \breve{w}_t^{-\epsilon_w} n_t^d / \mu_t^w + \phi_w \beta \frac{\lambda_{t+1}}{\lambda_t} \frac{\left[(\pi_t)^{\iota_w} (\breve{\pi}_{t+1})^{1-\iota_w} \right]^{-\epsilon_w}}{\pi_{t+1} \pi_{w,t+1}^{-1-\epsilon_w}} \left(\frac{\breve{w}_t}{\breve{w}_{t+1}} \right)^{-\epsilon_w} \Gamma_{w,t+1}^1, \end{aligned}$$

and

$$\begin{aligned} \Gamma_{w,t}^2 &= \sum_{s=0}^{\infty} (\phi_w \beta)^s \frac{\lambda_{t+s}}{\lambda_t} \frac{P_t}{P_{t+s}} \frac{W_{t+s}}{W_t} n_{t+s}^d \breve{W}_t^{1-\epsilon_w} \left(\frac{Z_{t,s}^w}{W_{t+s}} \right)^{1-\epsilon_w} \\ &= \breve{w}_t^{1-\epsilon_w} n_t^d + \sum_{s=1}^{\infty} (\phi_w \beta)^s \frac{\lambda_{t+s}}{\lambda_t} \frac{P_t}{P_{t+s}} \frac{W_{t+s}}{W_t} n_{t+s}^d \breve{W}_t^{1-\epsilon_w} \left(\frac{Z_{t,s}^w}{W_{t+s}} \right)^{1-\epsilon_w} \\ &= \breve{w}_t^{1-\epsilon_w} n_t^d + \phi_w \beta \frac{\lambda_{t+1}}{\lambda_t} \frac{\left[(\pi_t)^{\iota_w} (\breve{\pi}_{t+1})^{1-\iota_w} \right]^{1-\epsilon_w}}{\pi_{t+1} \pi_{w,t+1}^{-\epsilon_w}} \left(\frac{\breve{w}_t}{\breve{w}_{t+1}} \right)^{1-\epsilon_w} \Gamma_{w,t+1}^2. \end{aligned}$$

Further, let $\Theta^w(t)$ denote the set of unions that cannot optimally set their wage in t. By (A.15), W_t evolves as follows:

$$\begin{aligned} W_t^{1-\epsilon_w} = \int_0^1 (W_t^l)^{1-\epsilon_w} dl &= (1-\phi_w) \breve{W}_t^{1-\epsilon_w} + \int_{\Theta^w(t)} \left[W_{t-1}^l (\pi_{t-1})^{\iota_w} (\breve{\pi}_t)^{1-\iota_w} \right]^{1-\epsilon_w} dl \\ &= (1-\phi_w) \breve{W}_t^{1-\epsilon_w} + \phi_w \left[(\pi_{t-1})^{\iota_w} (\breve{\pi}_t)^{1-\iota_w} W_{t-1} \right]^{1-\epsilon_w}. \end{aligned}$$

or, dividing both sides by $W_t^{1-\epsilon_w}$:

$$1 = (1-\phi_w) \breve{w}_t^{1-\epsilon_w} + \phi_w \left[\frac{(\pi_{t-1})^{\iota_w} (\breve{\pi}_t)^{1-\iota_w}}{\pi_{w,t}} \right]^{1-\epsilon_w}.$$

The third equality above follows from the fact that the distribution of wages that are not reoptimized in period t corresponds to the distribution of effective wages in period $t-1$, though with total mass reduced to ϕ_w.

Appendix A.7. Production and pricing

Appendix A.7.1. Final goods

Maximize

$$P_t y_t - P_{H,t} x_{H,t} - P_{F,t} x_{F,t},$$

subject to

$$y_t = \left[(1-\vartheta)^{\frac{1}{\gamma}} x_{H,t}^{\frac{\gamma-1}{\gamma}} + \vartheta^{\frac{1}{\gamma}} x_{F,t}^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}}, \tag{A.19}$$

taking prices as given. The FOCs are

$$x_{H,t} \quad : \quad x_{H,t} = (1-\vartheta) \left(\frac{P_{H,t}}{P_t} \right)^{-\gamma} y_t, \tag{A.20}$$

$$x_{F,t} \quad : \quad x_{F,t} = \vartheta \left(\frac{P_{F,t}}{P_t} \right)^{-\gamma} y_t. \tag{A.21}$$

Substituting out (A.20) and (A.21) in (A.19) yields the aggregate price index:

$$P_t = \left[(1-\vartheta) P_{H,t}^{1-\gamma} + \vartheta P_{F,t}^{1-\gamma} \right]^{\frac{1}{1-\gamma}}. \tag{A.22}$$

Appendix A.7.2. Home composite goods

Maximize

$$P_{H,t} y_{H,t} - \int_0^1 P_{H,t}^i x_{H,t}^i di, \tag{A.23}$$

subject to

$$y_{H,t} = \left[\int_0^1 (x_{H,t}^i)^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}}, \tag{A.24}$$

taking prices as given. Substituting out (A.24) in (A.23), the FOCs for all i are

$$x_{H,t}^i : P_{H,t} (x_{H,t}^i)^{-\frac{1}{\epsilon}} y_{H,t}^{\frac{1}{\epsilon}} = P_{H,t}^i,$$

or

$$x_{H,t}^i = (P_{H,t}^i / P_{H,t})^{-\epsilon} y_{H,t}. \tag{A.25}$$

Combining (A.25) with (A.24) yields

$$P_{H,t} = \left[\int_0^1 (P_{H,t}^i)^{1-\epsilon} di \right]^{\frac{1}{1-\epsilon}}. \tag{A.26}$$

Appendix A.7.3. Intermediate goods

With intra-period loans, per period profits are

$$P_{H,t}^i y_{H,t}^i - P_t w_t n_{it}^d - R_t^k k_{it} + X_t \frac{L_{it}}{R_t} - X_t L_{it} = P_{H,t}^i y_{H,t}^i - P_t w_t n_{it}^d - R_t^k k_{it} - X_t (R_t - 1) \frac{L_{it}}{R_t}.$$

Cost minimization.. Minimize

$$w_t n_{it}^d + r_t^k k_{it} + q_t(R_t - 1)\frac{L_{it}}{R_t},$$

subject to

$$y_{H,t}^i = a_t k_{it}^\alpha (n_{it}^d)^{1-\alpha}, \tag{A.27}$$

and

$$q_t \frac{l_{it}}{R_t} \geq \zeta^w w_t n_{it}^d + \zeta^k r_t^k k_{it}, \tag{A.28}$$

taking factor prices, interest rates and the output price as given. The Lagrangian is

$$\mathcal{F}_t = w_t n_{it}^d + r_t^k k_{it} + q_t(R_t - 1)\frac{l_{it}}{R_t} + mc_{it}[y_{H,t}^i - a_t k_{it}^\alpha (n_{it}^d)^{1-\alpha}] + \lambda_{it}^l \left(\zeta^w P_t w_t n_{it}^d + \zeta^k P_t r_t^k k_{it} - q_t \frac{l_{it}}{R_t}\right),$$

where mc_{it} and λ_{it}^l denote the Lagrangian multipliers associated with (A.27) and (A.28), respectively. The FOCs are

$$n_{it}^d \quad : \quad w_t(1 + \zeta^w \lambda_{it}^l) = mc_{it} a_t (1-\alpha) \left(\frac{k_{it}}{n_{it}^d}\right)^\alpha, \tag{A.29}$$

$$k_{it} \quad : \quad r_t^k(1 + \zeta^k \lambda_{it}^l) = mc_{it} a_t \alpha \left(\frac{k_{it}}{n_{it}^d}\right)^{\alpha-1}, \tag{A.30}$$

$$l_{it} \quad : \quad R_t - 1 = \lambda_{it}^l. \tag{A.31}$$

The last condition shows that $\lambda_{it}^l = \lambda_t^l$ for all i and therefore (A.28) holds with equality if $R_t^l > 1$. Combining (A.29) with (A.31) yields

$$w_t[1 + \zeta^w (R_t - 1)] = mc_{it} a_t (1-\alpha) \left(\frac{k_{it}}{n_{it}^d}\right)^\alpha. \tag{A.32}$$

Combining (A.29)-(A.31) yields

$$k_{it} = \frac{\alpha}{1-\alpha} \frac{w_t[1 + \zeta^w (R_t - 1)]}{r_t^k[1 + \zeta^k (R_t - 1)]} n_{it}^d. \tag{A.33}$$

This shows that k_{it}/n_{it}^d is the same for all i which implies that $mc_{it} = mc_t$ for all i by (A.32). Integrating (A.33) over i and using the market clearing conditions $\int_0^1 k_{it} di = k_t$ and $\int_0^1 n_{it}^d di = n_t^d$ then gives

$$k_t = \frac{\alpha}{1-\alpha} \frac{w_t[1 + \zeta^w (R_t - 1)]}{r_t^k[1 + \zeta^k (R_t - 1)]} n_t^d, \tag{A.34}$$

and combining (A.32) with (A.34) yields

$$mc_t = a_t^{-1} \left(w_t[1 + \zeta^w (R_t - 1)]\right)^{1-\alpha} \left(r_t^k[1 + \zeta^k (R_t - 1)]\right)^\alpha \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^\alpha.$$

Profit maximization.. Maximize

$$E_t \sum_{s=0}^{\infty} (\phi\beta)^s \frac{\lambda_{t+s} P_t}{\lambda_t P_{t+s}} \left(\check{P}_{H,t}^i Z_{t,s} - MC_{t+s}\right) \left(\frac{\check{P}_{H,t}^i Z_{t,s}}{P_{H,t+s}}\right)^{-\epsilon} y_{H,t+s},$$

subject to

$$y^i_{H,t+s} = \left(\frac{\check{P}^i_{H,t} Z_{t,s}}{P_{H,t+s}} \right)^{-\epsilon} y_{H,t+s}, \tag{A.35}$$

where $Z_{t,s} = 1$ for $s = 0$ and $Z_{t,s} = \Pi^s_{l=1} (\pi_{H,t+l-1})^\iota (\breve{\pi}_{t+l})^{1-\iota} = (P_{H,t+s-1}/P_{H,t-1})^\iota (\check{P}_{t+s}/\check{P}_t)^{1-\iota}$ for $s = 1, 2, \ldots, \infty$, taking λ_{t+s}, P_{t+s}, $P_{H,t+s}$, MC_{t+s} and $y_{H,t+s}$ as given. The FOC is

$$\check{P}^i_{H,t} \quad : \quad 0 = E_t \sum_{s=0}^{\infty} (\phi\beta)^s \frac{\lambda_{t+s} P_t}{\lambda_t P_{t+s}} \left[(1-\epsilon) \left(\check{P}^i_{H,t} \right)^{-\epsilon} Z_{t,s} + \epsilon \left(\check{P}^i_{H,t} \right)^{-\epsilon-1} MC_{t+s} \right] \left(\frac{Z_{t,s}}{P_{H,t+s}} \right)^{-\epsilon} y_{H,t+s}.$$

This shows that $\check{P}^i_{H,t} = \check{P}_{H,t}$ for all i. Multiplying through by $\check{P}_{H,t}$ and using (A.35) yields

$$0 = E_t \sum_{s=0}^{\infty} (\phi\beta)^s \frac{\lambda_{t+s} P_t}{\lambda_t P_{t+s}} y^i_{H,t+s} \left[(1-\epsilon) \check{P}_{H,t} Z_{t,s} + \epsilon MC_{t+s} \right]. \tag{A.36}$$

Rearranging (A.36) using $mc_{t+s} \equiv MC_{t+s}/P_{t+s}$ gives

$$\begin{aligned} & \epsilon E_t \sum_{s=0}^{\infty} (\phi\beta)^s \frac{\lambda_{t+s} P_t}{\lambda_t P_{t+s}} \check{P}^{-\epsilon}_{H,t} Z^{-\epsilon}_{t,s} P^{-1}_{H,t} P_{t+s} mc_{t+s} P^{\epsilon}_{H,t+s} y_{H,t+s} \\ = \quad & (\epsilon - 1) E_t \sum_{s=0}^{\infty} (\phi\beta)^s \frac{\lambda_{t+s} P_t}{\lambda_t P_{t+s}} (1-\epsilon) \check{P}^{1-\epsilon}_{H,t} Z^{1-\epsilon}_{t,s} P^{-1}_{H,t} P^{\epsilon}_{H,t+s} y_{H,t+s}. \end{aligned}$$

Defining $\check{p}_{H,t} \equiv \check{P}_{H,t}/P_{H,t}$ and $p_{H,t} \equiv P_{H,t}/P_t$, this expression can be re-written recursively as follows:

$$\epsilon E_t \Gamma^1_t = (\epsilon - 1) E_t \Gamma^2_t,$$

where

$$\begin{aligned} \Gamma^1_t &= \sum_{s=0}^{\infty} (\phi\beta)^s \frac{\lambda_{t+s} P_t}{\lambda_t P_{t+s}} \check{P}^{-\epsilon}_{H,t} Z^{-\epsilon}_{t,s} P^{-1}_{H,t} P_{t+s} mc_{t+s} P^{\epsilon}_{H,t+s} y_{H,t+s} \\ &= \check{p}^{-\epsilon}_{H,t} p^{-1}_{H,t} mc_t y_{H,t} + \sum_{s=1}^{\infty} (\phi\beta)^s \frac{\lambda_{t+s} P_t}{\lambda_t P_{t+s}} \check{P}^{-\epsilon}_{H,t} Z^{-\epsilon}_{t,s} P^{-1}_{H,t} P_{t+s} mc_{t+s} P^{\epsilon}_{H,t+s} y_{H,t+s} \\ &= \check{p}^{-\epsilon}_{H,t} p^{-1}_{H,t} mc_t y_{H,t} + \phi\beta \frac{\lambda_{t+1}}{\lambda_t} \frac{[(\pi_{H,t})^\iota (\breve{\pi}_{t+1})^{1-\iota}]^{-\epsilon}}{\pi_{t+1} \pi^{-1-\epsilon}_{H,t+1}} \left(\frac{\check{p}_{H,t}}{\check{p}_{H,t+1}} \right)^{-\epsilon} \Gamma^1_{t+1}, \end{aligned}$$

and

$$\begin{aligned} \Gamma^2_t &= \sum_{s=0}^{\infty} (\phi\beta)^s \frac{\lambda_{t+s} P_t}{\lambda_t P_{t+s}} \check{P}^{1-\epsilon}_{H,t} Z^{1-\epsilon}_{t,s} P^{-1}_{H,t} P^{\epsilon}_{H,t+s} y_{H,t+s} \\ &= \check{p}^{1-\epsilon}_{H,t} y_{H,t} + \sum_{s=1}^{\infty} (\phi\beta)^s \frac{\lambda_{t+s} P_t}{\lambda_t P_{t+s}} \check{P}^{1-\epsilon}_{H,t} Z^{1-\epsilon}_{t,s} P^{-1}_{H,t} P^{\epsilon}_{H,t+s} y_{H,t+s} \\ &= \check{p}^{1-\epsilon}_{H,t} y_{H,t} + \phi\beta \frac{\lambda_{t+1}}{\lambda_t} \frac{[(\pi_{H,t})^\iota (\breve{\pi}_{t+1})^{1-\iota}]^{1-\epsilon}}{\pi_{t+1} \pi^{-\epsilon}_{H,t+1}} \left(\frac{\check{p}_{H,t}}{\check{p}_{H,t+1}} \right)^{1-\epsilon} \Gamma^2_{t+1}. \end{aligned}$$

Further, let $\Theta(t)$ denote the set of firms that cannot optimally set their price in t. By (A.26), $P_{H,t}$ evolves as follows:

$$P_{H,t}^{1-\epsilon} = \int_0^1 \left(P_{H,t}^i\right)^{1-\epsilon} di \quad = \quad (1-\phi)\check{P}_{H,t}^{1-\epsilon} + \int_{\Theta(t)} \left[P_{H,t-1}^i(\pi_{H,t-1})^{\iota}(\breve{\pi}_t)^{1-\iota}\right]^{1-\epsilon} di$$
$$= \quad (1-\phi)\check{P}_{H,t}^{1-\epsilon} + \phi[(\pi_{H,t-1})^{\iota}(\breve{\pi}_t)^{1-\iota}P_{H,t-1}]^{1-\epsilon},$$

or, dividing both sides by $P_{H,t}^{1-\epsilon}$:

$$1 = (1-\phi)\check{p}_{H,t}^{1-\epsilon} + \phi[(\pi_{H,t-1})^{\iota}(\breve{\pi}_t)^{1-\iota}\pi_{H,t}^{-1}]^{1-\epsilon}.$$

The third equality above follows from the fact that the distribution of prices among firms not reoptimizing in t corresponds to the distribution of effective prices in $t-1$, though with total mass reduced to ϕ.

Appendix A.8. Market clearing

Appendix A.8.1. Law of one price

The small open economy assumptions implies $P_{F,t}^* = P_t^*$. The law of one price (LOP) for foreign goods then implies

$$P_{F,t} = X_t P_{F,t}^* = X_t P_t^*. \tag{A.37}$$

Combining (A.37) with (A.22) yields

$$p_{H,t} = \left(\frac{1-\vartheta q_t^{1-\gamma}}{1-\vartheta}\right)^{\frac{1}{1-\gamma}}. \tag{A.38}$$

Using (A.38) for $t \geq 1$ and $t-1 \geq 0$, the CPI inflation rate can be expressed in terms of producer price inflation as follows:

$$\pi_t = \pi_{H,t}\left(\frac{1-\vartheta q_t^{1-\gamma}}{1-\vartheta q_{t-1}^{1-\gamma}}\right)^{\frac{1}{\gamma-1}},$$

where

$$\pi_{H,t} = \frac{p_{H,t}}{p_{H,t-1}}\pi_t.$$

Further, the LOP for domestic goods implies

$$P_{H,t} = X_t P_{H,t}^*. \tag{A.39}$$

Appendix A.8.2. Goods market

In the market for final goods, the clearing condition is

$$y_t = c_t + i_t. \tag{A.40}$$

For home composite and intermediate goods we have, respectively,

$$y_{H,t} = x_{H,t} + x_{H,t}^* + g_t, \tag{A.41}$$

and

$$y_{H,t}^i = x_{H,t}^i, \quad \text{for all } j. \tag{A.42}$$

Substituting (A.9) and (A.20) into (A.41) and using (A.39) and (A.40) then gives

$$y_{H,t} = (1-\vartheta)\left(p_{H,t}\right)^{-\gamma}\left(c_t + i_t\right) + \vartheta^* \left(\frac{p_{H,t}}{q_t}\right)^{-\gamma^*} y_t^* + g_t.$$

Appendix A.8.3. Factor market

In the market for labor, the clearing condition is

$$n_t = \int_0^1 n_t^l dl = n_t^d \Delta_{w,t}, \tag{A.43}$$

where $n_t^d = \int_0^1 n_{it}^d di$ and $\Delta_{w,t}$ is a wage dispersion term that satisfies

$$\begin{aligned}
\Delta_{w,t} = \int_0^1 \left(\frac{W_t^l}{W_t}\right)^{-\epsilon_w} dl &= (1-\phi_w)\breve{w}_t^{-\epsilon_w} + \int_{\Theta^w(t)} \left[\left(\frac{W_{t-1}^l}{W_t}\right)(\pi_{t-1})^{\iota}(\breve{\pi}_t)^{1-\iota}\right]^{-\epsilon_w} dl \\
&= (1-\phi_w)\breve{w}_t^{-\epsilon_w} + [(\pi_{t-1})^{\iota}(\breve{\pi}_t)^{1-\iota}\pi_{w,t}^{-1}]^{-\epsilon_w} \int_{\Theta^w(t)} \left(\frac{W_{t-1}^l}{W_{t-1}}\right)^{-\epsilon_w} dl \\
&= (1-\phi_w)\breve{w}_t^{-\epsilon_w} + \phi_w[(\pi_{t-1})^{\iota}(\breve{\pi}_t)^{1-\iota}\pi_{w,t}^{-1}]^{-\epsilon_w}\Delta_{w,t-1}.
\end{aligned}$$

In the market for capital, the clearing condition is

$$\int_0^1 k_{it} di = k_t. \tag{A.44}$$

Appendix A.8.4. Loan market

In the market for loans, the clearing condition is

$$\left(R_t - 1\right)/R_t \int_0^1 l_{it} di = l_{t-1}\pi_t^{*-1} - l_t/R_t. \tag{A.45}$$

Appendix A.8.5. Aggregate supply

Integrating (A.27) over i using (A.41) and the fact that $k_{it}/n_{it}^d = k_t/n_t^d$ yields

$$\int_0^1 y_{H,t}^i di = a_t(k_t/n_t^d)^{\alpha} \int_0^1 n_{it}^d di = a_t k_t^{\alpha}(n_t^d)^{1-\alpha}. \tag{A.46}$$

Integrating (A.21) over i further yields

$$\int_0^1 y_{H,t}^i di = y_{H,t} \int_0^1 \left(\frac{P_{H,t}^i}{P_{H,t}}\right)^{-\epsilon} di = y_{H,t}\Delta_t, \tag{A.47}$$

where Δ_t is a price dispersion term that satisfies

$$\begin{aligned}
\Delta_t = \int_0^1 \left(\frac{P_{H,t}^i}{P_{H,t}}\right)^{-\epsilon} di &= (1-\phi)\breve{p}_{H,t}^{-\epsilon} + \int_{\Theta(t)} \left[\left(\frac{P_{H,t-1}^i}{P_{H,t}}\right)(\pi_{H,t-1})^{\iota}(\breve{\pi}_t)^{1-\iota}\right]^{-\epsilon} di \\
&= (1-\phi)\breve{p}_{H,t}^{-\epsilon} + [(\pi_{H,t-1})^{\iota}(\breve{\pi}_t)^{1-\iota}\pi_{H,t}^{-1}]^{-\epsilon} \int_{\Theta(t)} \left(\frac{P_{H,t-1}^i}{P_{H,t-1}}\right)^{-\epsilon} di \\
&= (1-\phi)\breve{p}_{H,t}^{-\epsilon} + \phi[(\pi_{H,t-1})^{\iota}(\breve{\pi}_t)^{1-\iota}\pi_{H,t}^{-1}]^{-\epsilon}\Delta_{t-1}.
\end{aligned}$$

Combining (A.46) and (A.47) yields

$$y_{H,t}\Delta_t = a_t k_t^{\alpha}(n_t^d)^{1-\alpha}.$$

Appendix A.8.6. Aggregate payouts

Aggregate payouts are given by

$$\begin{aligned}\Sigma_t \quad = \quad & \underbrace{P_t y_t - P_{H,t}x_{H,t} - P_{F,t}x_{F,t}}_{\text{Final goods firms}} + \underbrace{P_{H,t}y_{H,t} - \int_0^1 P_{H,t}^i x_{H,t}^i di}_{\text{Home composite goods firms}} \\ & + \underbrace{\int_0^1 \left[P_{H,t}^i y_{H,t}^i - W_t n_{it}^d - R_t^k k_{it} - X_t(R_t-1)\frac{L_{it}}{R_t}\right] di}_{\text{Intermediate goods firms}} \\ & + \underbrace{W_t n_t^d - \int_0^1 W_t^l n_t^l dl}_{\text{Labor packers}} + \underbrace{\int_0^1 W_t^l n_t^l dl - W_t^h n_t}_{\text{Intermediate labor unions}} \\ & + \underbrace{X_t\frac{V_t}{R_{v,t}\Upsilon_t} - X_t V_{t-1} + X_t\frac{M_t}{R_t} - X_t M_{t-1} + X_t\frac{L_t}{R_t} - X_t L_{t-1}}_{\text{Financial intermediary}},\end{aligned}$$

or, using (A.41) and (A.42) and (A.43)-(A.45),

$$\Sigma_t = P_t y_t + P_{H,t}(x_{H,t}^* + g_t) - P_{F,t}x_{F,t} - W_t^h n_t - R_t^k k_t + X_t\frac{V_t}{R_{v,t}\Upsilon_t} - X_t V_{t-1} + X_t\frac{M_t}{R_t} - X_t M_{t-1}.$$

Appendix A.8.7. Foreign asset position

Substituting out Σ_t in (A.5) holding with equality and using (A.40) and (A.1) yields

$$-X_t\left(\frac{V_t}{R_{v,t}\Upsilon_t} + \frac{B_{F,t}}{R_{F,t}}\right) = P_{H,t}x_{H,t}^* - P_{F,t}x_{F,t} - X_t\left(V_{t-1} + B_{F,t-1}\right). \tag{A.48}$$

From (A.22) and (A.39), real exports are

$$x_{H,t}^* = \vartheta^*\left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\gamma^*} y_t^* = \vartheta^*\left(\frac{p_{H,t}}{q_t}\right)^{-\gamma^*} y_t^*, \tag{A.49}$$

while from (A.9), (A.37) and (A.40), real imports are

$$x_{F,t} = \vartheta\left(\frac{P_{F,t}}{P_t}\right)^{-\gamma} y_t = \vartheta q_t^{-\gamma}\left(c_t + i_t\right). \tag{A.50}$$

Substituting out (A.49) and (A.50) in (A.48), using again (A.37) and dividing through by P_t gives

$$-q_t\left(\frac{v_t}{R_{v,t}\Upsilon_t} + \frac{b_{F,t}}{R_{F,t}}\right) = q_t^{\gamma^*} p_{H,t}^{1-\gamma^*}\vartheta^* y_t^* - \vartheta q_t^{1-\gamma}\left(c_t + i_t\right) - q_t\frac{v_{t-1} + b_{F,t-1}}{\pi_t^*}.$$

Appendix B. Non-linear equilibrium

The *rational expectations equilibrium* of the model is the set of sequences

$$\{\lambda_t, c_t, i_t, k_t, \lambda_t^k, r_t^k, n_t, n_t^d, \mu_t^w, \Gamma_{w,t}^1, \Gamma_{w,t}^2, \breve{w}_t, \Delta_{w,t}, \pi_{w,t}, w_t, y_{H,t}, mc_t, \Gamma_t^1, \Gamma_t^2,$$
$$\breve{p}_{H,t}, p_{H,t}, \Delta_t, \pi_{H,t}, \pi_t, q_t, R_{H,t}, R_{F,t}, R_t, R_{v,t}, \Psi_t, \delta_t, \tilde{\tau}_t, d_t, b_{H,t}, b_{F,t}, v_t\}_{t=0}^{\infty},$$

such that for given initial values and exogenous sequences

$$\{z_t, \varsigma_{w,t}, a_t, g_t, f_t, \mu_t, \psi_t, \varepsilon_{R,t}, \varepsilon_{\tau,t}, \breve{\pi}_t, y_t^*, \pi_t^*, R_t^*\}_{t=0}^{\infty},$$

the following conditions and the transversality conditions are satisfied:

$$\mathfrak{p}_t = F_{\bar{b}}(b_t) + F_{\bar{d}}(d_t) - F_{\bar{b},\bar{d}}(b_t, d_t), \tag{B.1}$$

$$\delta_t = \begin{cases} \omega & \text{with probability } \mathfrak{p}_t, \\ 0 & \text{with probability } 1 - \mathfrak{p}_t, \end{cases} \tag{B.2}$$

$$\frac{\tilde{\tau}_t}{\tau} = \left(\frac{\tilde{\tau}_{t-1}}{\tau}\right)^{\kappa_\tau} \left[\left(\frac{d_t}{d}\right)^{\kappa_d} \left(\frac{y_{H,t}}{y_H}\right)^{\kappa_y}\right]^{1-\kappa_\tau} \exp(\varepsilon_{\tau,t}), \tag{B.3}$$

$$d_t = b_{H,t} - b_{H,t-1}\pi_t^{-1} + q_t(b_{F,t} - b_{F,t-1}\pi_t^{*-1}), \tag{B.4}$$

$$q_t b_{F,t}/R_{F,t} = f_t b_{H,t}/R_{H,t}, \tag{B.5}$$

$$b_{H,t}/R_{H,t} + q_t b_{F,t}/R_{F,t} + \tilde{\tau}_t = p_{H,t} g_t + b_{H,t-1}\pi_t^{-1} + q_t b_{F,t-1}\pi_t^{*-1}, \tag{B.6}$$

$$\frac{R_{H,t}}{R_H} = \left(\frac{R_{H,t-1}}{R_H}\right)^{\alpha_R} \left[\frac{\breve{\pi}_t}{\bar{\pi}} \left(\frac{\pi_t}{\breve{\pi}_t}\right)^{\alpha_\pi} \left(\frac{y_{H,t}}{y_H}\right)^{\alpha_y} E_t \left(\frac{\delta_{t+1}}{\delta}\right)^{\frac{\alpha_\delta \delta}{1-\delta}}\right]^{1-\alpha_R} \exp(\varepsilon_{R,t}), \tag{B.7}$$

$$\lambda_t = z_t(c_t - hc_{t-1})^{-\sigma}, \tag{B.8}$$

$$\lambda_t w_t = \mu_t^w z_t \varsigma_{w,t} n_t^\eta, \tag{B.9}$$

$$\lambda_t q_t = R_t \beta E_t[\lambda_{t+1} q_{t+1} \pi_{t+1}^{*-1}], \tag{B.10}$$

$$\lambda_t = R_{H,t} \beta E_t[(1 - \delta_{t+1})\lambda_{t+1}\pi_{t+1}^{-1}], \tag{B.11}$$

$$\lambda_t \lambda_t^k = \beta E_t[\lambda_{t+1} r_{t+1}^k + \lambda_{t+1}\lambda_{t+1}^k (1 - \varpi)], \tag{B.12}$$

$$\lambda_t = \lambda_t \lambda_t^k \mu_t [1 - S(i_t/i_{t-1}) - S'(i_t/i_{t-1}) i_t/i_{t-1}] + \beta E_t[\lambda_{t+1}\lambda_{t+1}^k \mu_{t+1} S'(i_{t+1}/i_t)(i_{t+1}/i_t)^2], \tag{B.13}$$

$$k_{t+1} = \mu_t[1 - S(i_t/i_{t-1})]i_t + (1 - \varpi)\, k_t, \tag{B.14}$$

$$R_t^* = R_{F,t} E_t (1 - \delta_{t+1}), \tag{B.15}$$

$$R_t = R_{v,t} \Upsilon_t, \tag{B.16}$$

$$\Upsilon_t = \exp[\varphi\,(v_t - \bar{v})\,/y_H + (\psi_t - \psi)/\psi], \tag{B.17}$$

$$R_{v,t}/R_t^* = v_1\,(R_{F,t}/R_t^*)^{v_2}\,, \tag{B.18}$$

$$\epsilon_w \Gamma^1_{w,t} = (\epsilon_w - 1)\Gamma^2_{w,t}, \tag{B.19}$$

$$\Gamma^1_{w,t} = \breve{w}_t^{-\epsilon_w} n_t^d/\mu_t^w + \phi_w \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{[(\pi_t)^{\iota_w}\,(\breve{\pi}_{t+1})^{1-\iota_w}]^{-\epsilon_w}}{\pi_{t+1}\pi_{w,t+1}^{-1-\epsilon_w}} \left(\frac{\breve{w}_t}{\breve{w}_{t+1}}\right)^{-\epsilon_w} \Gamma^1_{w,t+1} \right\}, \tag{B.20}$$

$$\Gamma^2_{w,t} = \breve{w}_t^{1-\epsilon_w} n_t^d + \phi_w \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{[(\pi_t)^{\iota_w}\,(\breve{\pi}_{t+1})^{1-\iota_w}]^{1-\epsilon_w}}{\pi_{t+1}\pi_{w,t+1}^{-\epsilon_w}} \left(\frac{\breve{w}_t}{\breve{w}_{t+1}}\right)^{1-\epsilon_w} \Gamma^2_{w,t+1} \right\}, \tag{B.21}$$

$$1 = (1 - \phi_w)\breve{w}_t^{1-\epsilon_w} + \phi_w \left(\frac{(\pi_{t-1})^{\iota_w}(\breve{\pi}_t)^{1-\iota_w}}{\pi_{w,t}} \right)^{1-\epsilon_w}, \tag{B.22}$$

$$n_t = n_t^d \Delta_{w,t}, \tag{B.23}$$

$$\Delta_{w,t} = (1 - \phi_w)\breve{w}_t^{-\epsilon_w} + \phi_w[(\pi_{t-1})^{\iota}(\breve{\pi}_t)^{1-\iota}\pi_{w,t}^{-1}]^{-\epsilon_w}\Delta_{w,t-1}, \tag{B.24}$$

$$\pi_{w,t} = (w_t/w_{t-1})\pi_t, \tag{B.25}$$

$$\frac{k_t}{n_t^d} = \frac{\alpha}{1-\alpha} \frac{w_t[1 + \zeta^w(R_t - 1)]}{r_t^k[1 + \zeta^k(R_t - 1)]}, \tag{B.26}$$

$$mc_t = a_t^{-1}\,(w_t[1 + \zeta^w(R_t - 1)])^{1-\alpha}\,(r_t^k[1 + \zeta^k(R_t - 1)])^{\alpha} \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^{\alpha}, \tag{B.27}$$

$$\epsilon \Gamma_t^1 = (\epsilon - 1)\Gamma_t^2, \tag{B.28}$$

$$\Gamma_t^1 = \breve{p}_{H,t}^{-\epsilon} p_{H,t}^{-1} mc_t y_{H,t} + \phi\beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{[(\pi_{H,t})^{\iota}(\breve{\pi}_{t+1})^{1-\iota}]^{-\epsilon}}{\pi_{t+1}\pi_{H,t+1}^{-1-\epsilon}} \left(\frac{\breve{p}_{H,t}}{\breve{p}_{H,t+1}}\right)^{-\epsilon} \Gamma^1_{t+1} \right\}, \tag{B.29}$$

$$\Gamma_t^2 = \breve{p}_{H,t}^{1-\epsilon} y_{H,t} + \phi\beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{[(\pi_{H,t})^{\iota}(\breve{\pi}_{t+1})^{1-\iota}]^{1-\epsilon}}{\pi_{t+1}\pi_{H,t+1}^{-\epsilon}} \left(\frac{\breve{p}_{H,t}}{\breve{p}_{H,t+1}}\right)^{1-\epsilon} \Gamma^2_{t+1} \right\}, \tag{B.30}$$

$$1 = (1-\phi)\breve{p}_{H,t}^{1-\epsilon} + \phi[(\pi_{H,t-1})^{\iota}(\breve{\pi}_t)^{1-\iota}\pi_{H,t}^{-1}]^{1-\epsilon}, \tag{B.31}$$

$$\pi_{H,t} = (p_{H,t}/p_{H,t-1})\pi_t, \tag{B.32}$$

$$p_{H,t} = \left(\frac{1-\vartheta q_t^{1-\gamma}}{1-\vartheta}\right)^{\frac{1}{1-\gamma}}, \tag{B.33}$$

$$y_{H,t} = (1-\vartheta)\, p_{H,t}^{-\gamma}\,(c_t + i_t) + \vartheta^*\,(p_{H,t}/q_t)^{-\gamma^*}\, y_t^* + g_t, \tag{B.34}$$

$$y_{H,t}\Delta_t = a_t k_t^{\alpha}(n_t^d)^{1-\alpha}, \tag{B.35}$$

$$\Delta_t = (1-\phi)\breve{p}_{H,t}^{-\epsilon} + \phi[(\pi_{H,t-1})^{\iota}(\breve{\pi}_t)^{1-\iota}\pi_{H,t}^{-1}]^{-\epsilon}\Delta_{t-1}, \tag{B.36}$$

$$-q_t\left(\frac{v_t}{R_{v,t}\Upsilon_t} + \frac{b_{F,t}}{R_{F,t}}\right) = q_t^{\gamma^*} p_{H,t}^{1-\gamma^*}\vartheta^* y_t^* - \vartheta q_t^{1-\gamma}\,(c_t + i_t) - q_t\frac{v_{t-1} + b_{F,t-1}}{\pi_t^*}. \tag{B.37}$$

In addition, real exports and imports are, respectively,

$$x_{H,t}^* = \vartheta^*(p_{H,t}/q_t)^{-\gamma^*} y_t^*,$$

and

$$x_{F,t} = \vartheta q_t^{-\gamma}\,(c_t + i_t)\,.$$

The exogenous processes are

$$\log(x_t/\bar{x}) = \rho_x \log(x_{t-1}/\bar{x}) + \varepsilon_t^x, \qquad \rho_x \in [0,1), \qquad \bar{x} > 0,$$

for $x = \{z, \varsigma_w, a, g, f, \mu, \psi, \breve{\pi}, \pi^*, R^*, y^*\}$, where the ε_t^x are n.i.d. innovations.

Appendix C. Steady state

We show how to solve for the steady state taking as given R_H, δ, π, q, n, mc, μ^w, $s_{b_H} = b_H/y_H$, $s_{b_F} = b_H/y_F$, and $s_g = g/y_H$. The parameters β, $\bar{\pi}$, ϵ, ϵ_w, ς_w, $\bar{\pi}^*$, $\vartheta^* y^*$ and $\bar{g}$ are determined endogenously while the values of the remaining parameters are taken as given.

We then obtain from the exogenous processes for R_t^*, a_t, μ_t, z_t and ψ_t:

$$R^* = \bar{R}^*,\ a = \bar{a},\ \mu = \bar{\mu},\ z = \bar{z},\ \psi = \bar{\psi}. \tag{C.1}$$

From (B.7) and the exogenous process for $\breve{\pi}_t$:

$$\bar{\pi} = \breve{\pi} = \pi. \tag{C.2}$$

From (B.17):

$$\Upsilon = 1. \tag{C.3}$$

From (B.11) and using (B.2):

$$\beta = \pi / [R_H(1-\delta)] . \tag{C.4}$$

From (B.13):

$$\lambda^k = 1/\mu. \tag{C.5}$$

From (B.12):

$$r^k = \lambda^k(1/\beta - 1 + \varpi). \tag{C.6}$$

From (B.15):

$$R_F = R^*/(1-\delta). \tag{C.7}$$

From (B.18):

$$R_v = v_1 R_F^{v_2} (R^*)^{1-v_2}. \tag{C.8}$$

From (B.16):

$$R = R_v \Upsilon. \tag{C.9}$$

From (B.10) and the exogenous process for π_t^*:

$$\bar{\pi}^* = \pi^* = R\beta. \tag{C.10}$$

From (B.32):

$$\pi_H = \pi. \tag{C.11}$$

From (B.33):

$$p_H = \left(\frac{1-\vartheta q^{1-\gamma}}{1-\vartheta} \right)^{\frac{1}{1-\gamma}}. \tag{C.12}$$

From (B.31) and using (C.11):

$$\check{p}_H = 1. \tag{C.13}$$

From (B.28)-(B.30) and using (C.2), (C.11) and (C.13):

$$\epsilon = \frac{p_H/mc}{p_H/mc - 1}. \tag{C.14}$$

From (B.36) and using (C.2), (C.11) and (C.13):

$$\Delta = 1. \tag{C.15}$$

From (B.27):

$$w = \left(\frac{\alpha^\alpha (1-\alpha)^{1-\alpha} amc}{(r^k[1+\zeta^k(R-1)])^\alpha} \right)^{\frac{1}{1-\alpha}} [1+\zeta^w(R-1)]^{-1}. \tag{C.16}$$

From (B.25):

$$\pi_w = \pi. \tag{C.17}$$

From (B.22) and using (C.2) and (C.17):

$$\breve{w} = 1. \tag{C.18}$$

From (B.19)-(B.21) and using (C.2), (C.17) and (C.18):

$$\epsilon_w = \frac{\mu^w}{\mu^w - 1}. \tag{C.19}$$

From (B.24) and using (C.2), (C.17) and (C.18):

$$\Delta_w = 1. \tag{C.20}$$

From (B.23):

$$n^d = n/\Delta_w. \tag{C.21}$$

From (B.20)-(B.21) and using (C.2), (C.17) and (C.18):

$$\Gamma_w^1 = (n^d/\mu^w)/(1 - \phi_w \beta), \tag{C.22}$$

$$\Gamma_w^2 = n^d/(1 - \phi_w \beta). \tag{C.23}$$

From (B.26):

$$k = \frac{\alpha w n^d}{(1-\alpha)\, r^k}[1 + \zeta^w (R - 1)][1 + \zeta^k (R - 1)]^{-1}. \tag{C.24}$$

From (B.14):

$$i = \varpi k/\mu. \tag{C.25}$$

From (B.35):

$$y_H = a k^\alpha (n^d)^{1-\alpha}/\Delta. \tag{C.26}$$

From (B.29)-(B.30) and using (C.2), (C.11) and (C.13):

$$\Gamma^1 = p_H^{-1} m c y_H/(1 - \phi\beta), \tag{C.27}$$

$$\Gamma^2 = y_H/(1 - \phi\beta). \tag{C.28}$$

From $s_g = g/y_H$ and the exogenous process for g_t:

$$\bar{g} = g = s_g y_H. \tag{C.29}$$

From $s_{b_H} = b_H/y_H$:

$$b_H = s_{b_H} y_H. \tag{C.30}$$

From $s_{b_F} = b_F/y_F$:

$$b_F = s_{b_F} y_F. \tag{C.31}$$

From (B.5):

$$f = \frac{q b_F R_H}{R_F b_H} \tag{C.32}$$

From (B.4):

$$d = b_H(1 - \pi^{-1}) + q b_F(1 - \pi^{*-1}). \tag{C.33}$$

From (B.6):

$$\tilde{\tau} = p_H g + b_H \pi^{-1} + q b_F \pi^{*-1} - b_H/R_H - q b_F/R_F. \tag{C.34}$$

From (B.34) and (B.37) and using (C.12):

$$c = p_H\left(y_H - g\right) - q\bar{v}\left[\pi^{*-1} - \left(R_v\Upsilon\right)^{-1}\right] - qb_F\left(\pi^{*-1} - R_F^{-1}\right) - i, \tag{C.35}$$

where $\bar{v} = v$. From (B.34):

$$\vartheta^* y^* = \frac{y_H - (1-\vartheta)\, p_H^{-\gamma}\,(c+i) - g}{(p_H/q)^{-\gamma^*}}. \tag{C.36}$$

From (B.8):

$$\lambda = z(c - hc)^{-\sigma}. \tag{C.37}$$

From (B.9):

$$\varsigma_w = \lambda w/(\mu^w z n^\eta). \tag{C.38}$$

In addition, we have

$$x_H^* = (p_H/q)^{-\gamma^*}\vartheta^* y^*,$$

$$x_F = \vartheta q^{-\gamma}\,(c+i)\,.$$

Appendix D. Log-linearization

This appendix contains the linearized version of the equilibrium conditions (B.2)-(B.30). The log deviation and absolute deviation of a variable x_t from its steady state x are denoted by $\hat{x}_t$ and $\tilde{x}_t$, respectively. For the steady state, we assume that the real exchange rate satisfies $q = 1$ and we set $\bar{v} = 0$.

From (B.2) and using $\Phi_b = \left(f_{\bar{b}}\,(b) - \frac{\partial F_{\bar{b},\bar{d}}(b,d)}{\partial \bar{b}}\right) b/\left(1-\delta\right)$, $\Phi_d = \left(f_{\bar{d}}\,(d) - \frac{\partial F_{\bar{b},\bar{d}}(b,d)}{\partial \bar{d}}\right) d/\left(1-\delta\right)$:

$$\frac{\delta}{1-\delta}\hat{\delta}_t = \omega\left(\Phi_b \hat{b}_t + \Phi_d \hat{d}_t\right). \tag{D.1}$$

From (B.3):

$$\hat{\bar{\tau}}_t = \kappa_\tau \hat{\bar{\tau}}_{t-1} + (1-\kappa_\tau)\left(\kappa_d \hat{d}_t + \kappa_y \hat{y}_{H,t}\right) + \varepsilon_{\tau,t}. \tag{D.2}$$

From (B.4):

$$d\hat{d}_t = b_H \hat{b}_{H,t} - \frac{b_H}{\pi}(\hat{b}_{H,t-1} - \hat{\pi}_t) + b_F(\hat{q}_t + \hat{b}_{F,t}) - \frac{b_F}{\pi^*}(\hat{q}_t + \hat{b}_{F,t-1} - \hat{\pi}_t^*). \tag{D.3}$$

From (B.5):

$$\hat{q}_t + \hat{b}_{F,t} - \hat{R}_{F,t} = \hat{f}_t + \hat{b}_{H,t} - \hat{R}_{H,t}. \tag{D.4}$$

From (B.3) and (B.6):

$$\begin{aligned} & \frac{b_H}{R_h}\left(\hat{b}_{H,t} - \hat{R}_{H,t}\right) + \frac{b_F}{R_F}\left(\hat{q}_t + \hat{b}_{F,t} - \hat{R}_{F,t}\right) + \tilde{\tau}\hat{\bar{\tau}}_t \\ = \quad & g\left(\hat{g}_t - \frac{\vartheta}{1-\vartheta}\hat{q}_t\right) + \frac{b_H}{\pi}\left(\hat{b}_{H,t-1} - \hat{\pi}_t\right) + \frac{b_F}{\pi^*}(\hat{q}_t + \hat{b}_{F,t-1} - \hat{\pi}_t^*). \end{aligned} \tag{D.5}$$

From (B.7):

$$\hat{R}_{H,t} = \alpha_R \hat{R}_{H,t-1} + (1-\alpha_R)[\hat{\bar{\pi}}_t + \alpha_\pi(\hat{\pi}_t - \hat{\bar{\pi}}_t) + \alpha_y \hat{y}_{H,t} + \alpha_\delta \frac{\delta}{1-\delta} E_t \hat{\delta}_{t+1}] + \varepsilon_{R,t}. \tag{D.6}$$

From (B.8):

$$\hat{\lambda}_t = \hat{z}_t - \frac{\sigma}{1-h}\left(\hat{c}_t - h\hat{c}_{t-1}\right). \tag{D.7}$$

From (B.9):

$$\hat{\lambda}_t + \hat{w}_t = \hat{\mu}_t^w + \hat{z}_t + \hat{\varsigma}_{w,t} + \eta \hat{n}_t. \tag{D.8}$$

From (B.10):

$$\hat{\lambda}_t + \hat{q}_t = \hat{R}_t + E_t[\hat{\lambda}_{t+1} + \hat{q}_{t+1} - \hat{\pi}^*_{t+1}]. \tag{D.9}$$

From (B.11):

$$\hat{\lambda}_t = \hat{R}_{H,t} + E_t \left[\hat{\lambda}_{t+1} - \hat{\pi}_{t+1} - \frac{\delta}{1-\delta} \hat{\delta}_{t+1} \right]. \tag{D.10}$$

From (B.12):

$$\hat{\lambda}_t + \hat{\lambda}_t^k = \beta E_t \left[\frac{r^k}{\lambda^k} (\hat{r}^k_{t+1} + \hat{\lambda}_{t+1}) + (1-\omega) (\lambda^k_{t+1} + \hat{\lambda}_{t+1}) \right]. \tag{D.11}$$

From (B.13) and using $S(1) = S'(1) = 0$:

$$S''(\hat{\imath}_t - \hat{\imath}_{t-1}) = \hat{\lambda}_t^k + \hat{\mu}_t + \beta S''(E_t[\hat{\imath}_{t+1}] - \hat{\imath}_t). \tag{D.12}$$

From (B.14) and using (C.25):

$$\hat{k}_{t+1} = (1-\varpi)\hat{k}_t + \varpi(\hat{\mu}_t + \hat{\imath}_t). \tag{D.13}$$

From (B.15):

$$\hat{R}^*_t = \hat{R}_{F,t} - \frac{\delta}{1-\delta} E_t[\hat{\delta}_{t+1}]. \tag{D.14}$$

From (B.16):

$$\hat{R}_t = \hat{R}_{v,t} + \hat{\Upsilon}_t. \tag{D.15}$$

From (B.17):

$$\hat{\Upsilon}_t = \varphi \tilde{v}_t / y_H + \hat{\psi}_t. \tag{D.16}$$

From (B.18):

$$\hat{R}_{v,t} - \hat{R}^*_t = \upsilon_2(\hat{R}_{F,t} - \hat{R}^*_t). \tag{D.17}$$

From (B.19):

$$\hat{\Gamma}^1_{w,t} = \hat{\Gamma}^2_{w,t}. \tag{D.18}$$

From (B.20) and using (C.2), (C.17), (C.18) and (C.27):

$$\begin{aligned} \hat{\Gamma}^1_{w,t} \;\; &= \;\; (1-\phi_w\beta)(\hat{n}^d_t - \epsilon_w \widehat{\tilde{w}}_t - \hat{\mu}^w_t) \\ &\quad + \phi_w \beta E_t \left[\begin{array}{c} \hat{\lambda}_{t+1} - \hat{\lambda}_t - \epsilon_w \iota_w \hat{\pi}_t - \epsilon_w (1-\iota_w) \widehat{\tilde{\pi}}_{t+1} - \hat{\pi}_{t+1} \\ + (1+\epsilon_w) \hat{\pi}_{w,t+1} - \epsilon_w \widehat{\tilde{w}}_t + \epsilon_w \widehat{\tilde{w}}_{t+1} + \hat{\Gamma}^1_{w,t+1} \end{array} \right]. \end{aligned} \tag{D.19}$$

From (B.21) and using (C.2), (C.17), (C.18) and (C.28):

$$\begin{aligned} \hat{\Gamma}^2_{w,t} \;\; &= \;\; (1-\phi_w\beta)[\hat{n}^d_t + (1-\epsilon_w)\widehat{\tilde{w}}_t] \\ &\quad + \phi_w \beta E_t \left[\begin{array}{c} \hat{\lambda}_{t+1} - \hat{\lambda}_t + (1-\epsilon_w) \iota_w \hat{\pi}_t + (1-\epsilon_w)(1-\iota_w) \widehat{\tilde{\pi}}_{t+1} - \hat{\pi}_{t+1} \\ + \epsilon_w \hat{\pi}_{w,t+1} + (1-\epsilon_w) \widehat{\tilde{w}}_t - (1-\epsilon_w) \widehat{\tilde{w}}_{t+1} + \hat{\Gamma}^2_{w,t+1} \end{array} \right]. \end{aligned} \tag{D.20}$$

From (B.22) and using (C.2), (C.17) and (C.18):

$$\widehat{\tilde{w}}_t = \frac{\phi_w}{\phi_w - 1}[\iota_w \hat{\pi}_{t-1} + (1-\iota_w)\widehat{\tilde{\pi}}_t - \hat{\pi}_{w,t}]. \tag{D.21}$$

From (B.23):

$$\hat{n}_t = \hat{n}_t^d + \hat{\Delta}_{w,t}. \tag{D.22}$$

From (B.24) and using (C.2), (C.17), (C.18) and (C.20):

$$\hat{\Delta}_{w,t} = (\phi_w - 1)\epsilon_w \widehat{\tilde{w}}_t - \phi_w \epsilon_w [\iota_w \hat{\pi}_{t-1} + (1-\iota_w)\widehat{\breve{\pi}}_t - \hat{\pi}_{w,t}] + \phi_w \Delta_{w,t-1}. \tag{D.23}$$

From (B.25):

$$\hat{\pi}_{w,t} = \hat{w}_t - \hat{w}_{t-1} + \hat{\pi}_t. \tag{D.24}$$

From (B.26):

$$\hat{k}_t - \hat{n}_t^d = \hat{w}_t - \hat{r}_t^k + \left(\frac{\zeta^w}{1+\zeta^w(R-1)} - \frac{\zeta^k}{1+\zeta^k(R-1)} \right) R\hat{R}_t. \tag{D.25}$$

From (B.27):

$$\widehat{mc}_t = (1-\alpha)\left(\hat{w}_t + \frac{\zeta^w R}{1+\zeta^w (R-1)} \hat{R}_t \right) + \alpha \left(\hat{r}_t^k + \frac{\zeta^k R}{1+\zeta^k (R-1)} \hat{R}_t \right) - \hat{a}_t. \tag{D.26}$$

From (B.28):

$$\hat{\Gamma}_t^1 = \hat{\Gamma}_t^2. \tag{D.27}$$

From (B.29) and using (C.2), (C.11), (C.13) and (C.27):

$$\begin{aligned} \hat{\Gamma}_t^1 \quad = \quad & (1-\phi\beta)(\widehat{mc}_t + \hat{y}_{H,t} - \hat{p}_{H,t} - \epsilon\widehat{\tilde{p}}_{H,t}) \\ & + \phi\beta E_t \left[\begin{array}{c} \hat{\lambda}_{t+1} - \hat{\lambda}_t - \epsilon\iota\hat{\pi}_{H,t} - \epsilon(1-\iota)\widehat{\breve{\pi}}_{t+1} \\ -\hat{\pi}_{t+1} + (1+\epsilon)\hat{\pi}_{H,t+1} - \epsilon\widehat{\tilde{p}}_{H,t} + \epsilon\widehat{\tilde{p}}_{H,t+1} + \hat{\Gamma}_{t+1}^1 \end{array} \right]. \end{aligned} \tag{D.28}$$

From (B.30) and using (C.2), (C.11), (C.13) and (C.28):

$$\begin{aligned} \hat{\Gamma}_t^2 \quad = \quad & (1-\phi\beta)[\hat{y}_{H,t} + (1-\epsilon)\widehat{\tilde{p}}_{H,t}] \\ & + \phi\beta E_t \left[\begin{array}{c} \hat{\lambda}_{t+1} - \hat{\lambda}_t + (1-\epsilon)\iota\hat{\pi}_{H,t} + (1-\epsilon)(1-\iota)\widehat{\breve{\pi}}_{t+1} \\ -\hat{\pi}_{t+1} + \epsilon\hat{\pi}_{H,t+1} + (1-\epsilon)\widehat{\tilde{p}}_{H,t} - (1-\epsilon)\widehat{\tilde{p}}_{H,t+1} + \hat{\Gamma}_{t+1}^2 \end{array} \right]. \end{aligned} \tag{D.29}$$

From (B.31) and using (C.13):

$$\widehat{\tilde{p}}_{H,t} = \frac{\phi}{\phi-1}[\iota\hat{\pi}_{H,t-1} + (1-\iota)\widehat{\breve{\pi}}_t - \hat{\pi}_{H,t}]. \tag{D.30}$$

From (B.32):

$$\hat{\pi}_{H,t} = \hat{p}_{H,t} - \hat{p}_{H,t-1} + \hat{\pi}_t. \tag{D.31}$$

From (B.33) and using (C.12):

$$\hat{p}_{H,t} = \frac{\vartheta}{\vartheta-1}\hat{q}_t. \tag{D.32}$$

From (B.34) and using (C.12):

$$y_H \hat{y}_{H,t} = \vartheta^* y^* \gamma^* \hat{q}_t + (1-\vartheta)(c\hat{c}_t + i\hat{\imath}_t) - [\gamma(1-\vartheta)(c+i) + \gamma^*\vartheta^* y^*]\hat{p}_{H,t} + \vartheta^* y^* \hat{y}_t^* + g\hat{g}_t. \tag{D.33}$$

From (B.35) and using (C.26) and (C.15):

$$\hat{y}_{H,t} + \hat{\Delta}_t = \hat{a}_t + \alpha \hat{k}_t + (1-\alpha)\hat{n}_t^d. \tag{D.34}$$

From (B.36) and using (C.2), (C.11), (C.13) and (C.15):

$$\hat{\Delta}_t = (\phi - 1)\epsilon \widehat{\tilde{p}}_{H,t} - \phi\epsilon[\iota\hat{\pi}_{H,t-1} + (1-\iota)\widehat{\bar{\pi}}_t - \hat{\pi}_{H,t}] + \phi\hat{\Delta}_{t-1}. \tag{D.35}$$

From (B.37) and using (C.12):

$$\begin{aligned} \frac{\tilde{v}_t}{R_v \Upsilon} - \frac{\tilde{v}_{t-1}}{\pi^*} &= \vartheta(c\hat{c}_t + i\hat{\imath}_t) - \vartheta^* y^*[\hat{q}_t + \hat{y}_t^* + (1-\gamma^*)\,\hat{p}_{H,t}] + (1-\gamma)\vartheta(c+i)\hat{q}_t \\ &\quad - \frac{b_F}{R_F}(\hat{q}_t + \hat{b}_{F,t} - \hat{R}_{F,t}) + \frac{b_F}{\pi^*}(\hat{q}_t + \hat{b}_{F,t-1} - \hat{\pi}_t^*). \end{aligned} \tag{D.36}$$

In addition, we have

$$\hat{x}_{H,t}^* = \gamma^*(\hat{q}_t - \hat{p}_{H,t}) + \hat{y}_t^*,$$

$$\hat{x}_{F,t} = \vartheta q^{-\gamma}[-\gamma(c+i)\hat{q}_t + c\hat{c}_t + i\hat{\imath}_t].$$

Appendix E. Linear equilibrium

The system (D.1)-(D.29) can be written in a more compact form as follows. From (D.7)-(D.8) and (D.22) we have the households' FOC for **consumption and labor supply**:

$$\hat{\lambda}_t = \hat{z}_t - \frac{\sigma}{1-h}(\hat{c}_t - h\hat{c}_{t-1}), \tag{E.1}$$

$$\eta\hat{n}_t = \hat{w}_t - \hat{\mu}_t^w - \hat{\varsigma}'_{w,t}. \tag{E.2}$$

Here, we defined $\hat{\varsigma}'_{w,t} \equiv \frac{1}{\Theta_1}\hat{\varsigma}_{w,t}$, where Θ_1 is given below. From (D.11)-(D.13), we have the FOCs and the law of motion for **physical capital and investment**:

$$\hat{\lambda}_t = \hat{\lambda}_t^k + \beta E_t\left[\frac{r^k}{\lambda^k}(\hat{r}_{t+1}^k + \hat{\lambda}_{t+1}) + (1-\omega)(\lambda_{t+1}^k + \hat{\lambda}_{t+1})\right], \tag{E.3}$$

$$S''(\hat{\imath}_t - \hat{\imath}_{t-1}) = \hat{\lambda}_t^k + \hat{\mu}_t + \beta S''(E_t[\hat{\imath}_{t+1}] - \hat{\imath}_t), \tag{E.4}$$

$$\hat{k}_{t+1} = (1-\varpi)\hat{k}_t + \varpi(\hat{\mu}_t + \hat{\imath}_t). \tag{E.5}$$

Combining (B.19)-(B.22) and using (B.22) we obtain the Phillips curve for **wage inflation**:

$$\hat{\pi}_{w,t} - (1-\iota_w)\widehat{\bar{\pi}}_t - \iota_w\hat{\pi}_{t-1} = \beta(E_t[\hat{\pi}_{w,t+1}] - (1-\iota_w)\rho_{\bar{\pi}}\widehat{\bar{\pi}}_t - \iota_w\hat{\pi}_t) - \Theta_1\hat{\mu}_t^w,$$

or, using (B.25):

$$\hat{w}_t - \hat{w}_{t-1} + \hat{\pi}_t - (1-\iota_w)\widehat{\bar{\pi}}_t - \iota_w\hat{\pi}_{t-1} = \beta(E_t[\hat{w}_{t+1} + \hat{\pi}_{t+1}] - \hat{w}_t - (1-\iota_w)\rho_{\bar{\pi}}\widehat{\bar{\pi}}_t - \iota_w\hat{\pi}_t) - \Theta_1\hat{\mu}_t^w, \tag{E.6}$$

with $\Theta_1 \equiv \frac{(1-\phi_w)(1-\phi_w\beta)}{\phi_w}$. From (D.22), (D.25), (D.26) and (D.34) we have equations for the firms' **production function, capital-labor ratio and marginal costs**:

$$\hat{y}_{H,t} = \hat{a}_t + \alpha\hat{k}_t + (1-\alpha)(\hat{n}_t - \hat{\Delta}_{w,t}) - \hat{\Delta}_t, \tag{E.7}$$

$$\hat{k}_t - \hat{n}_t = \hat{w}_t - \hat{r}^k_t + (\Theta_2 - \Theta_3)\hat{R}_t - \hat{\Delta}_{w,t}, \tag{E.8}$$

$$\widehat{mc}_t = (1-\alpha)(\hat{w}_t + \Theta_2\hat{R}_t) + \alpha(\hat{r}^k_t + \Theta_3\hat{R}_t) - \hat{a}_t, \tag{E.9}$$

with $\Theta_2 \equiv \frac{\zeta^w R}{1+\zeta^w(R-1)}$ and $\Theta_3 \equiv \frac{\zeta^k R}{1+\zeta^k(R-1)}$. Combining (D.27)-(D.30) and using (D.32) we obtain the Phillips curve for **producer price inflation**:

$$\hat{\pi}_{H,t} - \widehat{\breve{\pi}}_t = \Theta_4\left(\frac{\vartheta}{1-\vartheta}\hat{q}_t + \widehat{mc}_t\right) + \frac{\iota}{1+\iota\beta}(\hat{\pi}_{H,t-1} - \widehat{\breve{\pi}}_t) + \frac{\beta}{1+\iota\beta}(E_t[\hat{\pi}_{H,t+1}] - \rho_{\breve{\pi}}\widehat{\breve{\pi}}_t) - \frac{\iota\beta\,(1-\rho_{\breve{\pi}})}{1+\iota\beta}\widehat{\breve{\pi}}_t, \tag{E.10}$$

with $\Theta_4 \equiv \frac{(1-\phi)(1-\phi\beta)}{(1+\iota\beta)\phi}$. From (D.31) and (D.32) we obtain the equation for **CPI inflation**:

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \frac{\vartheta}{1-\vartheta}(\hat{q}_t - \hat{q}_{t-1}). \tag{E.11}$$

Using (B.22) in (D.23) and (D.30) in (D.35) shows that the **wage and price dispersion terms** satisfy:

$$\hat{\Delta}_{w,t} = \phi_w\Delta_{w,t-1}, \tag{E.12}$$

$$\hat{\Delta}_t = \phi\hat{\Delta}_{t-1}. \tag{E.13}$$

From (D.1), (D.9), (D.10) and (B.15)-(B.18) we have the remaining **capital market equations**:

$$\hat{\lambda}_t = \hat{R}_{H,t} + E_t[\hat{\lambda}_{t+1} - \hat{\pi}_{t+1} - \omega\left(\Phi_b\hat{b}_{t+1} + \Phi_d\hat{d}_{t+1}\right)], \tag{E.14}$$

$$\hat{\lambda}_t = \hat{R}_t + E_t[\hat{\lambda}_{t+1} - \hat{\pi}^*_{t+1} + \hat{q}_{t+1}] - \hat{q}_t, \tag{E.15}$$

$$\hat{R}_t = \upsilon_2\hat{R}_{F,t} + (1-\upsilon_2)\hat{R}^*_t + \hat{\Upsilon}_t, \tag{E.16}$$

$$\hat{\Upsilon}_t = \varphi\tilde{v}_t/y_H + \hat{\psi}_t, \tag{E.17}$$

$$\hat{R}_{F,t} = \hat{R}^*_t + \omega E_t[\Phi_b\hat{b}_{t+1} + \Phi_d\hat{d}_{t+1}]. \tag{E.18}$$

From (D.1)-(D.6) we have the equations describing **fiscal and monetary policy**:

$$d\hat{d}_t = b_H\hat{b}_{H,t} - \frac{b_H}{\pi}(\hat{b}_{H,t-1} - \hat{\pi}_t) + b_F(\hat{q}_t + \hat{b}_{F,t}) - \frac{b_F}{\pi^*}(\hat{q}_t + \hat{b}_{F,t-1} - \hat{\pi}^*_t), \tag{E.19}$$

$$\hat{q}_t + \hat{b}_{F,t} - \hat{R}_{F,t} = \hat{f}_t + \hat{b}_{H,t} - \hat{R}_{H,t}, \tag{E.20}$$

$$
\begin{aligned}
&\frac{b_H}{R_h}\left(\hat{b}_{H,t}-\hat{R}_{H,t}\right)+\frac{b_F}{R_F}\left(\hat{q}_t+\hat{b}_{F,t}-\hat{R}_{F,t}\right)+\tilde{\tau}\widehat{\tilde{\tau}}_t \\
= \quad & g\left(\hat{g}_t-\frac{\vartheta}{1-\vartheta}\hat{q}_t\right)+\frac{b_H}{\pi}\left(\hat{b}_{H,t-1}-\hat{\pi}_t\right)+\frac{b_F}{\pi^*}(\hat{q}_t+\hat{b}_{F,t-1}-\hat{\pi}^*_t),
\end{aligned} \tag{E.21}
$$

$$
\widehat{\tilde{\tau}}_t=\kappa_\tau\widehat{\tilde{\tau}}_{t-1}+(1-\kappa_\tau)\left(\kappa_d\hat{d}_t+\kappa_y\hat{y}_{H,t}\right)+\varepsilon_{\tau,t}, \tag{E.22}
$$

$$
\hat{R}_{H,t}-\alpha_R\hat{R}_{H,t-1}=(1-\alpha_R)\left(\widehat{\breve{\pi}}_t+\alpha_\pi(\hat{\pi}_t-\widehat{\breve{\pi}}_t)+\alpha_y\hat{y}_{H,t}+\alpha_\delta\frac{\delta}{1-\delta}E_t[\hat{\delta}_{t+1}]\right)+\varepsilon_{R,t}. \tag{E.23}
$$

Using (D.32) in (D.33) and (D.36) we obtain the **goods market clearing condition and current account equation**:

$$
y_H\hat{y}_{H,t}=\left[\gamma\vartheta\,(c+i)+\frac{\gamma^*}{1-\vartheta}\vartheta^*y^*\right]\hat{q}_t+(1-\vartheta)\,(c\hat{c}_t+i\hat{\imath}_t)+\vartheta^*y^*\hat{y}^*_t+g\hat{g}_t, \tag{E.24}
$$

$$
\begin{aligned}
\frac{\tilde{v}_t}{R_v\Upsilon}-\frac{\tilde{v}_{t-1}}{\pi^*} \quad = \quad & \vartheta\left[(c\hat{c}_t+i\hat{\imath}_t)+(1-\gamma)\,(c+i)\,\hat{q}_t\right]-\vartheta^*y^*\left[\left(1+(1-\gamma^*)\,\frac{\vartheta}{\vartheta-1}\right)\hat{q}_t+\hat{y}^*_t\right] \\
& -\frac{b_F}{R_F}(\hat{q}_t+\hat{b}_{F,t}-\hat{R}_{F,t})+\frac{b_F}{\pi^*}(\hat{q}_t+\hat{b}_{F,t-1}-\hat{\pi}^*_t).
\end{aligned} \tag{E.25}
$$

The **exogenous processes** are:

$$
\hat{z}_t=\rho_z\hat{z}_{t-1}+\varepsilon_{z,t}, \tag{E.26}
$$

$$
\hat{\varsigma}'_{w,t}=\rho_w\hat{\varsigma}'_{w,t-1}+\varepsilon_{w',t}, \tag{E.27}
$$

$$
\hat{a}_t=\rho_a\hat{a}_{t-1}+\varepsilon_{a,t}, \tag{E.28}
$$

$$
\hat{g}_t=\rho_g\hat{g}_{t-1}+\varepsilon_{g,t}, \tag{E.29}
$$

$$
\hat{f}_t=\rho_f\hat{f}_{t-1}+\varepsilon_{f,t}, \tag{E.30}
$$

$$
\hat{\mu}_t=\rho_\mu\hat{\mu}_{t-1}+\varepsilon_{\mu,t}, \tag{E.31}
$$

$$
\hat{\psi}_t=\rho_\psi\hat{\psi}_{t-1}+\varepsilon_{\psi,t}, \tag{E.32}
$$

$$
\widehat{\breve{\pi}}_t=\rho_{\breve{\pi}}\widehat{\breve{\pi}}_{t-1}+\varepsilon_{\breve{\pi},t}, \tag{E.33}
$$

$$
\hat{y}^*_t=\rho_{y^*}\hat{y}^*_{t-1}+\varepsilon_{y^*,t}, \tag{E.34}
$$

$$
\hat{\pi}^*_t=\rho_{\pi^*}\hat{\pi}^*_{t-1}+\varepsilon_{\pi^*,t}, \tag{E.35}
$$

$$\hat{R}^*_t = \rho_{R^*}\hat{R}^*_{t-1} + \varepsilon_{R^*,t}, \tag{E.36}$$

with $\varepsilon_{w',t} \equiv \frac{1}{\Theta_1}\varepsilon_{w,t}$. Then, the *rational expectations equilibrium* of the linearized model is a set of sequences

$$\{\hat{c}_t, \hat{\imath}_t, \hat{k}_t, \hat{r}^k_t, \hat{\lambda}^k_t, \hat{n}_t, \hat{w}_t, \hat{\lambda}_t, \hat{\mu}^w_t, \hat{\Delta}_{w,t}, \hat{y}_{H,t}, \widehat{mc}_t, \hat{q}_t, \hat{\pi}_{H,t}, \hat{\pi}_t, \hat{\Delta}_t, \hat{R}_{H,t}, \hat{\bar{\tau}}_t,$$
$$\hat{R}_{F,t}, \hat{R}_t, \hat{\Psi}_t, \hat{d}_t, \hat{f}_t, \hat{b}_{H,t}, \hat{b}_{F,t}, \hat{v}_t, \hat{z}_t, \hat{\varsigma}'_{w,t}, \hat{a}_t, \hat{g}_t, \hat{\mu}_t, \hat{\psi}_t, \hat{\bar{\pi}}_t, \hat{y}^*_t, \hat{\pi}^*_t, \hat{R}^*_t\}_{t=0}^{\infty}$$

satisfying (E.1)-(E.36) and the transversality conditions, for given initial asset endowments and initial price levels $P_{H,-1}$ and $P_{F,-1}$, and given n.i.d. innovations $\{\varepsilon_{z,t}, \varepsilon_{w',t}, \varepsilon_{a,t}, \varepsilon_{g,t}, \varepsilon_{f,t}, \varepsilon_{\mu,t}, \varepsilon_{\psi,t}, \varepsilon_{\bar{\pi},t}, \varepsilon_{R,t}, \varepsilon_{\tau,t}, \varepsilon_{y^*,t}, \varepsilon_{\pi^*,t}, \varepsilon_{R^*,t}\}_{t=0}^{\infty}$. Finally, we add the definitions of exports, $\{\hat{x}^*_{H,t}\}_{t=0}^{\infty}$, and imports, $\{\hat{x}_{F,t}\}_{t=0}^{\infty}$, which satisfy

$$\hat{x}^*_{H,t} = \frac{\gamma^*}{1-\vartheta}\hat{q}_t + \hat{y}^*_t,$$
$$\hat{x}_{F,t} = \vartheta\left[c\hat{c}_t + i\hat{\imath}_t - \gamma\,(c+i)\,\hat{q}_t\right].$$

Appendix F. Details on the estimation

Appendix F.1. Methodology

Formally, let $P(\theta_{M_i}|M_i)$ denote the prior distribution of the vector of structural parameters θ_{M_i} for model M_i, and let $L(Y^T|\theta_{M_i}, M_i)$ denote the likelihood function for the observed data $Y^T = [Y_1, \ldots, Y_T]'$. For $t = 1, \ldots, T$ the solution to the log-linearized model has a state-space representation with the state equation $x_t = Fx_{t-1} + G\varepsilon_t$ and the observation equation $Y_t = Hx_t + u_t$, where the vectors x_t, $\varepsilon_t \sim N(0, \Sigma_\varepsilon)$ and $u_t \sim N(0, \Sigma_u)$ collect model variables, structural shocks and measurement errors, respectively. The Kalman filter is applied to evaluate $L(Y^T|\theta_{M_i}, M_i)$ and the posterior distribution

$$P(\theta_{M_i}|Y^T, M_i) = \frac{L(Y^T|\theta_{M_i}, M_i)P(\theta_{M_i}|M_i)}{\int L(Y^T|\theta_{M_i}, M_i)P(\theta_{M_i}|M_i)d\theta_{M_i}} \propto L(Y^T|\theta_{M_i}, M_i)P(\theta_{M_i}|M_i)$$

is evaluated with the Metropolis-Hastings (MH) algorithm. We then assess the evidence of model M_i over another (not necessarily nested) model M_j by the Bayes factor $p(Y^T|M_i)/\ p(Y^T|M_j)$, which summarizes the sample evidence in favor of model M_i, the marginal data density $p(Y^T|M_i) = \int L(Y^T|\theta_{M_i}, M_i)P(\theta_{M_i}|M_i)d\theta_{M_i}$ indicating the likelihood of model M_i conditional on the observed data. Further, for $t = 1, \ldots, T$ the shocks $\varepsilon_{t|T}$ are recovered by application of the Kalman smoother at the parameter estimates. This step also yields smoothed estimates $x_{t|T}$ of the unobserved states.

Appendix F.2. Data

All data are seasonally adjusted and consumer price indexes are used to construct real variables with base year 1998, except for domestic output where the GDP deflator is used.

The domestic variable definitions and their sources are as follows:

- GDP: Real gross domestic product, Central Bank of the Republic of Turkey.
- CONS: Real private consumption expenditure, Central Bank of the Republic of Turkey.
- INV: Real gross fixed capital formation, Turkish Statistical Institute.
- WR: Real wages, Turkish Statistical Institute.

- INF: Annualized rate of change of the quarterly CPI, Turkish Statistical Institute.
- INT: Annual nominal interest rate for 3-month treasury bills, constructed from data obtained from the Central Bank of the Republic of Turkey; if 3-month bills were not issued in some quarter, we use the closest maturity available.
- REER: Real CPI-based effective exchange rate, OECD main economic indicators.
- GOV: Real government consumption expenditure, Central Bank of the Republic of Turkey.
- F: Share of foreign currency to domestic currency debt, Central Bank of the Republic of Turkey.
- SD: Nominal deficit-to-GDP ratio, Central Bank of the Republic of Turkey.

Foreign output GDP* and inflation INF* are constructed from euro area real GDP and annual inflation rates according to the Harmonized Index of Consumer Prices obtained from the Area-Wide Model database (Fagan et al., 2005), and real U.S. GDP and the CPI-based U.S. inflation rate (all urban sample, all items) obtained from the U.S. Bureau of Economic Analysis. Aggregate foreign GDP and foreign inflation are computed according to the trade weights in the basket targeted by the Turkish central bank during the exchange rate targeting period (see Görmez and Yılmaz, 2007). That is, the euro area obtains a weight of 0.77 and the U.S. obtains a weight of 1. The foreign interest rate INT^* is approximated through the annual yield on the J.P. Morgan Emerging Markets Bond Index Global Composite. Since this series starts only in 1998Q1 it is backdated using growth rates of the J.P. Morgan Emerging Markets Bond Index Global Performing Sovereign Spread.

Appendix F.3. Calibrated parameters and steady state values

Table F.1 lists the calibrated parameters and their values as well as the implied steady state values of the endogenous variables.

Appendix G. Sensitivity analysis

In this appendix we assess the robustness of our main results to model specification and alternative estimation choices. In particular, we first estimate alternative versions of the baseline model on the full sample and then estimate the baseline model on subsamples.

Appendix G.1. Alternative model versions

This appendix describes the alterations of the baseline model with sovereign risk considered in the sensitivity analysis and the implied changes to the model's equations. First, we add an exchange rate stabilization term in the monetary authority's reaction function to capture the fact that before 2001 the CBRT's official monetary policy strategy included nominal exchange rate targeting (see Görmez and Yılmaz, 2007). Second, we investigate whether monetary policy takes into account the fiscal position by allowing for a response to the debt level. Third, we assume that, in addition to the wage bill, firms need to finance capital expenditures in advance using loans from financial intermediaries. Fourth, to assess how much the estimated degree of price stickiness depends on the choice of shocks, we include a price markup shock. Fifth, we use preferences that allow for a variable wealth effect on labor supply and estimate the strength of the wealth effect. These preferences are proposed by Galí et al. (2012) as a way to match the joint behavior of labor market variables and other macroeconomic variables over the business cycle. They are in turn based on the preferences proposed by Jaimovich and Rebelo (2009). Finally, we calibrate the strength of pass-through from sovereign

Table F.1: Calibrated and implied parameters and steady state values.

Calibrated parameters and st. st. values		Implied parameters and st. st. values	
δ, ϖ	0.013	β	0.995
π	1.022	R_v	1.021
R_H	1.040	R	1.021
R^*	1.018	π^*	1.013
v_1	1	$\breve{\pi}$	1.022
q	1	R_F	1.030
v	0	mc	0.9
ϵ	10	p_H	1
ϵ_w	21	r^k	0.017
a, z, μ, Υ	1	w	2.246
$\rho_{\breve{\pi}}$	0.975	y_H	1.124
α	0.32	k	18.613
n	0.3	i	0.233
s_g	0.108	c	0.762
s_{b_H}	0.27*4	f	0.67
s_{b_F}	0.15*4	$\tilde{\tau}$	0.154
ϑ	0.25	$\upsilon^* y^*$	0.257
ζ^w	1	b	1.85
ζ^k	0	d	0.035
σ, η	2		

Notes. Implied parameters and steady state values are computed at the posterior mean of the estimated parameters for the model with sovereign risk.

to private credit conditions to $v_2 = 0.55$, following Harjes (2011) and Corsetti et al. (2013, 2014), instead of estimating it. In detail, we consider the following alternative versions of the model, one at a time:

1. We include an exchange rate stabilization term in the monetary authority's reaction function by setting $\alpha_X \neq 0$. Thus (E.23) is replaced by

$$\begin{aligned} \hat{R}_{H,t} &= \alpha_R \hat{R}_{H,t-1} \\ &+ (1-\alpha_R)\left(\widehat{\breve{\pi}}_t + \alpha_\pi(\hat{\pi}_t - \widehat{\breve{\pi}}_t) + \alpha_y \hat{y}_t + \alpha_\delta \frac{\delta}{1-\delta} E_t[\hat{\delta}_{t+1}] + \alpha_{\Delta X}(\hat{q}_t - \hat{q}_{t-1} - \hat{\pi}^*_t + \hat{\pi}_t)\right) + \varepsilon_{R,t}. \end{aligned}$$

2. We allow for a response to the level of total debt, $\alpha_b \neq 0$, in the monetary authority's reaction function, changing (E.23) to

$$\hat{R}_{H,t} = \alpha_R \hat{R}_{H,t-1} + (1-\alpha_R)\left(\widehat{\breve{\pi}}_t + \alpha_\pi(\hat{\pi}_t - \widehat{\breve{\pi}}_t) + \alpha_y \hat{y}_t + \alpha_\delta \frac{\delta}{1-\delta} E_t[\hat{\delta}_{t+1}] - \alpha_b \hat{b}_t\right) + \varepsilon_{R,t}.$$

3. We assume that, in addition to the wage bill, firms need to finance capital expenditures in advance using loans from the financial intermediaries. This implies that $\zeta^k = 1$ in (E.8) and (E.9), instead of setting $\zeta^k = 0$.
4. We include a price mark-up shock. After normalizing the variance of the shock the Phillips curve for

producer price inflation (E.10) becomes

$$
\begin{aligned}
\hat{\pi}_{H,t} - \widehat{\breve{\pi}}_t &= \Theta_4 \left(\frac{\vartheta}{1-\vartheta} \hat{q}_t + \widehat{mc}_t \right) + \frac{\iota}{1+\iota\beta} \left(\hat{\pi}_{H,t-1} - \widehat{\breve{\pi}}_t \right) \\
&\quad + \frac{\beta}{1+\iota\beta} \left(E_t \left[\hat{\pi}_{H,t+1} \right] - \rho_{\breve{\pi}} \widehat{\breve{\pi}}_t \right) - \frac{\iota\beta \left(1 - \rho_{\breve{\pi}} \right)}{1+\iota\beta} \widehat{\breve{\pi}}_t + \hat{\mu}_t^{\pi}.
\end{aligned}
$$

5. We use the following alternative preference specification:

$$
E_0 \sum_{t=0}^{\infty} \beta^t z_t \left[\frac{1}{1-\sigma} (c_t - h\breve{c}_{t-1})^{1-\sigma} - \Theta_t \varsigma_{w,t} \frac{1}{1+\eta} n_t^{1+\eta} \right], \quad \beta \in (0,1), \quad \sigma > 0, \quad \eta \geq 0.
$$

   These preferences allow for a variable wealth effect on labor supply through the endogenous preference shifter $\Theta_t \equiv \chi_t (\breve{c}_t - h\breve{c}_{t-1})^{-\sigma}$ with $\chi_t = \chi_{t-1}^{1-\upsilon} \left(\breve{c}_t - h\breve{c}_{t-1} \right)^{\sigma\upsilon}$ and $\upsilon \in [0,1]$, which is taken as given by each individual household. The latter is proposed by Galí et al. (2012) as a way to match the joint behavior of labor market variables and other macroeconomic variables over the business cycle. Its main role in our model is to allow for an arbitrarily low wealth effect on labor supply, in line with a tradition of related studies for small open economies that rely on the latter to explain, among other things, the impact of foreign shocks and in particular contractionary effects of shocks to foreign interest rates (see Mendoza, 1991; Neumeyer and Perri, 2005; García-Cicco et al., 2010). It nests as extreme cases preferences with constant relative risk aversion (CRRA) for $\upsilon = 1$ and the preferences with a zero wealth effect proposed by Greenwood et al. (1988) for $\upsilon = 0$. This preference specification is related, but not identical, to the one proposed by Jaimovich and Rebelo (2009) and modified to allow for internal habits by Schmitt-Grohé and Uribe (2012). The difference is that it assumes external habits as in Smets and Wouters (2007) and related monetary DSGE models and one of the extreme cases is CRRA and not the (less conventional) preferences from King (1988). We estimate the strength of the wealth effect υ in the alternative preference specification, instead of calibrating it to $\upsilon = 0$.

6. We calibrate the strength of pass-through from sovereign to private credit conditions in (E.15) to $\upsilon_2 = 0.55$, instead of estimating it.

The results are documented in Table G.1. All in all, the parameter estimates are relatively stable across models but the marginal likelihoods tend to be lower than for the baseline model.

Appendix G.2. Subsample estimates

We also estimate the baseline model on subsamples. This is motivated by the economic reforms in Turkey implemented after the 2000/01 financial crisis. These reforms initiated a pronounced disinflationary period along which also the level and the volatility of nominal interest rates and the expected default rate declined considerably. The following analysis is therefore useful to assess the interactions of monetary and fiscal policy in such a context. We follow the approach of Canova (2009) and divide the data into two subsamples consisting of 1994Q3-2002Q4 and 2005Q1-2013Q3 and use the estimated posterior distributions from the first to form priors for the second subsample. We drop two years of observations in-between to ensure that the data are independent.[19] Since all posteriors from the first subsample are close to normal distributions we use (mostly) normal distributions with the estimated means and standard deviations implied by the posteriors as priors for the second subsample.

[19] In this way, the two subsamples are also of (nearly) identical length such that the parameters can be estimated with similar precision.

Table G.1: Sensitivity of parameter estimates and data densities.

	Parameter	Bench-mark model	1994:Q3-2002:Q1 Post.	1994:Q3-2002:Q1 95% HPDI	2004:Q1-2013:Q3 Post.	2004:Q1-2013:Q3 95% HPDI	Exch. rate resp.	Debt resp.	Working loans capital	Mark-up shock	JR pref-erences	Calibr. $v_2 =$ 0.55
σ	Risk aversion	1.82	2.08	[1.32, 2.92]	1.77	[1.01, 2.57]	1.87	1.86	1.82	1.64	1.82	1.85
ϕ	Price stickiness	0.84	0.76	[0.65, 0.86]	0.97	[0.92, 1.02]	0.84	0.84	0.84	0.84	0.84	0.85
ι	Price indexation	0.49	0.57	[0.29, 0.84]	0.64	[0.28, 0.99]	0.51	0.49	0.49	0.49	0.48	0.50
ϕ_w	Wage stickiness	0.86	0.83	[0.70, 0.94]	0.83	[0.74, 0.93]	0.87	0.85	0.86	0.80	0.86	0.87
ι_w	Wage indexation	0.46	0.52	[0.24, 0.80]	0.51	[0.24, 0.79]	0.45	0.47	0.46	0.48	0.47	0.45
ζ^w	Working capital wages	0.77	0.75	[0.47, 0.99]	0.75	[0.45, 1.04]	0.76	0.78	0.78	0.76	0.77	0.77
ζ^k	Working capital capital	–	–	–	–	–	–	–	0.64	–	–	–
S''	Inv. adj. cost elast.	5.41	5.59	[3.25, 8.04]	4.69	[2.33, 7.12]	5.70	5.56	5.41	4.71	5.45	5.73
γ	Subst. elast., home	0.44	0.39	[0.13, 0.64]	0.38	[0.18, 0.58]	0.43	0.45	0.44	0.38	0.45	0.48
γ^*	Subst. elast., foreign	0.17	0.22	[0.06, 0.39]	0.20	[0.05, 0.34]	0.17	0.17	0.17	0.19	0.17	0.15
υ	Wealth effect	0.03	–	–	–	–	–	–	–	–	0.54	–
Φ_b	Debt elasticity	0.01	0.010	[0.00, 0.03]	0.008	[0.00, 0.02]	0.01	0.01	0.01	0.01	0.01	0.01
Φ_d	Deficit elasticity	0.13	0.117	[0.05, 0.20]	0.039	[-0.02, 0.11]	0.13	0.13	0.13	0.12	0.13	0.12
ω	Haircut	0.55	0.589	[0.35, 0.82]	0.497	[0.21, 0.76]	0.56	0.55	0.56	0.56	0.56	0.56
v_2	Sov. risk pass-through	0.18	0.162	[-0.10, 0.48]	0.225	[-0.11, 0.56]	0.16	0.20	0.18	0.10	0.19	–
φ	Priv. risk premium elast.	0.00	0.005	[0.00, 0.01]	0.004	[0.00, 0.01]	0.00	0.00	0.00	0.00	0.00	0.01
α_R	Int. rate smoothing	0.24	0.24	[0.08, 0.41]	0.33	[0.16, 0.50]	0.26	0.25	0.24	0.24	0.24	0.24
α_π	Mon. inflation resp.	2.70	2.47	[1.81, 3.17]	2.44	[1.68, 3.20]	2.30	2.84	2.70	2.62	2.72	2.74
α_y	Mon. output resp.	0.15	0.12	[0.01, 0.27]	0.13	[0.01, 0.26]	0.15	0.16	0.15	0.16	0.15	0.13
α_δ	Mon. def. rate resp.	0.24	0.10	[-0.72, 0.86]	0.32	[-0.52, 1.13]	0.32	0.26	0.24	0.21	0.24	0.19
α_X	Mon. exch. rate resp.	–	–	–	–	–	0.29	–	–	–	–	–
α_b	Mon. debt resp.	–	–	–	–	–	–	0.03	–	–	–	–
κ_τ	Tax smoothing	0.47	0.49	[0.29, 0.68]	0.57	[0.36, 0.78]	0.47	0.45	0.47	0.47	0.47	0.46
κ_d	Tax deficit resp.	1.38	1.40	[1.05, 1.79]	1.20	[0.75, 1.61]	1.38	1.36	1.37	1.36	1.37	1.41
κ_y	Tax output resp.	0.56	0.51	[0.02, 0.99]	0.52	[0.05, 0.99]	0.52	0.58	0.56	0.49	0.56	0.60
ρ_z	AR(1) cons. preference	0.35	0.47	[0.13, 0.81]	0.39	[0.12, 0.68]	0.36	0.36	0.36	0.35	0.35	0.35
ρ_μ	AR(1) inv. efficiency	0.58	0.60	[0.25, 0.93]	0.62	[0.35, 0.86]	0.59	0.57	0.58	0.57	0.59	0.59
ρ_a	AR(1) productivity	0.85	0.76	[0.56, 0.97]	0.74	[0.55, 0.91]	0.83	0.85	0.85	0.54	0.85	0.86
ρ_{μ^w}	AR(1) labor supply	0.43	0.38	[0.13, 0.65]	0.38	[0.10, 0.62]	0.42	0.44	0.43	0.48	0.43	0.43
ρ_g	AR(1) gov. cons.	0.62	0.60	[0.37, 0.84]	0.58	[0.41, 0.76]	0.62	0.62	0.62	0.62	0.62	0.62
ρ_f	AR(1) for. debt share	0.95	0.89	[0.78, 0.99]	0.96	[0.91, 1.00]	0.95	0.95	0.95	0.95	0.95	0.95
ρ_ψ	AR(1) int. rate parity	0.93	0.85	[0.71, 0.97]	0.81	[0.70, 0.91]	0.94	0.93	0.93	0.90	0.93	0.97
ρ_{y^*}	AR(1) for. demand	0.97	0.96	[0.93, 1.00]	0.98	[0.96, 1.00]	0.97	0.97	0.97	0.97	0.97	0.97
ρ_{π^*}	AR(1) for. inflation	0.35	0.52	[0.25, 0.79]	0.42	[0.23, 0.63]	0.35	0.35	0.35	0.35	0.34	0.35
ρ_{R^*}	AR(1) for. int. rate	0.88	0.87	[0.80, 0.94]	0.87	[0.80, 0.94]	0.88	0.88	0.88	0.88	0.88	0.89
ρ_{μ^π}	AR(1) price markup	–	–	–	–	–	–	–	–	0.62	–	–
σ_z	Std. cons. pref. inn.	0.09	0.11	[0.05, 0.17]	0.09	[0.03, 0.15]	0.09	0.09	0.09	0.08	0.09	0.09
σ_μ	Std. inv. eff. inn.	0.06	0.06	[0.01, 0.11]	0.07	[0.01, 0.14]	0.06	0.06	0.06	0.06	0.06	0.06
σ_a	Std. prod. inn.	0.06	0.07	[0.03, 0.12]	0.04	[0.02, 0.07]	0.06	0.05	0.06	0.04	0.06	0.06
σ_w	Std. wage markup inn.	0.03	0.06	[0.03, 0.09]	0.02	[0.01, 0.03]	0.03	0.03	0.03	0.03	0.03	0.03
σ_g	Std. gov. cons. inn.	0.04	0.04	[0.03, 0.05]	0.04	[0.03, 0.05]	0.04	0.04	0.04	0.04	0.04	0.04
σ_f	Std. for. debt share inn.	0.07	0.08	[0.05, 0.10]	0.06	[0.04, 0.08]	0.07	0.07	0.07	0.07	0.07	0.07
σ_τ	Std. tax inn.	0.21	0.24	[0.17, 0.31]	0.12	[0.06, 0.19]	0.21	0.22	0.21	0.21	0.21	0.22
σ_R	Std. int. rate inn.	0.04	0.07	[0.05, 0.10]	0.02	[0.01, 0.03]	0.04	0.04	0.04	0.04	0.04	0.04
$\sigma_{\bar{\pi}}$	Std. infl. target inn.	0.02	0.03	[0.02, 0.04]	0.01	[0.01, 0.01]	0.02	0.02	0.02	0.02	0.02	0.02
σ_ψ	Std. int. rate parity inn.	0.01	0.03	[0.01, 0.06]	0.01	[0.01, 0.01]	0.01	0.01	0.01	0.01	0.01	0.01
σ_{y^*}	Std. for. dem. inn.	0.01	0.00	[0.00, 0.01]	0.01	[0.01, 0.01]	0.01	0.01	0.01	0.01	0.01	0.01
σ_{π^*}	Std. for. infl. inn.	0.00	0.00	[0.00, 0.00]	0.00	[0.00, 0.01]	0.00	0.00	0.00	0.00	0.00	0.00
σ_{R^*}	Std. for. int. rate inn.	0.00	0.01	[0.01, 0.01]	0.00	[0.00, 0.00]	0.00	0.00	0.00	0.00	0.00	0.00
σ_{μ^π}	Std. price markup inn.	–	–	–	–	–	–	–	–	0.01	–	–
	Log data density	1693.52	663.62		947.21		1696.02	1687.89	1693.25	1691.96	1692.97	1691.10

Notes. See Table 1 in the main text for details on the estimation and the parameterization of the prior distributions.

The results are provided in Table G.1. Generally, the posterior means of the parameters are relatively stable across subsamples. For most parameters the 95% credible sets overlap. For several parameters, there are interesting shifts in the estimated means. The default elasticity Φ_d declines from 0.12 to 0.04 and the haircut ω from 0.59 to 0.50. This coincides with a marked reduction in policy volatility. The standard deviation of innovations to the policy rate and to the inflation objective, σ_R and $\sigma_{\breve{\pi}}$, decline from 0.07 to 0.02 and from 0.03 to 0.01, respectively. There is also some evidence of stronger interest rate smoothing by the central bank, as α_R increases from 0.24 to 0.33, while the reaction coefficient of monetary policy to inflation remains similar across subsamples. Together, these parameter shifts indicate that the monetary policy reforms introduced after 2001 have contributed to reducing sovereign risk premia and thereby stabilizing the economy by reducing monetary policy volatility. Still, the estimates of the two key parameters determining the importance of sovereign risk beliefs, the default elasticity Φ_d and the expected loss in case of default ω, are not statistically different for the two subsamples.

Appendix H. Additional results

This appendix provides several additional results to complement the analysis from the main text. First, Table H.1 documents the conditional posterior variance decomposition. Second, Table H.2 displays selected moments of the observed data and the corresponding model-implied moments. Third, Table H.3 documents one-step ahead root mean squared forecast errors. Fourth, Figures H.2 to H.4 show the prior and posterior distributions for all parameters. Fifth, Figures H.5 plots the observed data against the smoothed variables. Finally, Figures H.6 and H.7 show standard multivariate convergence diagnostics based on two MH chains for each version of the model.

Table H.1: Conditional posterior variance decomposition.

	With sov. risk (M_1)									*No sov. risk (M_2)*							
	Out-put	Cons.	Inv.	Infl.	Int. rate	Real wage	RE-ER	Def./GDP	Def. rate	Out-put	Cons.	Inv.	Infl.	Int. rate	Real wage	RE-ER	Def./GDP
Horizon $h = 1$																	
Cons. pref. ε_z	12.8	45.8	0.4	0.0	0.0	0.4	0.1	0.0	0.0	19.3	86.1	2.2	0.6	0.2	7.1	1.4	0.0
Inv. eff. ε_μ	2.0	0.0	13.4	0.0	0.0	0.0	0.0	0.0	0.0	9.4	0.8	90.5	0.4	0.1	0.0	0.2	0.0
Productivity ε_a	25.6	2.9	21.3	0.1	0.2	2.3	15.2	0.2	0.2	0.1	0.0	0.0	0.0	0.0	2.2	0.1	0.0
Wage markup ε_w	9.5	1.1	8.2	0.0	0.1	76.7	5.3	0.1	0.1	0.3	0.0	0.0	0.0	0.0	67.1	0.3	0.0
Gov. cons. ε_g	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	5.7	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Lump-sum tax ε_τ	0.4	0.2	0.2	3.5	7.1	0.9	4.0	93.3	93.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88.4
Int. rate ε_R	16.8	4.7	2.7	11.4	14.9	2.1	15.0	1.0	1.0	54.1	8.4	5.8	34.3	61.2	9.0	48.8	7.2
Infl. targ $\varepsilon_{\breve{\pi}}$	20.6	10.3	9.1	36.5	9.7	0.2	6.4	0.6	0.7	3.5	0.5	0.1	31.2	7.3	1.4	4.0	0.7
For. demand ε_{y^*}	0.7	0.1	0.1	0.2	0.2	0.1	0.3	0.0	0.0	0.4	0.1	0.1	0.4	0.3	0.2	0.5	0.0
For. inflation ε_{π^*}	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
For. int. rate ε_{R^*}	0.2	3.2	3.1	5.9	8.6	1.9	6.5	0.8	0.7	0.5	1.0	0.7	5.1	4.7	2.2	6.7	0.8
Int. rate parity ε_ψ	5.1	31.7	41.5	42.4	59.2	15.5	47.3	3.9	3.5	6.7	3.1	0.7	28.0	26.2	10.8	38.0	2.7
Horizon $h = 4$																	
Cons. pref. ε_z	3.0	20.5	0.5	0.0	0.2	0.3	0.1	0.0	0.0	22.6	86.9	3.6	0.5	0.9	9.9	2.6	0.1
Inv. eff. ε_μ	1.5	0.1	6.9	0.0	0.0	0.0	0.0	0.0	0.0	29.9	2.3	92.1	0.3	0.1	0.1	0.3	0.0
Productivity ε_a	51.0	17.2	34.8	10.0	16.5	1.3	28.3	2.3	2.1	0.3	0.1	0.0	0.1	0.1	3.1	0.2	0.0
Wage markup ε_w	18.8	6.5	12.7	4.2	7.1	78.6	10.3	1.0	0.9	1.1	0.2	0.1	0.3	0.3	79.0	0.9	0.0
Gov. cons. ε_g	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	2.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Lump-sum tax ε_τ	0.1	0.3	0.3	1.6	3.6	0.5	2.2	89.1	90.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88.3
Int. rate ε_R	4.3	3.4	1.2	5.7	8.8	0.6	3.4	1.0	1.0	34.0	7.3	3.4	22.5	51.9	2.8	27.9	6.8
Infl. targ $\varepsilon_{\breve{\pi}}$	12.6	16.2	7.6	52.1	18.3	1.8	1.7	1.3	1.5	2.1	0.5	0.0	58.2	24.4	0.4	2.8	1.3
For. demand ε_{y^*}	0.3	0.1	0.1	0.1	0.1	0.1	0.4	0.0	0.0	0.4	0.1	0.1	0.3	0.3	0.3	1.4	0.0
For. inflation ε_{π^*}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
For. int. rate ε_{R^*}	0.3	3.0	2.2	3.1	5.7	1.6	5.9	0.9	0.8	0.5	1.0	0.5	2.8	3.8	1.1	12.6	0.8
Int. rate parity ε_ψ	7.4	32.6	33.8	23.2	39.6	15.2	47.8	4.3	3.6	7.1	1.8	0.1	15.0	18.2	3.4	51.2	2.6
Horizon $h = 12$																	
Cons. pref. ε_z	1.0	9.8	0.5	0.0	0.2	0.2	0.1	0.0	0.0	14.1	84.8	5.9	0.4	1.5	10.5	2.4	0.1
Inv. eff. ε_μ	1.0	0.1	3.1	0.0	0.0	0.0	0.1	0.0	0.0	50.7	5.0	90.1	0.2	0.5	0.8	2.6	0.0
Productivity ε_a	62.5	32.2	44.0	10.5	20.6	1.2	29.8	3.7	3.1	0.3	0.1	0.0	0.1	0.1	3.5	0.2	0.0
Wage markup ε_w	19.2	10.4	13.1	3.8	7.7	64.2	9.3	1.3	1.2	1.8	0.6	0.2	0.3	0.4	78.0	1.3	0.0
Gov. cons. ε_g	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	1.2	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Lump-sum tax ε_τ	0.1	0.6	0.5	0.9	2.5	1.0	2.6	86.1	87.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.4
Int. rate ε_R	1.6	1.8	0.5	2.7	5.0	0.5	1.5	1.0	1.0	21.1	6.4	1.9	10.6	29.8	2.4	21.3	6.7
Infl. targ $\varepsilon_{\breve{\pi}}$	7.2	18.3	7.1	69.3	37.6	8.5	6.7	2.5	3.1	2.1	0.4	0.9	79.6	54.7	0.6	2.1	2.2
For. demand ε_{y^*}	0.2	0.1	0.1	0.0	0.1	0.3	0.7	0.0	0.0	0.5	0.3	0.2	0.1	0.2	0.6	4.1	0.0
For. inflation ε_{π^*}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
For. int. rate ε_{R^*}	0.2	2.2	1.6	1.5	3.3	2.1	5.1	0.9	0.8	0.6	1.0	0.4	1.3	2.2	0.9	17.6	0.8
Int. rate parity ε_ψ	6.8	24.5	29.6	11.3	23.0	22.1	44.0	4.3	3.5	7.6	1.5	0.4	7.3	10.7	2.8	48.3	2.6
Horizon $h = 40$																	
Cons. pref. ε_z	0.9	6.8	0.4	0.0	0.2	0.2	0.0	0.0	0.0	12.8	78.9	5.8	0.3	0.9	10.2	2.0	0.1
Inv. eff. ε_μ	1.0	0.4	2.5	0.0	0.0	0.0	0.4	0.0	0.0	51.7	10.5	87.1	0.2	0.4	2.9	26.5	0.0
Productivity ε_a	60.5	25.7	39.1	7.7	18.6	1.1	26.2	3.7	3.0	0.3	0.1	0.0	0.0	0.1	3.4	0.2	0.0
Wage markup ε_w	17.0	7.6	10.9	2.7	6.9	45.8	7.1	1.3	1.1	1.7	0.5	0.2	0.2	0.3	74.6	1.0	0.0
Gov. cons. ε_g	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Lump-sum tax ε_τ	0.2	1.4	1.0	0.8	3.0	1.8	2.8	83.6	85.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.2
Int. rate ε_R	1.3	1.3	0.4	1.9	4.5	0.4	0.9	1.0	1.0	18.2	5.9	1.7	5.8	18.1	2.3	14.7	6.7
Infl. targ $\varepsilon_{\breve{\pi}}$	10.6	37.6	16.7	77.6	43.2	30.6	26.3	5.2	5.4	6.0	0.5	3.5	88.7	72.4	1.0	2.7	2.5
For. demand ε_{y^*}	0.3	0.3	0.2	0.0	0.1	0.7	1.1	0.0	0.0	1.0	1.0	0.6	0.1	0.1	1.8	7.5	0.0
For. inflation ε_{π^*}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
For. int. rate ε_{R^*}	0.3	1.6	1.3	1.1	3.0	1.6	3.0	0.9	0.8	0.5	1.0	0.3	0.7	1.3	0.8	12.6	0.8
Int. rate parity ε_ψ	7.7	17.3	27.4	8.1	20.6	17.9	32.1	4.3	3.5	6.8	1.6	0.6	4.0	6.5	3.1	32.7	2.6

Notes. Table entries refer to the contribution to the conditional variance (in percent) at horizon h, with $h = 1, 4, 12, 40$ quarters, at the posterior mean. Some of the totals may not sum up to 100% due to rounding errors.

Table H.2: Selected moments of observed data and model-implied moments.

	Standard deviation		Std. deviation rel. to output		Correlation with output		Autocorrel. of order 1		Autocorrel. of order 4	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
With sovereign risk (M_1)										
Output	0.050	0.116	1.00	1.00	1.00	1.00	0.90	0.98	0.43	0.80
Consumption	0.049	0.128	0.97	1.10	0.89	0.81	0.83	0.98	0.45	0.87
Investment	0.153	0.443	3.04	3.82	0.89	0.85	0.88	0.99	0.33	0.85
Inflation	0.258	0.302	–	–	0.03	-0.07	0.92	0.90	0.82	0.77
Nom. int. rate	0.527	0.523	–	–	0.04	-0.42	0.85	0.90	0.79	0.70
Real wage	0.096	0.178	–	–	0.39	0.20	0.85	0.95	0.36	0.77
Real exch. rate	0.086	0.375	–	–	-0.26	0.07	0.78	0.98	0.18	0.86
Gov. cons.	0.055	0.055	1.09	0.48	0.38	0.05	0.62	0.62	0.46	0.15
Deficit ratio	0.059	0.061	–	–	-0.43	-0.29	0.65	0.35	0.49	0.26
For. demand	0.030	0.027	0.60	0.23	0.01	0.06	0.98	0.97	0.77	0.89
For. inflation	0.016	0.016	–	–	0.29	0.00	0.29	0.35	-0.14	0.02
For. int. rate	0.049	0.039	–	–	-0.19	-0.04	0.94	0.88	0.69	0.60
No sovereign risk (M_2)										
Output	0.050	0.052	1.00	1.00	1.00	1.00	0.90	0.93	0.43	0.66
Consumption	0.049	0.076	0.97	1.45	0.89	0.38	0.83	0.95	0.45	0.66
Investment	0.153	0.304	3.04	5.82	0.89	0.63	0.88	0.98	0.33	0.78
Inflation	0.258	0.366	–	–	0.03	-0.16	0.92	0.88	0.82	0.83
Nom. int. rate	0.527	0.390	–	–	0.04	-0.26	0.85	0.88	0.79	0.73
Real wage	0.096	0.138	–	–	0.39	0.03	0.85	0.93	0.36	0.67
Real exch. rate	0.086	0.236	–	–	-0.26	0.19	0.78	0.94	0.18	0.79
Gov. cons.	0.055	0.055	1.09	1.06	0.38	0.10	0.62	0.62	0.46	0.15
Deficit ratio	0.059	0.054	–	–	-0.43	-0.08	0.65	0.34	0.49	0.09
For. demand	0.030	0.027	0.60	0.51	0.01	0.12	0.98	0.97	0.77	0.90
For. inflation	0.016	0.016	–	–	0.29	0.00	0.29	0.35	-0.14	0.01
For. int. rate	0.049	0.038	–	–	-0.19	0.07	0.94	0.87	0.69	0.57

Notes. The model-implied moments are computed from the solution of the model at the posterior mean. The standard deviations of inflation rates and interest rates are in annualized percentage terms, the remaining standard deviations are in quarterly percentage terms.

Table H.3: One-step ahead forecast errors.

	Mean forecast error ME		Root mean squared forecast error RMSE	
	With sov. risk *(M_1)*	*No sov. risk* *(M_2)*	*With sov. risk* *(M_1)*	*No sov. risk* *(M_2)*
Output	-0.16	-0.38	1.48	1.52
Consumption	-0.38	-0.50	1.18	1.00
Investment	-0.77	-0.32	3.59	2.88
Inflation	1.06	-1.14	6.67	7.66
Real wage	8.32	11.06	18.09	21.72
Nom. interest rate	-0.44	-0.21	1.53	1.62
Real exch. rate	0.82	-0.69	2.20	3.26
Gov. consumption	-0.01	-0.01	2.02	2.09
Deficit ratio	-0.84	1.20	4.70	4.55
For. output	0.00	0.00	0.09	0.08
For. inflation	0.02	0.02	1.01	1.00
For. interest rate	0.38	0.41	0.69	0.75

Notes. The mean forecast errors and the root mean squared forecast errors are computed according to the formulas MFE $= T^{-1}\sum_{t=1}^{T} F_t$ and RMSFE $= \sqrt{T^{-1}\sum_{t=1}^{T} F_t^2}$, respectively, where F_t is the difference between the observed variable Y_t and its one-step ahead forecast from the Kalman filter Y_t^f, i.e. $F_t = Y_t - Y_t^f$. Inflation rates and interest rates are measured in annualized percentage terms, the remaining variables are in quarterly percentage terms.

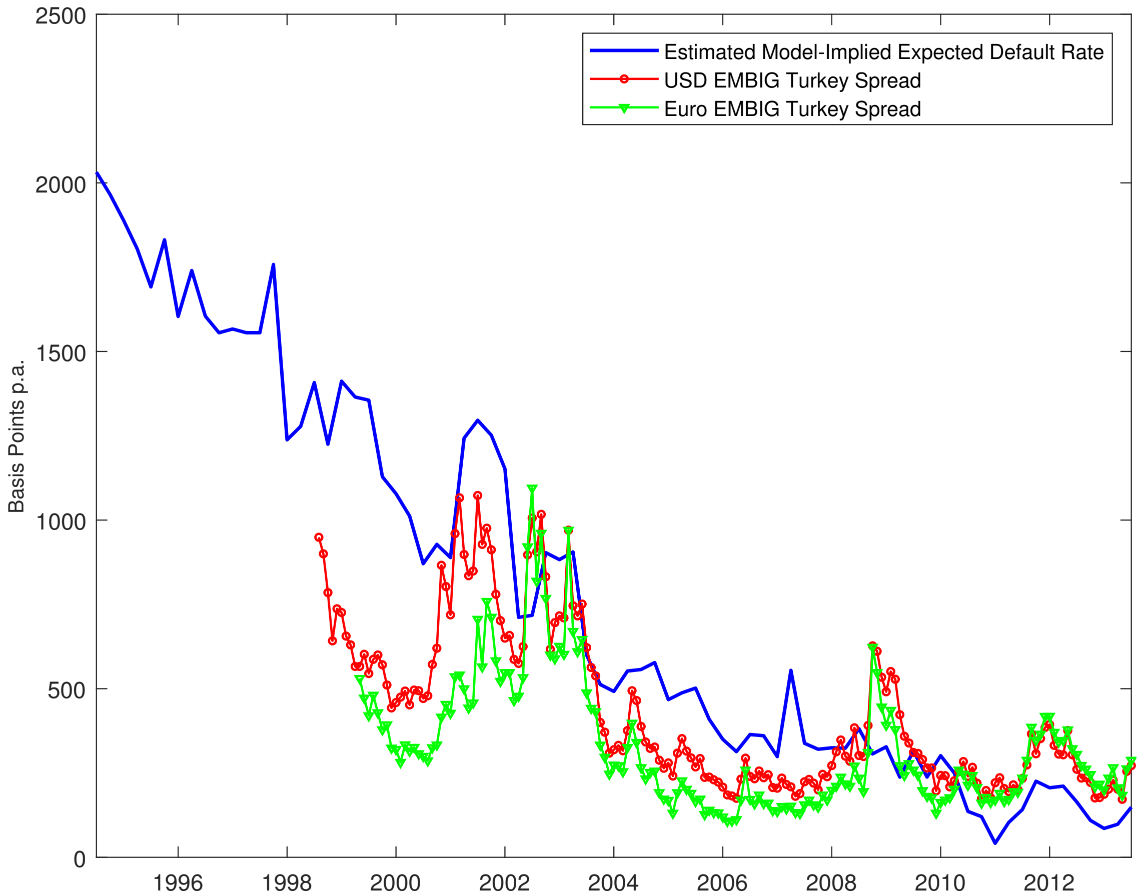

Figure H.1: Model-implied expected default rate ($E_t\delta_{t+1}$) and EMBIG Turkey spreads. *Notes.* The model-implied default rate is the estimate implied by the Kalman smoother at the posterior mean (1994Q3-2013Q3); source of EMBIG spreads (monthly data): J.P. Morgan and Bloomberg; 'USD' indicates spreads on U.S. dollar Brady bonds and loans over U.S. treasury bonds (08/1998-09/2013); 'Euro' indicates spreads on euro denominated bonds and loans over German bunds (05/1999-09/2013).

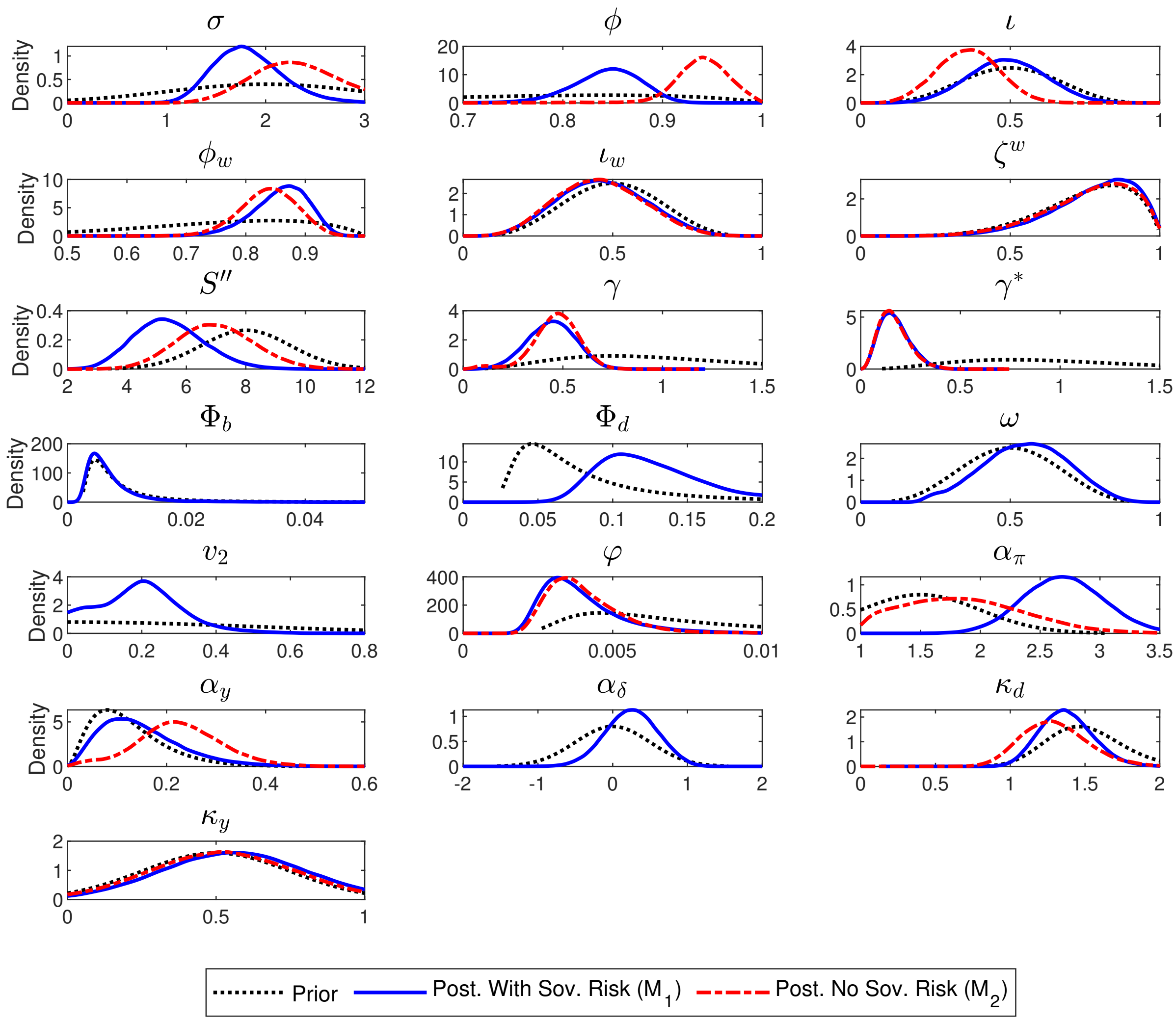

Figure H.2: Prior vs. posterior distributions, structural parameters.

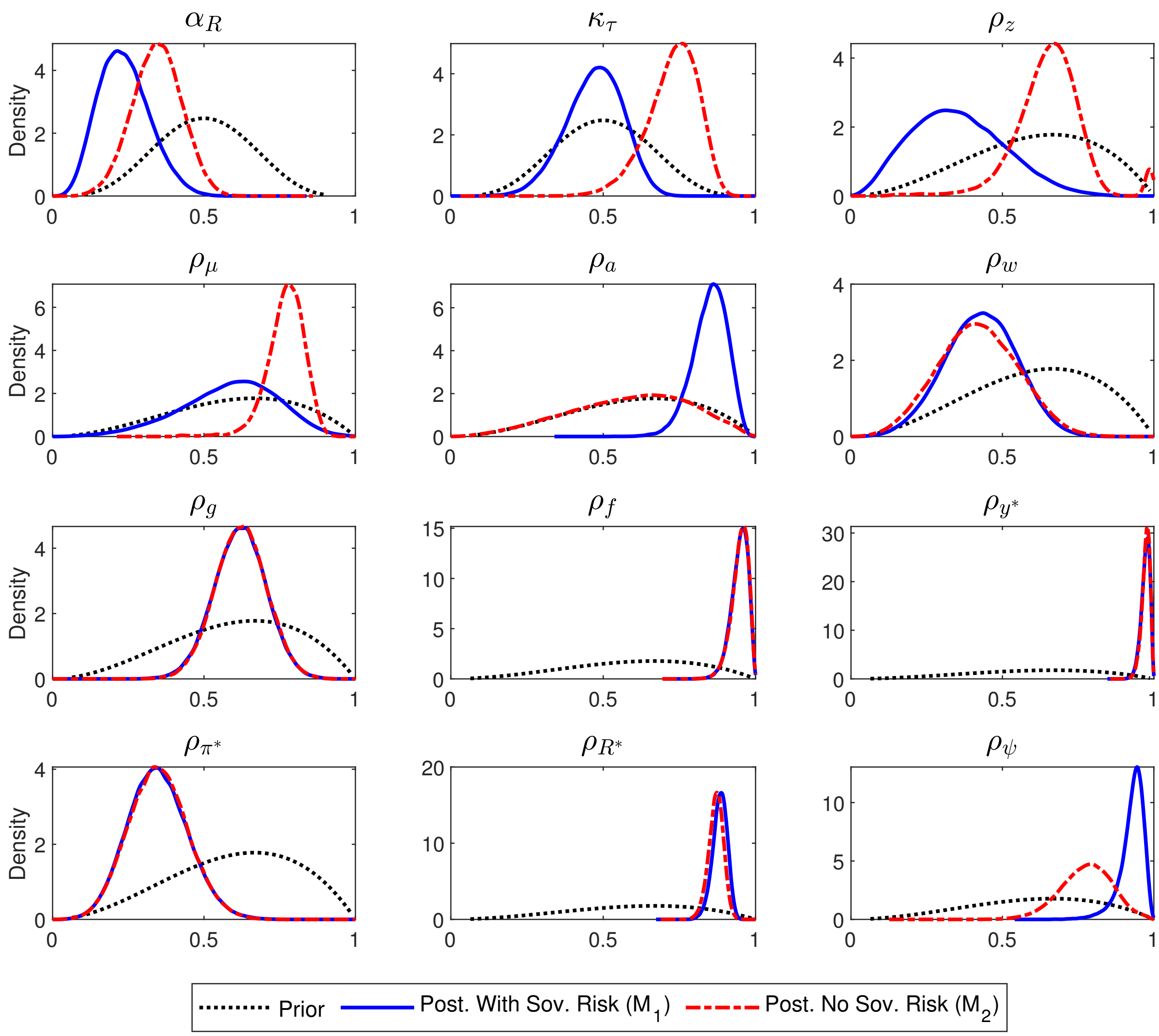

Figure H.3: Prior vs. posterior distributions, AR(1) coefficients.

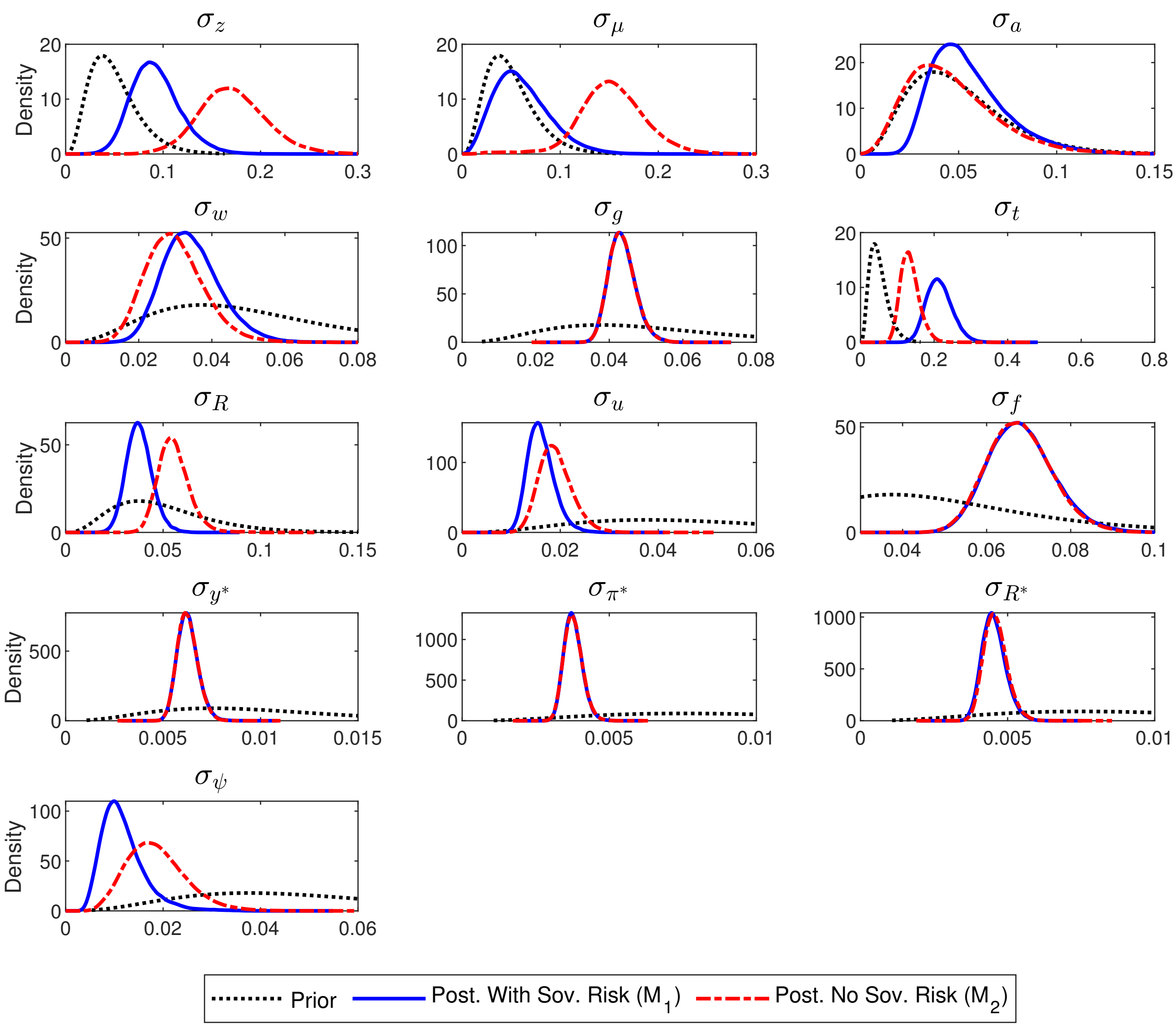

Figure H.4: Prior vs. posterior distributions, standard deviations.

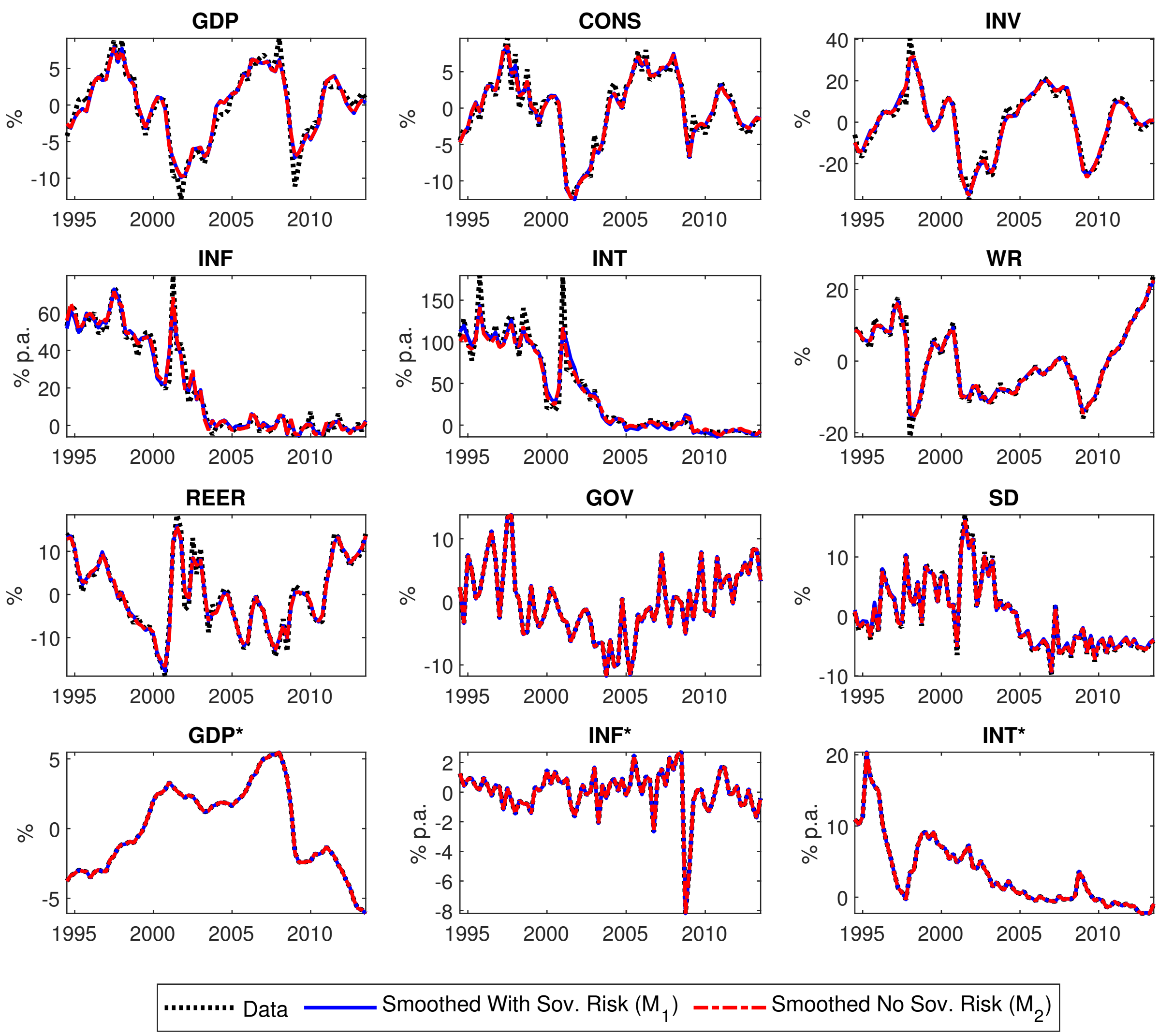

Figure H.5: Observed data vs. smoothed variables.

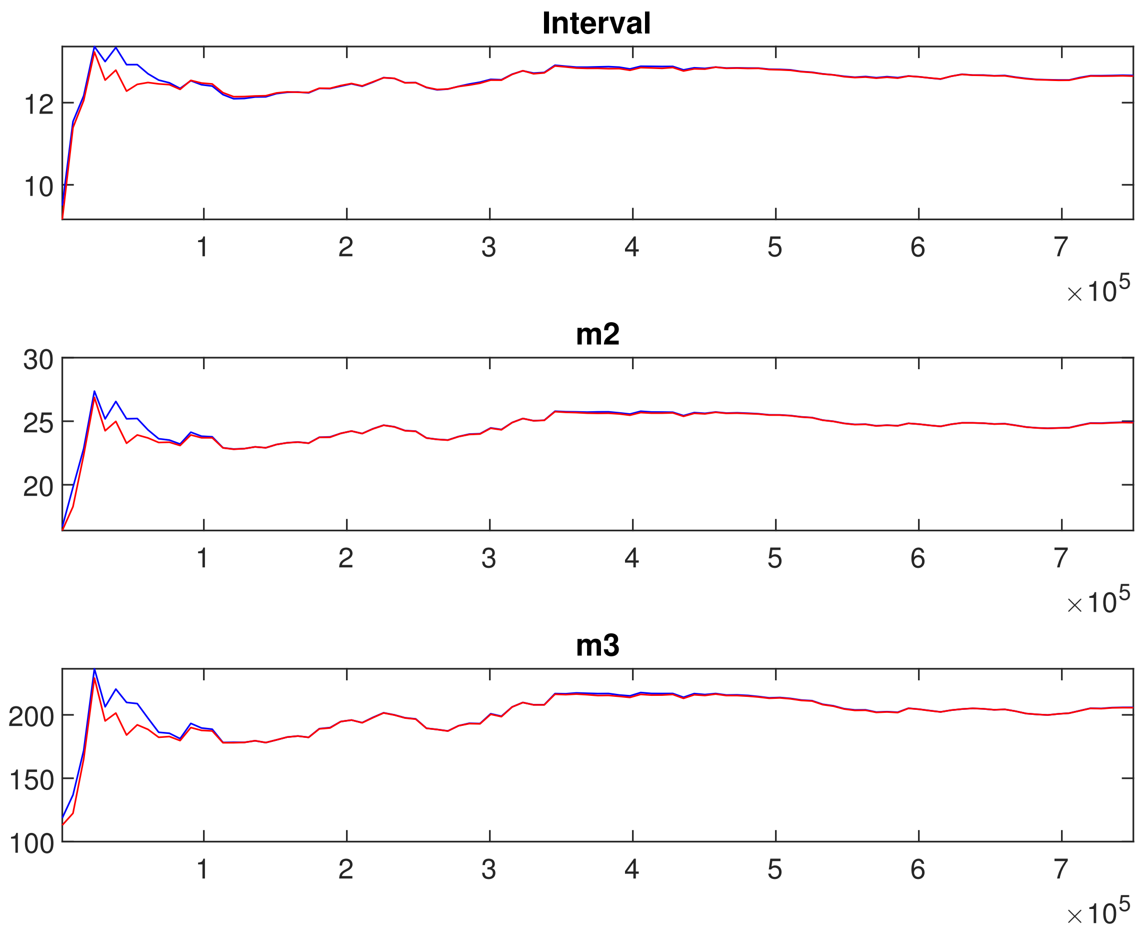

Figure H.6: Multivariate convergence diagnostics, model with sovereign risk.

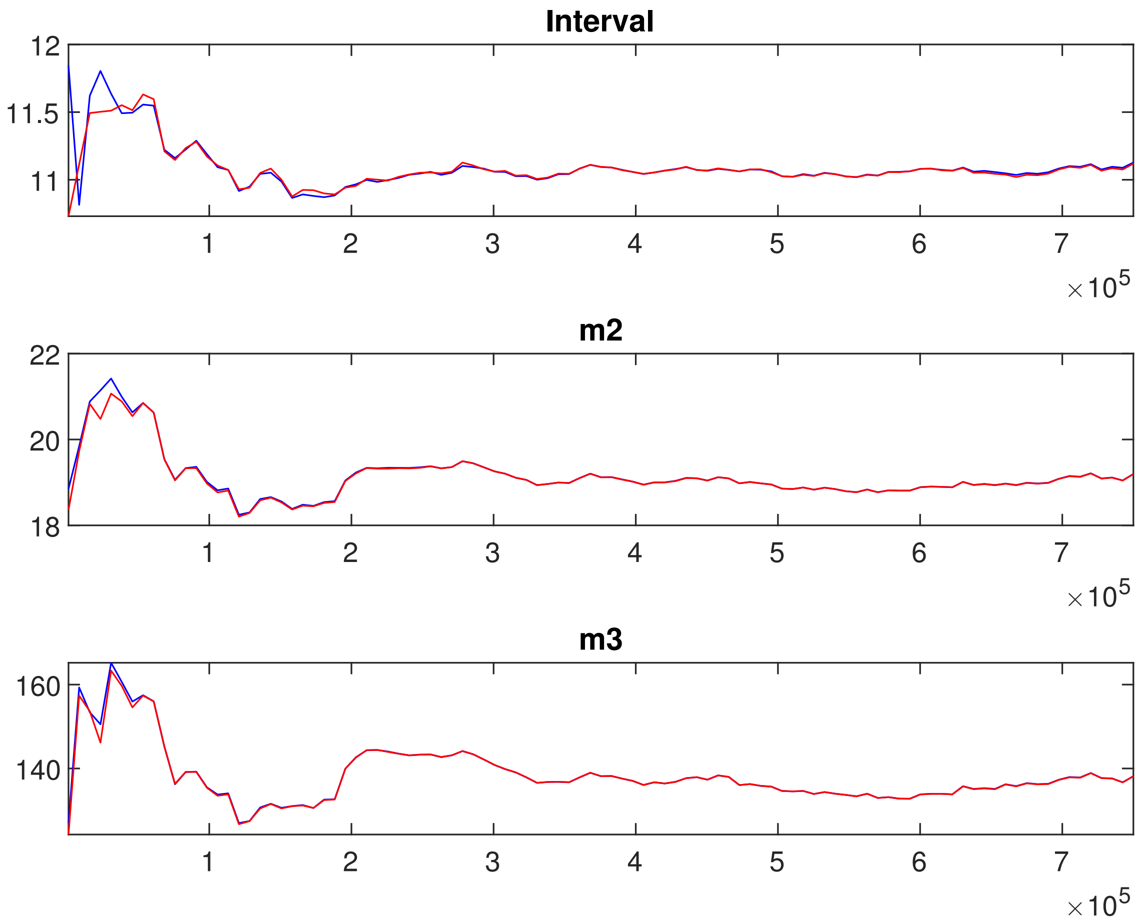

Figure H.7: Multivariate convergence diagnostics, model without sovereign risk.

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