Fiscal policy and the business cycle: the impact of government expenditures, public debt, and sovereign risk on macroeconomic fluctuations

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Chapter 5

Sovereign Default Risk and Macroecononomic Fluctuations in an Emerging Market Economy*

Abstract

This chapter examines the role of sovereign default risk for business cycle dynamics in an emerging market economy. We assess whether a small open economy model with sticky prices and endogenous sovereign default premia can explain the fluctuations of inflation, interest rates, and government debt along with real business cycles in Turkey. We compare estimation results for a basic version of the model where government debt is only relevant for the dynamics of fiscal variables and an augmented version where government debt matters for the dynamics of all variables due to a perceived risk of sovereign debt default. The results show that, unlike the basic model, the augmented model does not rely on large shocks or extreme parameter values to match the data. Comparatively small shocks are instead amplified through a self-enforcing feedback cycle between government debt, default premia, and nominal variables which brings the model closer to the data.

5.1 Introduction

A growing empirical literature seeks to explain business cycles in developed countries using new open-economy macroeconomic (NOEM) models (e.g. Adolfson, Laséen, Lindé, and Villani, 2007; Justiniano and Preston, 2008, 2010; Lubik and Schorfheide, 2007). The evidence for emerging market countries is however still scarce. One possible

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reason is that emerging market economies are often characterized by business cycle fluctuations that are difficult to generate with standard NOEM models. In particular, many emerging countries such as Argentina, Brazil, Mexico, Russia, and Turkey have been characterized by highly persistent and volatile inflation, nominal interest rates, and government debt. This chapter argues that it is useful to model investors' beliefs on sovereign debt default in order to obtain such dynamics in an empirical NOEM model for an emerging market economy.

We set up a small open economy model with sticky prices following Galí and Monacelli (2005) but including a government which borrows in domestic currency at home and in foreign currency abroad in line with the "original sin" literature (Eichengreen and Hausmann, 1999). The government follows a tax rule with at least some feedback from higher debt levels on taxes. Following Schabert and van Wijnbergen (2011), we argue that this rule may imply perceived infeasible rates of taxation, in which case the government is expected to default on (part of) its outstanding debt. The presence of sovereign default beliefs introduces an endogenous default premium, which depends on real government liabilities, in the households' consumption Euler equation. If the monetary authority follows an active interest rate policy, inflation increases imply higher real rates and an associated increase in the public debt service burden, which may lead to sovereign default fears. The latter generates a negative feedback from government debt on its expected return, which implies that current savings tend to be lower, putting pressure on the exchange rate, which increases inflation and the need for the monetary authority to raise interest rates, further increasing debt obligations and default premia, and so on. This destabilizing effect of active monetary policy in the presence of sovereign default beliefs, which has been pointed out by Blanchard (2005) and which has been analyzed theoretically by Schabert and van Wijnbergen (2006, 2011), is at the heart of our model.

Using this model we assess the role of sovereign default risk in explaining business cycle fluctuations in an emerging market economy, taking Turkey's experience as a natural experiment. In particular, Turkey was hit by a severe financial crisis in November 2000 when nominal interest rates increased sharply, accompanied by a downgrading of government debt to below investment grade. These observations indicate that fears of sovereign default played a relevant role, although a debt default did not actually occur. We thus estimate two variants of the model on quarterly Turkish data for the period 1994Q3-2008Q2 by Bayesian methods. The two variants differ only with respect to the existence of the default premium in the consumption Euler equation. Without that premium the model reduces to a standard NOEM model where the level of government debt is only relevant for the level of (lump-sum) taxes. With the premium the level of government debt matters for the dynamics of all variables.

Our results show that the basic model without sovereign default risk relies on relatively large shocks and extreme parameter values to match the data. The augmented model with default risk neither requires very large shocks nor extreme parameter values; instead, comparatively small shocks are amplified and propagated through the feedback mechanism between government debt, default premia, and nominal variables described above. Formal model comparisons clearly support the modification of the consumption Euler equation in the augmented model, whose forecasting performance is also significantly improved. We therefore conclude that modelling investors' beliefs on sovereign debt default can indeed lead to a better understanding of business cycle fluctuations in an emerging market economy.

In addition to the above-cited studies on empirical NOEM models, our study is related to the following literature. The empirical shortcomings of the consumption Euler equation have led some researchers to include reduced-form risk premium shocks in both closed and open economy models (e.g. Adolfson et al., 2007; Justiniano and Preston, 2010; Smets and Wouters, 2007). Other studies have explored the role of permanent productivity shocks (Aguiar and Gopinath, 2007) and financial frictions (e.g. Chang and Fernández, 2010; García-Cicco, Pancrazi, and Uribe, 2010; Neumeyer and Perri, 2005; Uribe and Yue, 2006) in explaining the empirical regularities of emerging market business cycles, in particular the high volatility of consumption relative to output and the countercyclicality of interest rates. Based on the seminal contribution of Eaton and Gersovitz (1981), the role of strategic government default has been investigated by Arellano (2008). She focuses on the terms of international loans that are endogenous to domestic fundamentals and depend on the incentives to default in order to explain co-movements between real interest rates and output.

Inspired by the idea that financial frictions are important for understanding emerging market business cycles, our contribution is to focus on the role of fiscal sustainability concerns in a model with nominal rigidities. While we also use stochastic shocks to describe past business cycles in Turkey, our findings suggest that a standard set of shocks cannot explain the Turkish experience in an NOEM model where fiscal sustainability concerns are absent. Instead, we find that the amplification and propagation mechanism due to sovereign risk does seem to be an important driving force of business cycle fluctuations in Turkey.[1] Finally, as in Schabert and van Wijnbergen (2011), in our model there is no strategic motive for the government to default on its debt. Default premia are instead determined by investors' beliefs that infeasible rates of taxation may *force* the government into default.

The remainder of the paper is organized as follows. Section 5.2 lays out the model. Section 5.3 describes the estimation of the model on quarterly Turkish data from 1994Q3 to 2008Q2. Section 5.4 presents the estimation results. We compare the basic model and the augmented model in terms of parameter estimates, marginal data densities, variance decompositions, and forecasting performance. We then implement counterfactual experiments based on the augmented model to understand how business cycles in Turkey have been influenced by sovereign risk, before comparing the impulse response dynamics generated by both model versions. Finally, we briefly summarize various sensitivity checks. Section 5.5 concludes.

5.2 Model description

We outline a small open economy model with sticky prices based on Galí and Monacelli (2005). The model considers expectations of sovereign default following Schabert and van Wijnbergen (2011), whose presence breaks Ricardian equivalence since the time path of government debt matters for equilibrium determination, but the model nests the Ricardian case where the time path of government debt is irrelevant for the allocation. We allow for foreign currency denominated debt to provide a realistic description of

[1] Given the findings of Chang and Fernández (2010) and García-Cicco, Pancrazi, and Uribe (2010), indicating that permanent productivity shocks tend to have a negligible role in explaining business cycles in emerging economies compared to financial frictions, we neglect such shocks in our analysis.

the conduct of fiscal policy in Turkey, where the government can only borrow limited amounts from abroad in Turkish lira. Eichengreen and Hausmann (1999) call this the "original sin" which typically characterizes emerging market economies. Changes in the real exchange rate then have a direct impact on expected sovereign default rates due to the presence of foreign currency denominated debt.

5.2.1 Public sector

The public sector consists of a government and a monetary authority. The price of domestic bonds is set by the monetary authority, and since government bonds are subject to perceived default risk, the monetary policy instrument is an interest rate on an asset which exhibits a contingent pay-off. Thus, the policy instrument carries a risk component that will be reflected in equilibrium (see Blanchard, 2005; Loyo, 2005; Schabert and van Wijnbergen, 2006, 2011).

Fiscal policy

The government issues one-period discount bonds denominated in domestic and foreign currency $B_{H,t}$ and $B_{F,t}$, respectively.[2] It 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.[3] 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 denominated bonds is endogenously determined in equilibrium.

The government is assumed to follow a simple tax feedback rule, adjusting lump-sum taxes in response to the outstanding stock of debt:

$$P_t\tilde{\tau}_t = \kappa(B_{H,t-1} + X_tB_{F,t-1}) + P_t\exp(\varepsilon_{\tau,t}), \tag{5.1}$$

[2]Time is indexed by $t = 0, 1, 2, \ldots, \infty$. Throughout, nominal (real) variables are denoted by capital (lower) letters, asterisks denote foreign variables and variables without time subscript denote non-stochastic steady state values.

[3]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, above that observed for private consumption (see e.g. Trionfetti, 2000; Brulhart and Trionfetti, 2004).

where $\varepsilon_{\tau,t} \sim N(0, \sigma_\tau^2)$ is a lump-sum tax shock and X_t denotes the domestic currency price of one unit of foreign currency. Following Bohn (1998), a tax rule of this type ensures fiscal solvency for any finite initial level of debt as long as $\kappa > 0$. However, it may imply politically infeasible levels of taxation as we discuss next.

Following Schabert and van Wijnbergen (2011), according to investors' beliefs, the government defaults when debt service would demand a politically infeasible level of taxation $\overline{T}$. Lenders do not know the exact value of $\overline{T}$, but they have a prior on its distribution, $h(\overline{T})$. Given that tax revenues are set according to (5.1), the perceived probability of default δ_t then equals the probability that the tax rule implies a level of $\tilde{\tau}_t$ exceeding $\overline{T}$:

$$\delta_t = \int_0^{\tilde{\tau}_t} h(\overline{T}) d\overline{T}. \tag{5.2}$$

Let $q_t = X_t P_t^* / P_t$ denote the real exchange rate and $\pi_t = P_t / P_{t-1}$ and $\pi_t^* = P_t^* / P_{t-1}$ home and foreign consumer price index (CPI) inflation, respectively. For a differentiable distribution function $h(\cdot)$ the impact of total real debt $b_t = b_{H,t-1}\pi_t^{-1} + q_t b_{F,t-1}\pi_t^{*-1}$ on the probability of default is given by $\partial\delta_t(\cdot)/\partial b_t = \kappa h(\kappa b_t) > 0$. Thus, the perceived default probability strictly increases with the real value of total debt. For the local analysis of the model we use the product of the ratio $(b_H/\pi)/(1-\delta)$ and the elasticity of the default probability with respect to the real value of total debt evaluated at the steady state:

$$\Phi = \frac{b_H/\pi}{1-\delta} \frac{\partial\delta_t(\cdot)}{\partial b_t}\bigg|_{b_t=b},$$

where $\delta = \delta(b) < 1$. We refer to Φ as the default elasticity and we treat it as a structural parameter in the empirical implementation. Note that $\Phi > 0$ if $b_H/\pi > 0$.[4]

To determine the division of total debt among domestic debt and foreign debt, we assume that the government issues foreign currency denominated debt as a time-varying fraction $f_t \geq 0$ of domestic debt, $X_t B_{F,t}/R_{F,t} = f_t B_{H,t}/R_{H,t}$, where f_t follows an autoregressive process in logs: $\log(f_t/\bar{f}) = \rho_f \log(f_{t-1}/\bar{f}) + \varepsilon_{f,t}$, with $\rho_f \in [0, 1)$ and $\varepsilon_{f,t} \sim N(0, \sigma_f^2)$. It is also assumed that the 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 households. Given the

[4] As noted by Schabert and van Wijnbergen (2011), the structure of the default premium has a structure that commands broad empirical support: see, for instance, Cantor and Packer (1996), Edwards (1994), Eichengreen and Mody (2010), Ferucci (2003), and Min (1998).

specification (5.2), the period-by-period perceived government budget constraint for any period t reads as follows:

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

where $P_t \tau_t = P_t \tilde{\tau}_t - \delta_t (B_{H,t-1} + X_t B_{F,t-1})$ 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 $\varepsilon_{g,t} \sim N(0, \sigma_g^2)$.

Monetary policy

In line with the actual behavior of the Central Bank of the Republic of Turkey (CBRT), CPI inflation stabilization is assumed to be the target of monetary policy. The monetary authority thus sets the domestic currency price of domestic bonds according to the reaction function

$$R_{H,t}/R_H = (\pi_t/\pi)^{\alpha_\pi} \exp(\varepsilon_{R,t}), \tag{5.3}$$

where $\varepsilon_{R,t} \sim N(0, \sigma_R^2)$. Interest rate smoothing did not seem to be a primary goal of the CBRT, so we do not include a smoothing term in the reaction function. As we are primarily interested in the interaction between an inflation targeting monetary authority and fiscal policy, we also do not include an output term for now. The CBRT was however targeting the exchange rate before the economic reforms in 2001 (see Gormez and lmaz, 2007). We therefore check the sensitivity of the estimation results to adding an exchange rate term and also an output term to the reaction function in Section 5.4.4.

5.2.2 Private sector

Domestic households

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

$$E_t \sum_{s=0}^{\infty} \beta^s \left[z_{t+s} \frac{1}{1-\sigma} c_{t+s}^{1-\sigma} - \frac{1}{1+\eta} n_{t+s}^{1+\eta} \right], \quad \beta \in (0,1), \quad \sigma > 0, \quad \eta \geq 0, \tag{5.4}$$

where z_t is a demand shock which follows an autoregressive process in logs: $\log z_t = \rho_z \log z_{t-1} + \varepsilon_{z,t}$, with $\rho_f \in [0,1)$ and $\varepsilon_{z,t} \sim N(0, \sigma_z^2)$. Domestic households invest in domestic and foreign currency denominated government bonds and in a complete set of state-contingent securities which are traded internationally. Let $\Gamma_{t,t+1}$ denote the stochastic discount factor for a one-period ahead nominal payoff S_{t+1} in foreign currency. The perceived flow budget constraint, which takes into account the household's default beliefs, is given by

$$\begin{aligned} & P_t c_t + P_t \tau_t + E_t(X_t \Gamma_{t,t+1} S_{t+1}) + B_{H,t}/R_{H,t} + X_t B_{F,t}^h / R_{F,t} \\ & \quad \leq X_t S_t + (1-\delta_t)(B_{H,t-1} + X_t B_{F,t-1}^h) + P_t w_t n_t + \Sigma_t, \end{aligned} \tag{5.5}$$

for given initial wealth endowments $B_{H,-1}$, $B_{F,-1}^h$, and S_0. Here, w_t is the real wage rate and Σ_t collects payouts from ownership of firms, which are both taken as given by the household.

The household's consumption basket is an aggregate of domestically produced goods $c_{H,t}$ and goods of foreign origin $c_{F,t}$, $c_t = \gamma c_{H,t}^{1-\vartheta} c_{F,t}^{\vartheta}$, where $\vartheta \in [0,1]$ denotes the import share and $\gamma = \vartheta^{-\vartheta}(1-\vartheta)^{\vartheta-1}$. The optimal allocation of consumption among $c_{H,t}$ and $c_{F,t}$ yields the demand functions $c_{H,t} = (1-\vartheta) P_t c_t / P_{H,t}$ and $c_{F,t} = \vartheta P_t c_t / P_{F,t}$, where $P_{F,t}$ is the price of foreign goods. The definition of the CPI follows as $P_t = P_{H,t}^{1-\vartheta} P_{F,t}^{\vartheta}$. The first-order conditions from maximization of (5.4) subject to a no-Ponzi-game condition and (5.5) are as follows:

$$\begin{aligned} \lambda_t &= z_t c_t^{-\sigma}, & \lambda_t &= R_{H,t} \beta E_t[(1-\delta_{t+1}) \lambda_{t+1} \pi_{t+1}^{-1}], \\ n_t^{\eta} &= \lambda_t w_t, & \lambda_t q_t &= R_{F,t} \beta E_t[(1-\delta_{t+1}) \lambda_{t+1} q_{t+1} \pi_{t+1}^{*-1}], \\ \Gamma_{t,t+1} &= \beta (X_{t+1}/X_t)(\lambda_{t+1}/\lambda_t) \pi_{t+1}^{-1}, \end{aligned} \tag{5.6}$$

where λ_t denotes the Lagrangian multiplier associated with (5.5). The budget constraint holds with equality and the transversality conditions are satisfied. It follows that, everything else equal, a higher expected default rate leads households to demand a higher interest rate.

Foreign households

The foreign economy is inhabited by a continuum of infinitely lived households with identical asset endowments and which have the same preference structure as domestic households. A representative foreign household's demand for domestically produced goods $c^*_{H,t}$ satisfies

$$c^*_{H,t} = \vartheta^* P^*_t c^*_t / P^*_{H,t}, \tag{5.7}$$

where $\vartheta^* \in [0,1]$, c^*_t is aggregate foreign consumption, and $P^*_{H,t}$ is the price of domestic goods expressed in foreign currency. The foreign household invests in state-contingent securities S_t and foreign currency denominated bonds issued by the domestic government $B^f_{F,t}$. The first order conditions are given by $\lambda^*_t = R_{F,t}\beta E_t[(1-\delta_{t+1})\lambda^*_{t+1}\pi^{*-1}_{t+1}]$ and

$$\Gamma_{t,t+1} = \beta(\lambda^*_{t+1}/\lambda^*_t)\pi^{*-1}_{t+1}, \tag{5.8}$$

where $\lambda^*_t = c^{*-\sigma}_t$. As the foreign economy is exogenous to the domestic economy, we assume for simplicity that foreign consumption and inflation follow a VAR process in logs with p lags: $[\log(c^*_t/\bar{c}^*), \log(\pi^*_t/\bar{\pi}^*)]' = \sum_{i=1}^{p} \Phi_{i*}[\log(c^*_{t-i}/\bar{c}^*), \log(\pi^*_{t-i}/\bar{\pi}^*)]' + [v_{c^*,t}, v_{\pi^*,t}]'$ where $I - \sum_{i=1}^{p} \Phi_{i*}$ is a non-singular matrix and $[v_{c^*,t}, v_{\pi^*,t}]' \sim N(0, \Sigma_*)$. Notice also that $B^h_{F,t} + B^f_{F,t} = B_{F,t}$, for all t, by market clearing.

Production and pricing

The production sector consists of final goods producers and intermediate goods producers. Final goods producers are perfectly competitive. They assemble the final domestic good $y_{H,t}$ from intermediate goods $y^i_{H,t}$, $i \in [0,1]$, through the technology $y_{H,t} = [\int_0^1 (y^i_{H,t})^{(\epsilon-1)/\epsilon} di]^{\epsilon/(\epsilon-1)}$, where ϵ denotes the elasticity of substitution among intermediate goods. Taking as given all intermediate goods prices $P^i_{H,t}$ and the final goods price $P_{H,t}$, profit maximization yields input demands

$$y^i_{H,t} = (P^i_{H,t}/P_{H,t})^{-\epsilon} y_{H,t} \tag{5.9}$$

for all i, where we have used the zero profit condition in the final goods sector, i.e. $P_{H,t}y_{H,t} = \int_0^1 P^i_{H,t}y^i_{H,t}di$. The price index for domestic goods $P_{H,t}$ follows from using (5.9) in the zero profit condition stated above: $P_{H,t} = [\int_0^1 (P^i_{H,t})^{1-\epsilon}di]^{1/(1-\epsilon)}$.

Intermediate goods production is conducted by a continuum of monopolistically competitive firms. Each firm i uses the technology $y^i_{H,t} = a_t n^i_t$, where a_t is common total factor productivity which follows an autoregressive process in logs: $\log a_t = \rho_a \log a_{t-1} + \varepsilon_{a,t}$, with $\rho_a \in [0, 1)$ and $\varepsilon_{a,t} \sim N(0, \sigma_a^2)$. Intermediate goods producers solve a two-stage problem. In the first stage, taking the input price w_t and the output price $P^i_{H,t}$ as given, firms hire labor to minimize costs, which yields the first-order conditions $P_t w_t = MC^i_t a_t$ for all i, where MC^i_t denotes nominal marginal costs. The equality $MC^i_t = MC_t$ holds since all firms face the same input prices and use the same technology. Expressing real marginal costs in terms of domestic prices, $mc_t = MC_t/P_{H,t}$, then yields the labor demand function $w_t = mc_t a_t P_{H,t}/P_t$.

In the second stage, given real marginal costs, intermediate goods producers choose prices $P^i_{H,t}$ to maximize profits. We allow for staggered price setting following Calvo (1983) and Yun (1996). Each period a fraction $1 - \phi$ of randomly selected firms is allowed to set an optimal new price $\check{P}^i_{H,t}$ or $\check{P}_{H,t}$, by symmetry. The remaining firms adjust their prices along with steady state producer price inflation π_H. Each firm i which receives permission to optimally reset its price maximizes the expected sum of discounted profits subject to (5.9):

$$\max E_t \sum_{s=0}^{\infty} \phi^s X_t \Gamma_{t,t+s}(P^i_{H,t} - P_{H,t+s}mc_{t+s})y^i_{H,t+s} \quad \text{s.t.} \quad y^i_{H,t} = (P^i_{H,t+s}/P_{H,t+s})^{-\epsilon} y_{H,t+s},$$

where $P^i_{H,t+s} = \check{P}_{H,t}\pi^s_H$ for $s = 1, 2, \ldots, \infty$. The first-order condition is given by

$$0 = E_t \sum_{s=0}^{\infty} \phi^s X_t \Gamma_{t,t+s} y^i_{H,t+s}[(1-\epsilon)\pi^s_H \check{P}_{H,t} + \epsilon P_{H,t+s}mc_{t+s}].$$

The price index of domestic goods follows as $P_{H,t}^{1-\epsilon} = (1-\phi)\check{P}_{H,t}^{1-\epsilon} + \phi(\pi_H P_{H,t-1})^{1-\epsilon}$.

5.2.3 Market clearing

Market clearing requires that the demand for labor services is equal to labor supply: $\int_0^1 n_t^i di = n_t$. Integrating $y_{H,t}^i = a_t n_t^i$ over all i, it then follows that $\int_0^1 y_{H,t}^i di = a_t n_t$. We assume that the domestic economy is small relative to the foreign economy, which implies that the foreign producer price level $P_{F,t}^*$ is identical to the foreign consumption price index P_t^*. Furthermore, the law of one price is assumed to hold separately for each good, such that $P_{F,t} = X_t P_{F,t}^*$ and $P_{H,t} = X_t P_{H,t}^*$. Using the definition of the CPI, foreign demand for domestic goods (5.7) can then be re-written as $c_{H,t}^* = \vartheta^* q_t^{1/(1-\vartheta)} c_t^*$ and domestic demand $c_{H,t} = (1-\vartheta)P_t c_t / P_{H,t}$ can be re-written as $c_{H,t} = (1-\vartheta) q_t^{\vartheta/(1-\vartheta)} c_t$, where we have used that $P_{H,t}/P_t = q_t^{\vartheta/(\vartheta-1)}$. Goods market clearing requires that aggregate supply $y_{H,t}$ equals aggregate demand $c_{H,t} + c_{H,t}^* + g_t$. The goods market clearing condition can be re-written as follows:

$$y_{H,t} = (1-\vartheta) q_t^{\vartheta/(1-\vartheta)} c_t + \vartheta^* q_t^{1/(1-\vartheta)} c_t^* + g_t.$$

The CPI inflation rate can be expressed in terms of producer price inflation through $\pi_t = \pi_{H,t}(q_t/q_{t-1})^{\vartheta/(1-\vartheta)}$ for all $t \geq 1$. Finally, combining (5.6) and (5.8) yields the international risk sharing condition $\lambda_t^* = \xi q_t \lambda_t$, which determines the relation between the levels of domestic and foreign marginal utility and the real exchange rate up to a positive constant ξ that depends on initial endowments.

5.3 Model estimation

We employ a log-linear approximation of the system of equilibrium conditions around the non-stochastic steady state. Appendix 5.A provides the log-linearized system and a definition of the rational expectations equilibrium. The model is then estimated by Bayesian methods as described in An and Schorfheide (2007).

5.3.1 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 by the Random Walk Metropolis (RWM) algorithm. The evidence of model M_i over another (not necessarily nested) model M_j is assessed 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 an application of the Kalman smoother at the parameter estimates. This step also yields smoothed estimates $x_{t|T}$ of the unobserved states. To evaluate the forecasting performance of alternative models, one-step ahead forecasts are computed conditional on period t information: $Y_{t+1|t} = Hx_{t+1|t}$, for all t, where $x_{t+1|t} = Fx_{t|t}$ and $x_{t|t}$ denote updates from the Kalman filter.[5]

5.3.2 Data description

We use quarterly Turkish data on real GDP, real private consumption, the annualized consumer price inflation rate, the nominal interest rate on 3-month Turkish lira denominated treasury bills, the real effective exchange rate, real government consumption, real Turkish lira denominated domestic government debt, real foreign consumption,

[5] We use version 4.2.0 of the Dynare toolbox for MATLAB in the computations. The marginal data densities are estimated using Geweke's (1999) modified harmonic mean estimator.

and the foreign consumer price inflation rate.[6] The sample period is 1994Q3-2008Q2.

Foreign variables are computed as trade-weighted averages of data for the U.S. and the euro area, which are Turkey's main trading partners. Nominal variables are demeaned in consistence with their steady state values. Real variables are transformed into natural logarithms and they are detrended using a linear trend.[7] Further details on data sources, definitions, and the construction of the foreign variables are provided in Appendix 5.B.

Domestic and foreign inflation (INF_t and INF_t^*) and the domestic interest rate (INT_t) are related to the model variables through the measurement equations $\text{INF}_t = 4\bar{\pi}\hat{\pi}_t$, $\text{INF}_t^* = 4\bar{\pi}^*\hat{\pi}_t^*$, and $\text{INT}_t = 4\bar{R}_H\hat{R}_{H,t}$. As the real effective exchange rate (REER_t) is constructed from all trading partners, it is not exactly equivalent to the model-implied real exchange rate, which relates to the U.S. and the euro area. To account for this fact, we include a measurement error in the equation for the real exchange rate $\text{REER}_t = \hat{q}_t + u_{q,t}$ with $u_{q,t} \sim N(0, \sigma_q^2)$.

5.3.3 Calibration

The steady state values that matter for the dynamics are calibrated to match sample averages. To match the average annual Turkish CPI inflation rate over the sample period of 37.2 percent, we set $\bar{\pi} = 1.093$. The average annualized 3-month treasury bill rate was approximately 72.4 percent, so we set $R_H = \bar{R}_H = 1.181$. The shares of private and government consumption in GDP and the share of foreign currency debt over domestic currency debt are also set to their empirical counterparts, i.e. $s_c = \bar{s}_c = 0.683$, $s_g = \bar{s}_g = 0.108$, and $f = \bar{f} = 0.829$. Furthermore, the subjective discount factor β is set to 0.99, which implies a steady state default probability $\delta = \bar{\delta} = 1 - \bar{\pi}/\bar{R}_H/\beta = 0.065$. The latter agrees with the average J.P. Morgan Emerging Market Bond Index Global (EMBIG) spread on Turkish governments bonds.

The parameters of the stochastic process for the foreign variables are calibrated by

[6] We only observe domestic currency denominated debt since the Turkish government issues external debt only at maturities longer than 3 months. Note that the nominal interest rate also refers to domestic debt.

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

fitting an identified VAR with $p = 4$ lags to detrended foreign consumption and the demeaned annual foreign inflation rate.[8] Steady state foreign inflation $\pi^* = \bar{\pi}^*$ is calibrated to match an average annual inflation rate of 2.4 percent. Foreign consumption and inflation are then included in the actual estimation step (fixing the VAR parameters) in order to recover the shocks of foreign origin. Finally, as the inverse Frisch elasticity of labor supply η is difficult to identify, we set it to 2, in line with available estimates (see Christoffel, Coenen, and Warne, 2008).

5.3.4 Priors

As, to our knowledge, the present study is the first study that estimates a DSGE model for Turkey, we have little prior information on the model's deep structural parameters. We therefore use uniform priors on theoretically plausible ranges for most parameters as we would with restricted maximum likelihood estimation. The prior distributions are provided in Table 5.1.

The inverse elasticity of intertemporal substitution σ and the inflation feedback in the monetary reaction function α_π obtain a lower bound of 0 and upper bounds of 20 and 10, respectively. The Calvo probability ϕ and the domestic degree of openness ϑ are restricted to the range $[0, 1]$ in consistence with their feasible values. To ensure a positive default elasticity, which is the case if steady state domestic debt is positive, the debt response κ in the tax rule is restricted to be larger than $\kappa_L = 1 - \beta(1 - \bar{\delta})$ with an upper bound of 10.[9] We use uniform priors on the range $[0, 1]$ for the AR(1) coefficients of the stochastic processes. The standard deviations of the shocks turned out to be weakly identified especially for the model without default risk (for which Ψ is set to zero). We therefore elicit inverse gamma priors with mean 0.05 and an infinite standard deviation, implying that a larger portion of the probability mass tends to fall on existing estimates for small open economies (see e.g. Adolfson et al., 2007; Justiniano and Preston, 2010; Lubik and Schorfheide, 2007), while the distribution still covers all of the feasible range.

[8] Our identifying assumption is that foreign consumption affects foreign inflation within a quarter but not vice versa, which is achieved through a recursive Cholesky identification scheme.

[9] The steady state satisfies $b_H/\pi = [g(1 + \bar{f})^{-1}]/[\kappa + \beta(1 - \bar{\delta}) - 1]$ and therefore $\Phi > 0$ when $b_H/\pi > 0$, which is the case if $\kappa > 1 - \beta(1 - \bar{\delta})$ since $g, \bar{f} > 0$.

Table 5.1: Prior distributions and posterior estimates for Turkey[a]

				With sov. risk (M_1)		No sov. risk (M_2)	
	Parameter	Dom.	Prior[b]	Post.	90% int.	Post.	90% int.
σ	Inv. subst. elast.	$\mathbb{R}^+$	$\mathrm{U}(0,20)$	1.87	[0.98, 2.81]	15.98	[14.04, 17.97]
ϕ	Price stickiness	[0,1]	$\mathrm{U}(0,1)$	0.46	[0.38, 0.55]	0.72	[0.66, 0.78]
ϑ	Openness	[0,1]	$\mathrm{U}(0,1)$	0.13	[0.05, 0.20]	0.02	[0.02, 0.04]
Φ	Default elasticity	$\mathbb{R}^+$	$\mathrm{U}(0,10)$	0.29	[0.24, 0.33]	–	–
α_π	Mon. infl. resp.	$\mathbb{R}$	$\mathrm{U}(0,10)$	1.83	[1.61, 2.05]	1.28	[1.18, 1.38]
κ	Tax debt resp.	$\mathbb{R}$	$\mathrm{U}(\kappa_L,10)$	0.59	[0.51, 0.66]	0.11	[0.08, 0.14]
ρ_z	AR(1) demand	[0,1)	$\mathrm{U}(0,1)$	0.77	[0.62, 0.93]	0.95	[0.89, 1.00]
ρ_a	AR(1) productivity	[0,1)	$\mathrm{U}(0,1)$	0.96	[0.92, 1.00]	0.60	[0.50, 0.71]
ρ_g	AR(1) gov. cons.	[0,1)	$\mathrm{U}(0,1)$	0.44	[0.31, 0.58]	0.76	[0.68, 0.85]
ρ_f	AR(1) debt share	[0,1)	$\mathrm{U}(0,1)$	0.90	[0.82, 0.98]	0.62	[0.17, 1.00]
σ_z	Std. demand inn.	$\mathbb{R}^+$	IG(0.05)	0.05	[0.03, 0.08]	0.44	[0.35, 0.52]
σ_a	Std. prod. inn.	$\mathbb{R}^+$	IG(0.05)	0.03	[0.02, 0.04]	0.06	[0.03, 0.09]
σ_g	Std. gov. cons. inn.	$\mathbb{R}^+$	IG(0.05)	0.04	[0.03, 0.04]	0.22	[0.18, 0.26]
σ_f	Std. debt share inn.	$\mathbb{R}^+$	IG(0.05)	0.25	[0.21, 0.29]	0.04	[0.01, 0.08]
σ_τ	Std. tax inn.	$\mathbb{R}^+$	IG(0.05)	0.07	[0.06, 0.09]	0.13	[0.10, 0.16]
σ_R	Std. int. rate inn.	$\mathbb{R}^+$	IG(0.05)	0.06	[0.05, 0.07]	0.06	[0.05, 0.07]
σ_q	Std. meas. REER_t	$\mathbb{R}^+$	IG(0.05)	0.11	[0.09, 0.13]	0.19	[0.15, 0.22]
$\sigma_{\tau,g}$	Corr. tax, gov. cons.	[-1,1]	$\mathrm{U}(-1,1)$	0.79	[0.66, 0.92]	0.45	[0.19, 0.67]
	Log data density[c]			895.51		748.23	

[a] The results are based on 500,000 draws from the RWM sampler, dropping the first 250,000 draws, and an average acceptance rate of approximately 25 percent. Posterior means are reported.
[b] $\mathrm{U}(a,b)$ refers to the continuous uniform distribution with lower bound a and upper bound b; $\mathrm{IG}(c)$ refers to the inverse gamma distribution with mean c and an infinite standard deviation.
[c] The data density $p(Y^T|M_i)$ is estimated using Geweke's (1999) modified harmonic mean estimator.

Finally, notice that Ricardian equivalence implies that lump-sum tax shocks only affect taxes and debt in the model without default risk whereas shocks to the foreign debt share only affect the division among foreign and domestic debt. As we observe no other fiscal variable other than domestic debt and government consumption, there is a stochastic singularity problem. To address this issue, we allow the innovations ε_τ and ε_g to be correlated and estimate the degree of correlation $\sigma_{\tau,g}$. A positive correlation coefficient would then point towards tax-financed changes in government consumption.

5.4 Discusssion of results

The discussion of results is organized as follows. In Section 5.4.1 we compare the basic model without default risk and the augmented model in terms of parameter estimates, posterior odds, variance decompositions, and forecasting performance. In Section 5.4.2 we implement several counterfactual experiments based on the estimated model to understand the amplification channels due to default risk. We then compare the estimated impulse responses from both model versions in Section 5.4.3. Robustness checks are deferred to Section 5.4.4.

5.4.1 Model comparison

Parameters and data densities

Table 5.1 reports the posterior means of the estimated parameters, their 90% probability intervals and the log (marginal) data densities for both model versions. The following results stand out. For the model with sovereign risk (M_1), the inverse intertemporal substitution elasticity σ, the degree of price stickiness ϕ, and the degree of openness ϑ are broadly in line with existing estimates for small open economies (e.g. Justiniano and Preston, 2010b; Lubik and Schorfheide, 2007), but not entirely so for the model without sovereign risk (M_2). A striking result is that M_2 has a significantly higher σ than M_1. We provide an interpretation of this result below.

The estimated default elasticity Φ equals 0.29 in M_1, which implies that the expected default rate is highly debt-elastic. This result confirms findings of Budina and van Wijnbergen (2008) showing that higher debt service obligations of the Turkish government have led to stronger expectations that these debt obligations might not be met. Furthermore, both the inflation response in the monetary reaction function α_π and the tax feedback κ are larger in M_1 than in M_2. In line with these results, GMM estimates of the implicit reaction function of the CBRT by Berument and Malatyali (2000) indicate a relatively large response of nominal rates to inflation when the authors control for fiscal developments.[10]

Another striking result is that most of the standard deviations of the innovations are significantly larger in M_2, in particular the domestic demand innovations and government consumption innovations as well as the measurement errors on the real exchange rate. An exception is the standard deviation of the foreign debt share which is how-

[10] Berument and Malatyali's (2000) results are however not directly comparable to ours due to differences in the specification of the reaction function and the estimation sample.

ever not well identified in M_2. Finally, a formal model comparison clearly supports the model with sovereign risk. The Bayes factor in favor of M_1 relative to M_2 is $p(Y^T|M_1)/p(Y^T|M_2) = \exp(895.51 - 748.23)$ which is equal to 9.2×10^{63}, indicating strong support for M_1 over M_2 conditional on the observed data.

Default premia and effective interest rates

Why does M_1 provide such a better fit to the observed data than M_2? To gain an intuition, notice that combining equations (5.11) and (5.19) in Appendix 5.A and using $E_t\hat{z}_{t+1} = \rho\hat{z}_t$ yields the following representation of the households' consumption Euler equation:

$$\sigma(E_t\hat{c}_{t+1} - \hat{c}_t) = \hat{R}_{H,t} - E_t\hat{\pi}_{t+1} - (1-\bar{\delta})^{-1}E_t\tilde{\delta}_{t+1} - (1-\rho)\hat{z}_t. \qquad (5.10)$$

Suppose that expected consumption growth $E_t\hat{c}_{t+1} - \hat{c}_t$ shows "different" dynamics than the expected real interest rate $\hat{R}_{H,t} - E_t\hat{\pi}_{t+1}$. Indeed, according to both models, estimated consumption growth was low in the first half of the sample whereas the real interest rate was relatively high. Such dynamics could be reconciled with (5.10) in the following three ways:

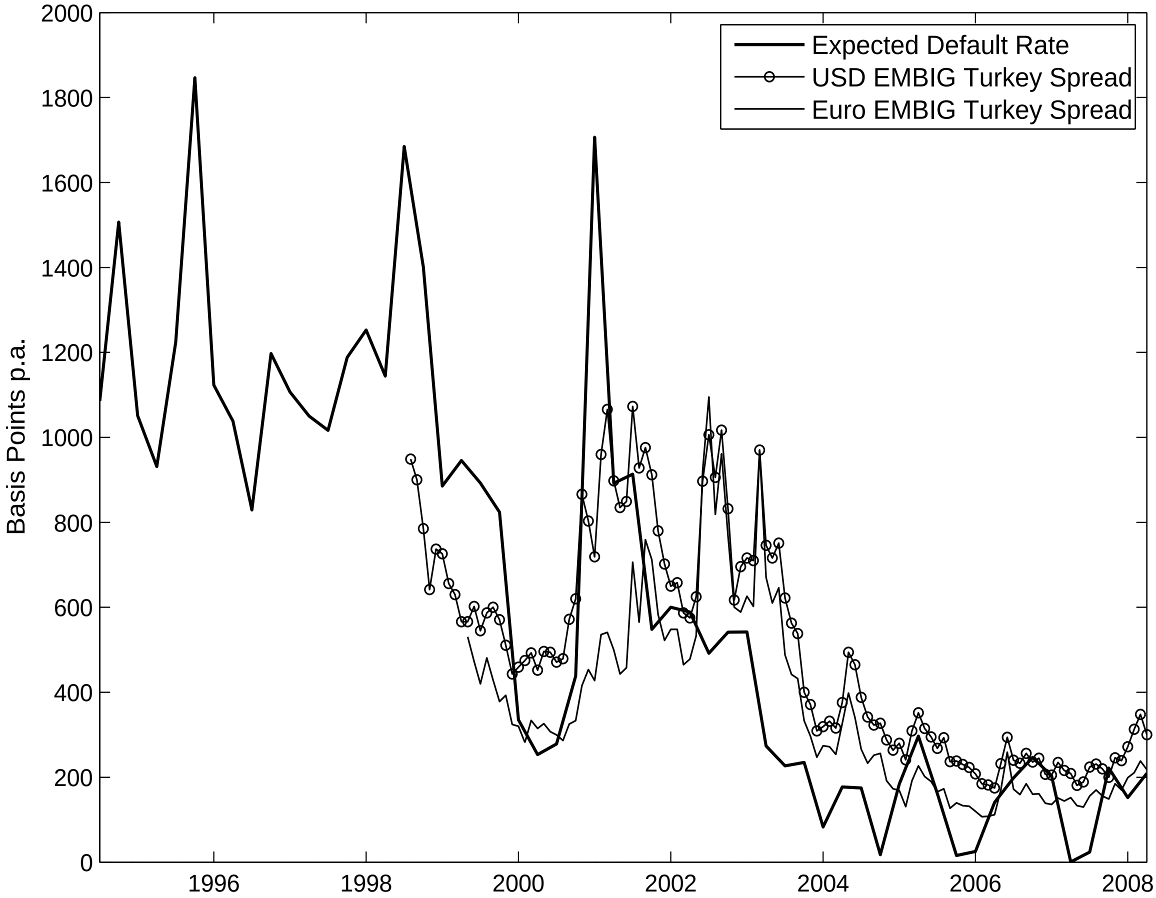
1) Suppose that $E_t\tilde{\delta}_{t+1} = 0$ for all t. With $1 - \rho > 0$, positive demand shocks $\hat{z}_t$ could make (5.10) hold if $E_t\hat{c}_{t+1} - \hat{c}_t$ is temporarily low relative to $\hat{R}_{H,t} - E_t\hat{\pi}_{t+1}$. Households would save less after a positive demand shock even if the real interest rate is high since they have a preference for temporarily higher consumption.

2) Alternatively, set both $E_t\tilde{\delta}_{t+1} = 0$ and $\hat{z}_t = 0$ for all t. A relatively large value on the inverse intertemporal substitution elasticity σ would increase the households' preferences for a smooth consumption path even if the real interest rate is not smooth.

3) A positive expected default rate can balance (5.10) with relatively small demand shocks and a moderate value of σ. Households would then invest less when the real interest rate is high due to stronger default fears, and vice versa.

All three explanations are relevant to understand our estimation results. First, according to the results for σ_z in Table 5.1, large demand shocks occur in M_2 whereas M_1 requires much smaller and less persistent shocks. Second, the estimated value of

Figure 5.1: Estimated expected default rate $E_t\delta_{t+1}$ and EMBIG Turkey spreads



Notes. The default rate is the estimate implied by the Kalman smoother at the posterior mean (1994Q3-2008Q2); 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 (08/1998-06/2008); "Euro" indicates spreads on euro denominated bonds and loans over German bunds (05/1999-06/2008).

σ is more than 8 times higher in M_2, generating a strong preference for consumption smoothing. Third, default premia were relatively high before Turkey's financial crisis in 2000-2001 but they have declined since then as can be seen from Figure 5.1 which plots the expected default rate $E_t\tilde{\delta}_{t+1}$ from M_1 implied by the Kalman smoother at the posterior mean (solid line). Therefore, the effective real interest rate net of default risk $\hat{R}_{H,t} - E_t\hat{\pi}_{t+1} - (1-\bar{\delta})^{-1}E_t\tilde{\delta}_{t+1}$ shows smoother dynamics than the actual real rate, which are easier to reconcile with the estimated path of expected consumption growth.

To gauge the plausibility of the magnitude and the dynamics of the estimated expected default rate, Figure 5.1 also plots 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.[11] There is a strong co-movement, although the EMBIG indicates smaller default premia before and during the 2000-2001 crisis and somewhat larger rates afterwards. The correlations between the model-implied default rate and (i) and (ii) are 0.74 and 0.59, respectively. The default premium implied by our model thus compares well with those alternative estimates of default risk in terms of their magnitude and dynamics.

Variance decomposition

To assess the importance of alternative structural shocks in driving the expected default rate and other selected variables, Table 5.2 reports their unconditional posterior variance decomposition. Regarding the default rate (M_1 only), economic shocks contribute 84 percent and policy shocks 16 percent to its variation. In M_1 most of the variation in consumption, output, debt, the nominal interest rate, and inflation is attributed to productivity shocks. In M_2, in line with the large estimated value of σ_z, domestic demand shocks explain almost all of the variation in consumption whereas foreign demand shocks explain most of the fluctuations of output, the interest rate, and inflation, while most of the fluctuations in government debt are explained by lump-sum tax shocks. The presence of default beliefs therefore leads to significant changes in the importance of particular shocks in driving the dynamics of the observed variables.[12]

Forecasting performance

Figure 5.2 compares selected observed variables and their one-step ahead forecasts implied by the two model versions. While both models seem to forecast output, consumption, and debt fairly well, it seems that M_1 generates better forecasts of inflation and the nominal interest rate. In particular, the interest rate forecasts produced by M_2 are excessively smooth compared to the observed data. Table 5.3 reports mean

[11] All variables are reported in basis points. The estimated expected default rate ($E_t\tilde{\delta}_{t+1}$) was converted into levels ($E_t\delta_{t+1}$) by adding the steady state value $\bar{\delta}$.

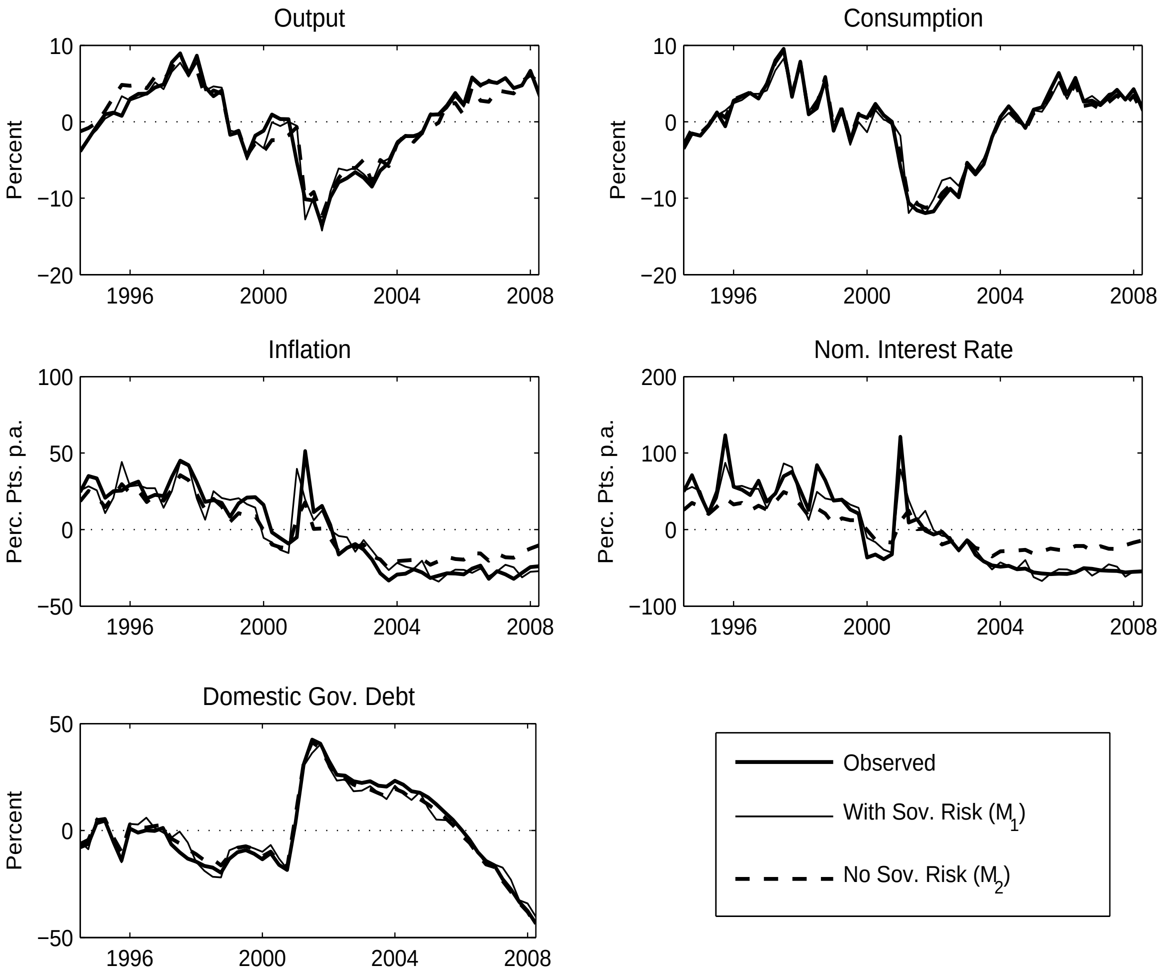
[12] Shocks to the foreign debt share only affect the division of government debt among foreign and domestic debt but not its overall level. Those shocks therefore do not have any impact on the default rate and thus also do not affect the remaining variables, which explains the zeroes in the row for ε_f in Table 5.2.

Table 5.2: Posterior variance decomposition[a]

	With sovereign risk (M_1)						*No sovereign risk (M_2)*				
	Def. rate	Output	Consum.	Inflation	Int. rate	Dom. debt	Output	Consum.	Inflation	Int. rate	Dom. debt
Economic shocks											
Productivity ε_a	77.1	96.8	76.1	79.7	79.0	67.8	4.5	0.2	35.7	25.6	2.5
Dom. demand ε_z	3.6	1.5	21.4	3.9	3.9	3.2	20.8	98.1	3.3	2.3	1.7
For. demand ε_{c^*}	2.0	0.2	0.8	1.9	1.8	1.7	43.4	1.1	38.1	27.3	22.2
For. prices ε_{π^*}	1.0	0.1	0.3	0.9	0.9	0.8	16.3	0.4	15.2	10.9	4.5
Total[b]	83.7	98.6	98.6	86.4	85.6	73.5	84.9	99.8	92.3	66.1	30.9
Policy shocks											
Int. rate ε_R	4.8	1.4	1.1	3.7	4.6	3.7	3.0	0.1	3.0	30.4	15.0
Gov. consum. ε_g	10.4	0.1	0.1	9.7	9.6	8.5	9.7	0.0	3.8	2.7	16.4
Lump-sum tax ε_τ	1.1	0.0	0.3	0.2	0.2	0.4	2.4	0.0	0.9	0.7	37.2
For. debt ε_f	0.0	0.0	0.0	0.0	0.0	13.9	0.0	0.0	0.0	0.0	0.5
Total[b]	16.3	1.5	1.5	13.6	14.4	26.5	15.1	0.1	7.7	33.8	69.1

[a] The table entries refer to the contribution of individual shocks to the unconditional variances (in percent) of observables at the posterior mean.
[b] Some of the totals do not sum up to 100% due to rounding errors.

Figure 5.2: Observed variables and their one-step ahead forecasts



Notes. Quarterly data, 1994:3-2008:2; one-step ahead forecasts are computed by the Kalman filter at the posterior mean; real variables are measured in percentage deviations from a linear trend, nominal variables are demeaned and in annualized percentage terms.

forecast errors (ME) and root mean squared forecast errors (RMSE) based on the one-step ahead forecasts. The RMSE are useful to judge the overall predictive performance of the two model versions. The ME help to judge whether any variable is repeatedly over- or underpredicted. The ME indicate that M_2 tends to overpredict the real exchange rate and underpredict government consumption. Both models tend to overpredict inflation and the nominal interest rate. Most of the RMSE are smaller for M_1, in particular the RMSE of the nominal interest rate, the real exchange rate, and government consumption. The RMSE of consumption is smaller in M_2, but recall that the

Table 5.3: One-step ahead forecast errors[a]

	Mean forecast error ME[b]		Root mean squared forecast error RMSE[c]	
	With sov. risk (M_1)	*No sov. risk* (M_2)	*With sov. risk* (M_1)	*No sov. risk* (M_2)
Output	-0.01	-0.03	1.05	1.57
Consumption	0.00	0.00	1.01	0.54
Inflation	0.14	0.11	10.07	9.79
Nom. interest rate	0.27	0.16	13.08	30.64
Domestic gov. debt	0.06	-0.05	3.52	2.45
Gov. consumption	0.00	-1.19	2.64	29.07
Real exch. rate	-0.05	0.40	11.20	15.89
For. consumption	0.03	0.02	0.27	0.28
For. inflation	-0.01	0.01	0.98	1.00

[a] The forecast errors F_t are computed as the difference between the observed variables Y_t and their one-step ahead forecasts Y_t^f as $F_t = Y_t - Y_t^f$, where Y_t and Y_t^f are measured in percent.
[b] The mean forecast errors are computed as $\text{ME} = T^{-1}\sum_{t=1}^{T} F_t$.
[c] The mean squared forecast errors are computed as $\text{RMSE} = (T^{-1}\sum_{t=1}^{T} F_t^2)^{1/2}$.

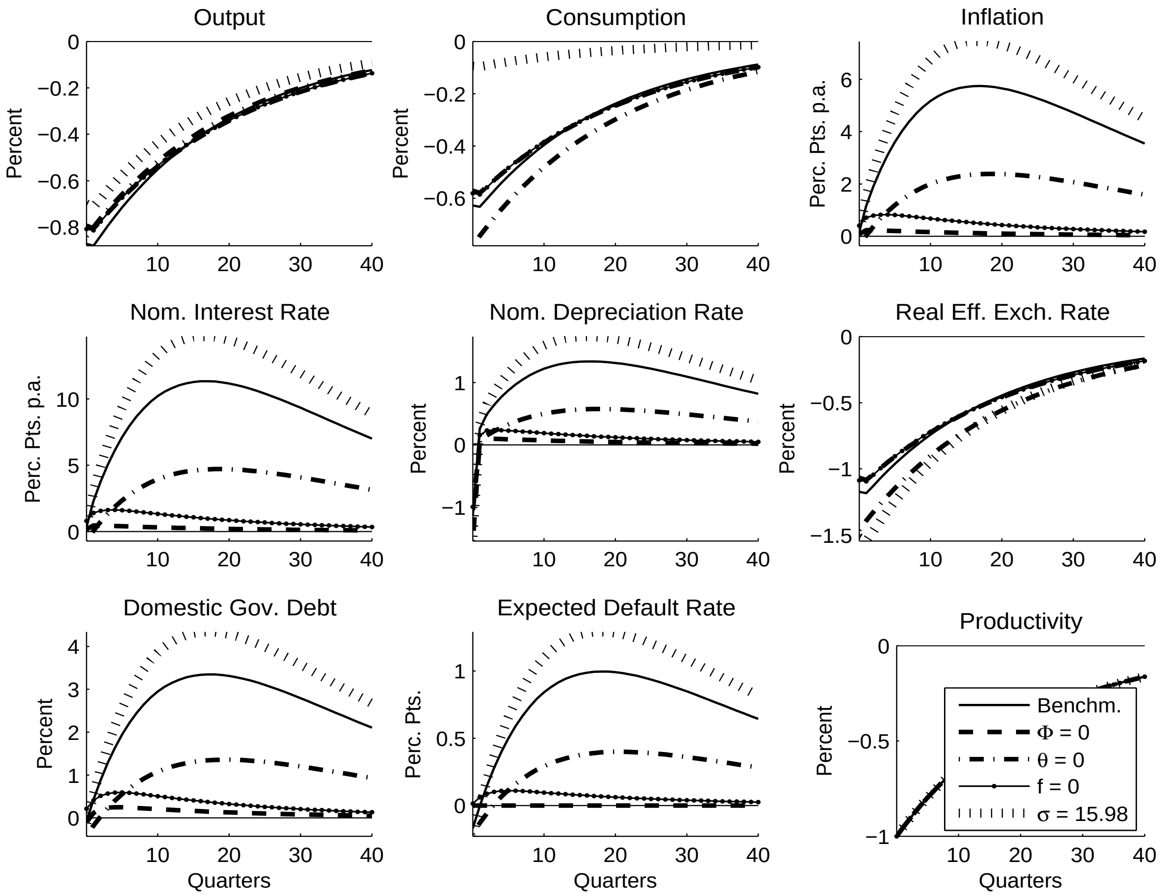
bulk of consumption fluctuations is driven by domestic demand shocks in that model, indicating empirical shortcomings of the basic consumption Euler equation. Overall, the model with sovereign risk thus performs better in terms of forecasting performance.

5.4.2 Amplification channels

We now describe several counterfactual experiments to isolate individual features of the model and to examine their importance in amplifying shocks. All of the following experiments are based on the estimated model with sovereign risk, which is referred to as the benchmark model: (i) the default elasticity Φ is set to zero, (ii) the degree of openness ϑ is set to zero, (iii) the foreign debt share $\bar{f}$ is set to zero, and (iv) the inverse intertemporal substitution elasticity σ is set to 15.98, its posterior mean in the model without sovereign risk. Figure 5.3 shows the impulse responses to a negative one percent productivity shock for the four experiments.

When the default elasticity Φ is set to zero (thick dashed line), Ricardian equivalence holds. The negative productivity shock causes a decline in output and a rise in intermediate goods firms' marginal costs, leading to an increase in prices and an ap-

Figure 5.3: Estimated and counterfactual impulse responses to a productivity shock



Notes. Based on model with sovereign risk; productivity shock is normalized to minus one percent; estimated impulse responses are calculated at the posterior mean and counterfactual impulse responses are calculated by changing one parameter at a time; real variables are measured in percentage deviations from steady state, nominal variables in absolute (annual) percentage point deviations from steady state.

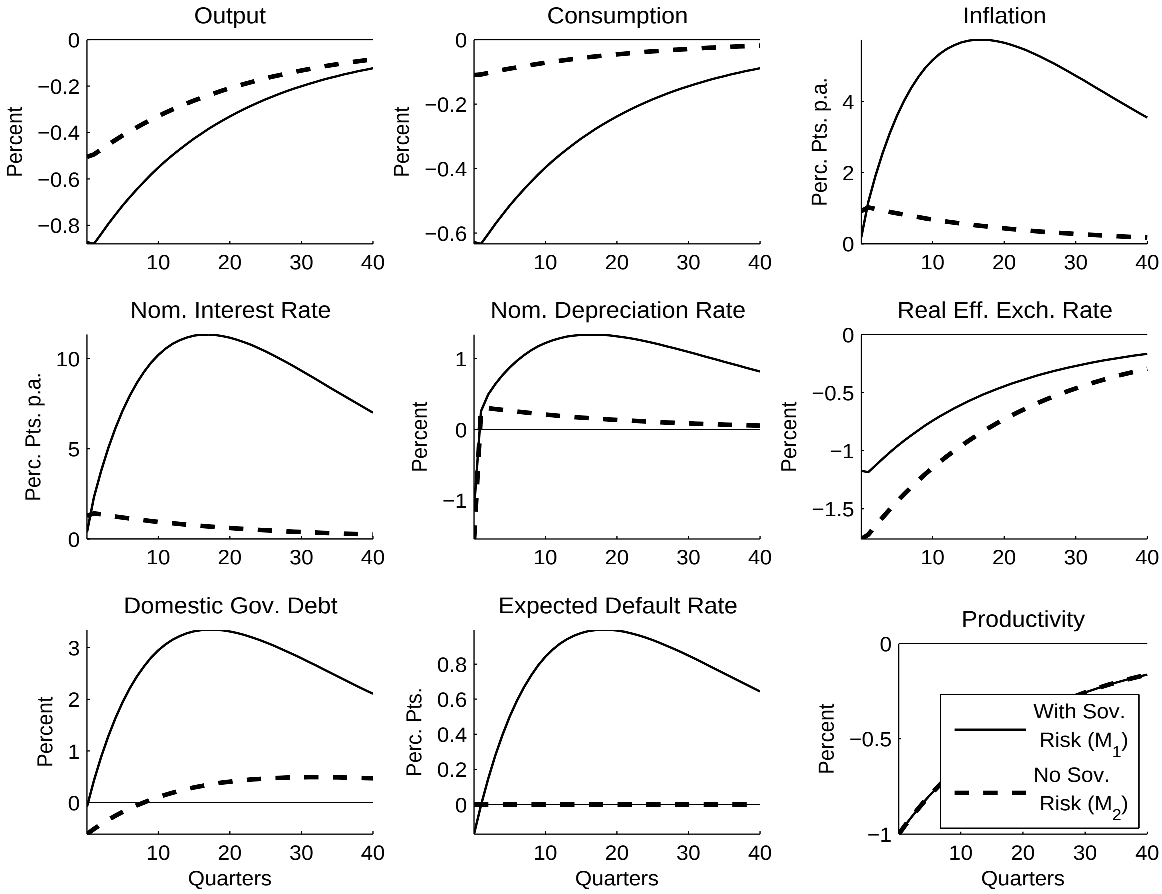
preciation of the real exchange rate. Domestic consumption falls due to international risk sharing and expenditure switching of domestic and foreign households. Domestic output therefore declines further. The monetary authority reacts to higher inflation by increasing the nominal interest rate. Government debt falls initially, due to the immediate beneficial exchange rate effect on foreign debt, but it rises afterwards due to higher debt service obligations resulting from higher interest rates.

In the benchmark model with a positive default elasticity (solid line) the real value of debt affects the expected effective rate of return to investors, which alters the dynamics through various channels. As before, higher inflation leads to higher nominal interest rates, higher debt service obligations, and higher debt. However, through the negative feedback from debt on its expected return savings tend to be lower and current consumption tends to be higher, leading to inflationary pressures. In order to contain inflation, the monetary authority raises the nominal interest rate by more than in experiment (i). Higher nominal rates in turn imply higher debt servicing costs and debt levels, further increasing expected default rates. The latter leads to additional inflationary pressures. The initial increase of inflation is thus amplified through the presence of default beliefs.

The exchange rate channel further enhances the inflationary pressures. The tendency of domestic current consumption to rise, resulting from the negative feedback from government debt on its return, feeds into pressure on the real exchange rate to depreciate through international risk sharing. A real depreciation would lead to expenditure switching of domestic households and increasing demand of foreign households for home goods. Moreover, domestic households would demand a higher nominal wage since the price level of aggregate consumption would rise due to higher prices of imported goods. To counteract these inflationary pressures, the monetary authority needs to raise the nominal interest rate even more. Conversely, in a closed economy (dashed-dotted line) the impact of the productivity shock on inflation and the nominal interest rate is significantly muted, such that the responses of government debt and the expected default rate are also smaller.

Similarly, without foreign currency denominated debt (solid line with dots) the effects on inflation, the nominal interest rate, and debt are smaller. In the absence of foreign debt, nominal depreciation does not trigger additional default beliefs due to debt revaluation. Moreover, the devaluing effect of higher domestic inflation on the stock of real debt is more pronounced if debt is only denominated in domestic currency. Finally, for high values of the inverse intertemporal substitution elasticity σ (bars) the response of consumption to an increase of the nominal interest rate is substantially muted since households have a strong preference for a smooth consumption path. The effectiveness of high nominal rates in containing inflationary pressures is reduced such that higher nominal rates are required. Higher nominal rates in turn imply higher debt and, again, higher expected default rates.

Figure 5.4: Estimated impulse responses to a productivity shock in both models



Notes. Productivity shock is normalized to minus one percent with persistence as estimated in the model with sovereign risk; impulse responses are calculated at the posterior mean; real variables are measured in percentage deviations from steady state, nominal variables in absolute (annual) percentage point deviations from steady state.

5.4.3 Estimated impulse responses

Having analyzed particular model features in isolation, we now compare the estimated impulse responses implied by the models with default risk (M_1) and without default risk (M_2). We focus again on the responses to a negative productivity shock which is normalized to have the persistence from M_1, i.e. we set $\rho_a = 0.96$. The dashed lines in Figure 5.4 show the impulse responses implied by M_2. The negative productivity shock causes a rise in inflation and a real appreciation. Domestic consumption and output fall. The monetary authority increases the nominal interest rate, government debt falls initially, and then shows a persistent increase due to higher debt service obligations resulting from higher interest rates.

In view of the counterfactuals above, the amplification of the responses of inflation, the nominal interest rate, and domestic debt implied by M_1 (solid line) can mainly be attributed to the presence of default beliefs. The different responses of output, consumption, and the real exchange rate seem to be mainly driven by the lower estimated substitution elasticity σ, which implies a more pronounced response of consumption to movements in the real effective interest rate. However, the effect on the real exchange rate is muted, since with a low σ fluctuations in domestic consumption only feed into small variations of the real exchange rate via international risk sharing. Finally, the higher estimated degree of openness further enhances the effects of default risk on nominal variables, government debt, and consumption.

5.4.4 Sensitivity checks

As a final step of the analysis, alternative versions of the benchmark model with default risk are estimated to check the sensitivity of the estimation results. The results are summarized in Table 5.4.

First, we introduce output and exchange rate stabilization terms in the monetary authority's reaction function to check whether the CBRT was targeting output and to capture the fact that before 2001 the CBRT's monetary policy strategy included nominal exchange rate targeting (see Gormez and lmaz, 2007). Thus (5.3) is replaced by the modified reaction function

$$R_{H,t}/R_H = (\pi_t/\pi)^{\alpha_\pi}(y_t/y)^{\alpha_y}(X_t/X_{t-1})^{\alpha_X}\exp(\varepsilon_{R,t}),$$

where X_t/X_{t-1} is the rate of nominal depreciation. We use uniform priors on the range $[-10, 10]$ for both the output feedback α_y and the exchange rate feedback α_X. While the estimated exchange rate feedback is fairly large (0.44), confirming that exchange rate stabilization was a concern of the CBRT, the estimated output feedback is close to zero (-0.01). The size of the inflation feedback α_π decreases compared to the benchmark model from 1.83 to 1.43, but the remaining parameter estimates do not change significantly. The data density falls, which suggests that the additional feedback terms

Table 5.4: Sensitivity of parameter estimates and data densities[a]

	Parameter	Prior[b]	Bench-mark model	Mod. mon. rule	Habit form-ation	Price index-ation	Smaller meas. error[b]	Max. likel. estim.
σ	Inv. subst. elast.	$U(0, 20)$	1.87	1.80	1.20	1.68	0.57	2.03
h	Habit formation	$U(0, 1)$	–	–	0.58	–	–	–
ϕ	Price stickiness	$U(0, 1)$	0.46	0.49	0.51	0.39	0.17	0.46
ι	Price indexation	$U(0, 1)$	–	–	–	0.47	–	–
ϑ	Openness	$U(0, 1)$	0.13	0.14	0.13	0.15	0.50	0.10
Φ	Default elasticity	$U(0, 10)$	0.29	0.29	0.26	0.31	0.28	0.31
α_π	Mon. infl. resp.	$U(0, 10)$	1.83	1.43	1.81	1.87	2.14	1.77
α_y	Mon. output resp.	$U(-10, 10)$	–	-0.01	–	–	–	–
α_X	Mon. ex. rate resp.	$U(-10, 10)$	–	0.44	–	–	–	–
κ	Tax debt resp.	$U(\kappa_L, 10)$	0.59	0.60	0.55	0.62	0.59	0.62
ρ_z	AR(1) demand	$U(0, 1)$	0.77	0.74	–	0.72	0.60	0.85
ρ_a	AR(1) productivity	$U(0, 1)$	0.96	0.95	0.97	0.94	0.92	0.97
ρ_g	AR(1) gov. cons.	$U(0, 1)$	0.44	0.44	0.48	0.46	0.58	0.40
ρ_f	AR(1) debt share	$U(0, 1)$	0.90	0.89	0.90	0.89	0.87	0.90
σ_z	Std. demand inn.	IG(0.05)	0.05	0.05	0.08	0.05	0.01	0.06
σ_a	Std. prod. inn.	IG(0.05)	0.03	0.03	0.03	0.03	0.02	0.03
σ_g	Std. gov. cons. inn.	IG(0.05)	0.04	0.04	0.04	0.04	0.04	0.04
σ_f	Std. debt share inn.	IG(0.05)	0.25	0.25	0.25	0.26	0.30	0.24
σ_τ	Std. tax inn.	IG(0.05)	0.07	0.07	0.07	0.08	0.09	0.07
σ_R	Std. int. rate inn.	IG(0.05)	0.06	0.07	0.06	0.06	0.07	0.06
σ_q	Std. meas. REER_t	IG(0.05)	0.11	0.11	0.11	0.11	–	0.11
$\sigma_{\tau,g}$	Corr. tax, gov. cons.	$U(-1, 1)$	0.79	0.79	0.74	0.78	0.51	0.90
	Log data density		895.51	889.90	891.19	895.91	862.77	–

[a] See Table 5.1 for details on the estimation and the parameterization of the prior distributions.
[b] For the specification with smaller measurement errors, the std. deviation σ_q is calibrated to 0.05.

do not improve the overall fit of the model.

Second, we check whether it matters if we drop the exogenous persistence mechanism in the domestic households' consumption Euler equation due to persistent demand shocks and add an endogenous persistence mechanism instead. In particular, we incorporate external habit formation in consumption, as in Adolfson et al. (2007) or Justiniano and Preston (2010a), and set $\rho_z = 0$ when estimating the model. The (domestic and foreign) households' preferences are modified accordingly:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\exp(\varepsilon_{z,t}) \frac{1}{1-\sigma} (c_t - h\breve{c}_{t-1})^{1-\sigma} - \frac{1}{1+\eta} n_t^{1+\eta} \right],$$

where $h \in (0, 1)$ and $\breve{c}_{t-1}$ denotes aggregate domestic consumption, which is taken as given by the individual households. We elicit a U$(0,1)$ prior on h in consistence with its theoretical domain. The first-order conditions for (domestic and foreign) consumption become $\lambda_t = \exp(\varepsilon_{z,t})\,(c_t - hc_{t-1})^{-\sigma}$ and $\lambda_t^* = (c_t^* - hc_{t-1}^*)^{-\sigma}$, where the equilibrium conditions $c_t = \breve{c}_t$ and $c_t^* = \breve{c}_t^*$ have been imposed for all t. Table 5.4 shows that, although h is fairly large with an estimated value of 0.58, the marginal data density falls and most parameters do not change significantly. The only exceptions are the substitution elasticity σ, which decreases from 1.87 to 1.20, and the volatility of demand shocks σ_z, which increases from five percent to eight percent.

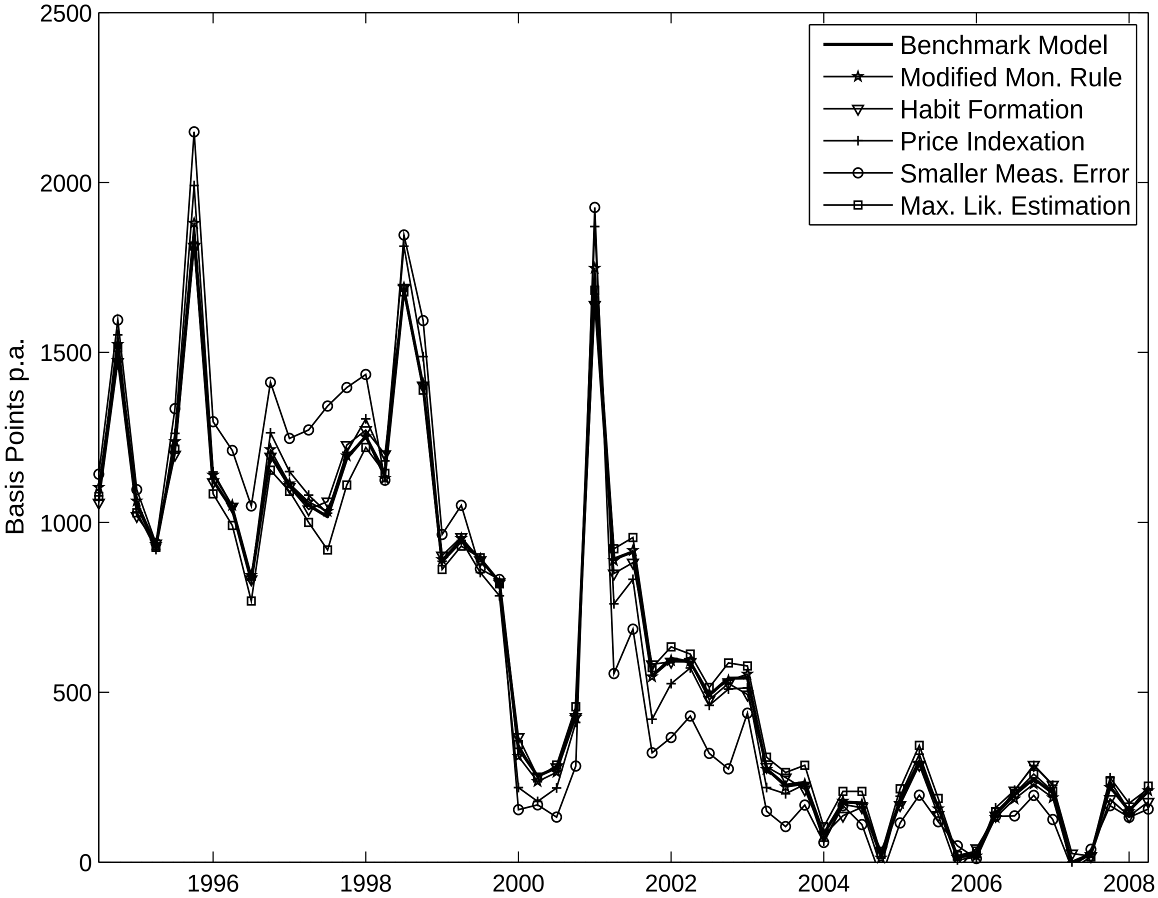
Third, to check whether incorporating an endogenous persistence mechanism for inflation affects our results, we allow for partial indexation to past and steady state producer price inflation following Smets and Wouters (2007). The firms of fraction ϕ that do not set prices optimally in period t are thus assumed to adjust prices according to the indexation rule $P_{H,t}^i = \check{P}_{H,t-1}(\pi_{H,t-1}^{\iota}\pi_H^{1-\iota})$, where $\iota \in [0,1]$ measures the degree of indexation to past producer price inflation. For $\iota = 0$ prices are fully indexed to the steady state inflation rate, as in the benchmark model, while for $\iota = 1$ prices are fully indexed to the previous period's inflation rate. Partial indexation leads to a modified log-linearized Phillips curve (5.16):

$$\hat{\pi}_{H,t} = (1-\phi)(1-\phi\beta)[\phi(1+\iota\beta)]^{-1}\widehat{mc}_t + \iota(1+\iota\beta)^{-1}\pi_{H,t-1} + \beta(1+\iota\beta)^{-1}E_t\hat{\pi}_{H,t+1}.$$

We elicit a U$(0,1)$ prior for ι in consistence with its theoretical domain. The estimated ι is positive but less than half (0.47) and the degree of price stickiness ϕ falls from 0.46 to 0.39, but the remaining estimates are stable. The data density increases by a few decimal points only. These results are in line with findings of Celasun, Gelos, and Prati (2004) indicating that the degree of inflation persistence induced by price indexation is comparably low in Turkey. Note that the estimated default elasticity Φ increases slightly such that default fears remain a relevant concern when controlling for backward-looking behavior in price setting.

Fourth, to gauge the importance of the measurement error on the real effective exchange rate, we calibrate its standard deviation σ_q to 0.05, i.e. its prior mean. Several estimates change, in particular the values of σ, ϕ, θ, and α_π, but the default

Figure 5.5: Estimated expected default rates $E_t\delta_{t+1}$ for alternative models



Note. Estimates implied by the Kalman smoother at the posterior mean.

elasticity does not change significantly. Finally, we estimate the benchmark model by constrained maximum likelihood (ML), restricting the model parameters on their theoretically feasible range according to the domains in Table 5.1. The ML results are broadly similar to the Bayesian estimation results. The default elasticity is again highly debt-elastic with an estimated value of 0.31.

The estimated expected default rates from all estimated versions of the model are plotted in Figure 5.5. The results are very similar across models, the only exception being the model where σ_q is not estimated. Even in this case the estimated default rate does however show a strong correlation with the estimate from the benchmark model. Overall, the estimation results thus seem robust to various changes in the specification of the model and its empirical implementation.

5.5 Conclusion

This chapter has set up an empirical DSGE model of a small open economy where a perceived risk of sovereign debt default leads to a time-varying default premium on government bonds in domestic and foreign households' consumption Euler equation. The default premium is linked to the stock of total government debt. We use the model to match Turkish time series data showing remarkable fluctuations in inflation, nominal interest rates, and government debt.

Our results show that the introduction of sovereign default risk helps to explain business cycles in Turkey in important ways. The presence of default beliefs not only amplifies the fluctuations of nominal variables and government debt, and thus helps to explain the high volatility of these variables, but also introduces a mutual link between the persistence of nominal variables and the persistence of government debt. Key to understand the improved fit is the consumption Euler equation for investments in government bonds. The time-varying default premium helps to reconcile the observed interest rate movements with expected consumption growth and inflation by reducing the effective rate of return on investing in government bonds.

To sum up, this chapter has shown that it is possible to build a realistic NOEM model to explain macroeconomic fluctuations in an emerging market economy where sovereign default risk is a relevant concern. We conclude by noting that there is empirical evidence that the relationship between government debt and default premia also contains non-linear elements (e.g. Bayoumi, Goldstein, and Woglom, 1995), such that the estimation approach used in this paper may only provide an incomplete picture of the link between sovereign risk and business cycle dynamics. Implementing empirical DSGE models with fiscal sustainability concerns by non-linear estimation procedures would therefore be a useful direction for future research.

5.A Equilibrium conditions

This appendix contains the extensive representation of the symmetric equilibrium conditions. The log deviation and absolute deviation of a variable x_t from its non-stochastic steady state value x are denoted by $\hat{x}_t$ and $\tilde{x}_t$, respectively. Variables with bars denote steady state values that are taken as given.

Households:

$$\hat{\lambda}_t = \hat{z}_t - \sigma \hat{c}_t, \tag{5.11}$$

$$\eta \hat{n}_t = \hat{\lambda}_t + \hat{w}_t, \tag{5.12}$$

$$\hat{\lambda}_t^* = -\sigma \hat{c}_t^*. \tag{5.13}$$

Production and pricing:

$$\hat{y}_{H,t} = \hat{a}_t + \hat{n}_t, \tag{5.14}$$

$$\widehat{mc}_t = \frac{\vartheta}{1-\vartheta}\hat{q}_t + \hat{w}_t - \hat{a}_t, \tag{5.15}$$

$$\hat{\pi}_{H,t} = \frac{(1-\phi)(1-\phi\beta)}{\phi}\widehat{mc}_t + \beta E_t \hat{\pi}_{H,t+1}, \tag{5.16}$$

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \frac{\vartheta}{1-\vartheta}(\hat{q}_t - \hat{q}_{t-1}). \tag{5.17}$$

Capital market:

$$\hat{\lambda}_t^* = \hat{q}_t + \hat{\lambda}_t, \tag{5.18}$$

$$\hat{\lambda}_t = E_t \hat{\lambda}_{t+1} + R_{H,t} - E_t \hat{\pi}_{t+1} - \frac{1}{1-\bar{\delta}} E_t \tilde{\delta}_{t+1}, \tag{5.19}$$

$$\hat{\lambda}_t^* = E_t \hat{\lambda}_{t+1}^* + \hat{R}_{F,t} - E_t \hat{\pi}_{t+1}^* - \frac{1}{1-\bar{\delta}} E_t \tilde{\delta}_{t+1}, \tag{5.20}$$

$$E_t \tilde{\delta}_{t+1} = \Phi\left(1-\bar{\delta}\right)\left(1+\bar{f}\right) E_t \hat{b}_{t+1}. \tag{5.21}$$

Policy:

$$\hat{q}_t + \hat{b}_{F,t} - \hat{R}_{F,t} = \hat{f}_t + \hat{b}_{H,t} - \hat{R}_{H,t}, \tag{5.22}$$

$$\left(1+\bar{f}\right)\hat{b}_t = \hat{b}_{H,t-1} - \hat{\pi}_t + \bar{f}\left(\hat{q}_t + \hat{b}_{F,t-1} - \hat{\pi}_t^*\right), \tag{5.23}$$

$$\begin{aligned} \hat{b}_{H,t} - \hat{R}_{H,t} + \bar{f}\left(\hat{q}_t + \hat{b}_{F,t} - \hat{R}_{F,t}\right) &= \frac{\kappa + \beta\left(1-\bar{\delta}\right) - 1}{\beta\left(1-\bar{\delta}\right)(1+\bar{f})^{-1}}\left(\hat{g}_t - \frac{\vartheta}{1-\vartheta}\hat{q}_t\right) \\ &\quad + \frac{(1-\kappa)(1+\bar{f})}{\beta\left(1-\bar{\delta}\right)}\hat{b}_t - \varepsilon_{\tau,t} \end{aligned} \tag{5.24}$$

$$\hat{R}_{H,t} = \alpha_\pi \hat{\pi}_t + \varepsilon_{R,t}. \tag{5.25}$$

Market clearing:

$$\begin{aligned} \hat{y}_{H,t} &= (1-\vartheta)\,\bar{s}_c\hat{c}_t + [1-(1-\vartheta)\,\bar{s}_c - \bar{s}_g]\,\hat{c}_t^* \\ &\quad + \left(\vartheta\bar{s}_c + \frac{1-(1-\vartheta)\,\bar{s}_c - \bar{s}_g}{1-\vartheta}\right)\hat{q}_t + \bar{s}_g\hat{g}_t. \end{aligned} \tag{5.26}$$

Stochastic processes:

$$\hat{z}_t = \rho_z\hat{z}_{t-1} + \varepsilon_{z,t}, \tag{5.27}$$

$$\hat{a}_t = \rho_a\hat{a}_{t-1} + \varepsilon_{a,t}, \tag{5.28}$$

$$\hat{g}_t = \rho_g\hat{g}_{t-1} + \varepsilon_{g,t}, \tag{5.29}$$

$$\hat{f}_t = \rho_f\hat{f}_{t-1} + \varepsilon_{f,t}, \tag{5.30}$$

$$\begin{aligned} \rho_{0*}^{cc}\hat{c}_t^* &= \rho_{1*}^{cc}\hat{c}_{t-1}^* + \rho_{1*}^{c\pi}\hat{\pi}_{t-1}^* + \rho_{2*}^{cc}\hat{c}_{t-2}^* + \rho_{2*}^{c\pi}\hat{\pi}_{t-2}^* \\ &\quad + \rho_{3*}^{cc}\hat{c}_{t-3}^* + \rho_{3*}^{c\pi}\hat{\pi}_{t-3}^* + \rho_{4*}^{cc}\hat{c}_{t-4}^* + \rho_{4*}^{c\pi}\hat{\pi}_{t-4}^* + \varepsilon_{c^*,t}, \end{aligned} \tag{5.31}$$

$$\begin{aligned} \rho_{0*}^{\pi\pi}\hat{\pi}_t^* + \rho_{0*}^{\pi c}\hat{c}_t^* &= \rho_{1*}^{\pi\pi}\hat{\pi}_{t-1}^* + \rho_{1*}^{\pi c}\hat{c}_{t-1}^* + \rho_{2*}^{\pi\pi}\hat{\pi}_{t-2}^* + \rho_{2*}^{\pi c}\hat{c}_{t-2}^* \\ &\quad + \rho_{3*}^{\pi\pi}\hat{\pi}_{t-3}^* + \rho_{3*}^{\pi c}\hat{c}_{t-3}^* + \rho_{4*}^{\pi\pi}\hat{\pi}_{t-4}^* + \rho_{4*}^{\pi c}\hat{c}_{t-4}^* + \varepsilon_{\pi^*,t}, \end{aligned} \tag{5.32}$$

where $\bar{s}_c$ and $\bar{s}_g$ denote the ratios of private consumption and government consumption over GDP, respectively.

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

$$\{\hat{c}_t, \hat{c}_t^*, \hat{\lambda}_t, \hat{\lambda}_t^*, \hat{z}_t, \hat{n}_t, \hat{w}_t, \hat{a}_t, \hat{y}_{H,t}, \widehat{mc}_t, \hat{q}_t, \hat{\pi}_{H,t}, \hat{\pi}_t, \hat{\pi}_t^*, \hat{b}_t, \hat{b}_{H,t}, \hat{b}_{F,t}, \hat{f}_t, \hat{g}_{t,}, \hat{R}_{H,t}, \hat{R}_{F,t}, \tilde{\delta}_t\}_{t=0}^{\infty}$$

satisfying (5.11)-(5.32) and the transversality conditions, for given initial asset endowments $B_{H,-1}$, $B_{F,-1}$, and S_0 and initial price levels $P_{H,-1}$ and $P_{F,-1}$. The i.i.d. innovations are given by $\{\varepsilon_{z,t}, \varepsilon_{a,t}, \varepsilon_{f,t}, \varepsilon_{g,t}, \varepsilon_{R,t},\ \varepsilon_{\tau,t}, \varepsilon_{c^*,t}, \varepsilon_{\pi^*,t}\}_{t=0}^{\infty}$.

5.B Detailed data description

This appendix provides details on data sources, definitions and the construction of foreign variables. The data is seasonally adjusted and the consumer price index is used to construct real variables with base year 1998, if they are only available in nominal terms from the original source.

The domestic variable definitions and their sources are as follows:

- GDP_t: Real gross domestic product, CBRT.
- CONS_t: Real private consumption expenditure, CBRT.
- GOV_t: Real government consumption expenditure, CBRT.
- DEBT_t: Domestic debt position of the treasury, CBRT.
- INT_t: Annual net interest rate for 3-month treasury bills, constructed from data obtained from the CBRT; if 3-month bills were not issued in some quarter, we use the closest maturity available.
- INF_t: Annualized rate of change of the quarterly CPI, State Institute of Statistics Turkey.
- REER_t: Real CPI-based effective exchange rate, OECD main economic indicators.

The foreign variables are constructed from euro area real private consumption and the annual inflation rate according to the HICP index obtained from the AWM database (Fagan, Henry, and Mestre, 2005), and real U.S. personal consumption and the CPI-based U.S. inflation rate (all urban sample, all items) obtained from the BEA. Aggregate foreign consumption CONS_t^* and foreign inflation INF_t^* are computed according to the trade weights in the basket targeted by the CBRT during the exchange rate targeting period (see Gormez and lmaz, 2007). That is, the euro area obtains a weight of 0.77 and the U.S. obtains a weight of one.