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A Bayesian Estimation of Real Business-Cycle Models for the Turkish Economy

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Abstract

We estimate a canonical small open economy real business-cycle model and its several extensions using a Bayesian approach to explore the effects of different structural shocks on macroeconomic fluctuations in Turkey. Alternative models include several theoretical exogenous shocks, such as those to temporary and permanent productivity, world interest rates, preferences, and domestic spending, as driving forces together with financial frictions. Results indicate that output is mostly driven by trend growth shocks, while temporary shocks are relatively less important. Although empirical results generally favor the stochastic trend model, in which there are only transitory and permanent productivity shocks as causative elements, an extended model with random world interest rates and various financial frictions can be a viable alternative to explain economic fluctuations.

JEL Codes: C11, E32, F40

Keywords: Real business-cycle models, financial frictions, Turkey, small open economy, emerging economies.

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1. Introduction

The sources of economic fluctuations in emerging economies have received considerable attention in the recent literature. As compared to developed economies, emerging economies tend to have more volatile consumption and income patterns, with countercyclical current accounts marked by frequent capital-flow reversals known as "sudden stops." Moreover, real interest rates are more volatile and counter-cyclical in emerging economies, as documented by several studies (e.g., Neumeyer and Perri, 2005; Aguiar and Gopinath, 2007). Based on the general framework of Mendoza (1991), a myriad of models have been proposed in the current literature that are capable of producing these stylized facts. However, these models are generally applied to data from emerging economies in Latin America.

This paper aims to provide an empirical contribution to the literature on the sources of economic fluctuations in emerging economies by estimating the standard stochastic growth model and its extensions/modifications using Turkish macroeconomic data. In our analysis, we incorporate several shocks that have been identified in the recent literature as major driving forces. In particular, the standard small open-economy model is augmented to encompass shocks to temporary and permanent productivity, world real interest rates, country-risk premiums, domestic spending, and preferences. We implement a specific-to-general methodology: we start with the stochastic model, incorporating only temporary and permanent productivity shocks—since that value has the smallest number of shocks—and then extend the model to include additional shocks. We also examine whether a model considering world interest-rate shocks and temporary productivity shocks coupled with financial frictions can explain Turkish economic fluctuations without adding the non-stationary productivity shocks.

We implement a Bayesian estimation procedure for the structural parameters of the model with Turkish data for two periods: one from the first quarter of 1988 to the fourth quarter of 2013, the other from the first quarter of 2002 to the third quarter of 2013. Alternative models are compared for marginal likelihoods and for their ability to replicate unconditional second moments of key macroeconomic aggregates. We also conduct a variance-decomposition analysis to assess the role played by these shocks in determining business-cycle fluctuations. The paper is organized as follows: after a brief survey of the related literature in Section 2, we present alternative models in Section 3. Section 4 sketches the Bayesian estimation procedure. Data, including calibration information, are provided in Section 5. Section 6 presents the empirical results for the full sample. Section 7 lists the empirical results for the subsample covering the period from the first quarter of 2002 to the third quarter of 2013. Section 8 compares the results of two different periods and concludes the study.

2. Literature Review

Recent empirical studies have analyzed the issue within the general framework of Mendoza (1991), who developed a small open-economy real business-cycle model and applied it to the Canadian economy. One of the main results of Mendoza (1991) is that the world interest shock plays a minor role in business cycles. The canonical open-economy real business-cycle (RBC) model of Mendoza (1991) has been elaborated on in several dimensions by incorporating other exogenous shocks. Following Mendoza (1991), Correia, Neves, and Rebelo (1995) applied the real business-cycle model to a small open economy, Portugal. In this model, the effects of three shocks—world interest rates, productivity, and government expenditure—were investigated. According to the results, productivity shocks are more important than other shocks.

External financial factors' contribution to business-cycle movements in emerging economies has also been emphasized by several studies. Calvo, Leiderman, and Reinhart (1993) set up a model for 10 Latin American countries to investigate whether such fluctuations are dominated by domestic or foreign shocks. They found foreign interest-rate shocks are key factors for the disruptions in 10 Latin American countries. In addition, the role of real interest rates and financial frictions in shaking up an economic system are also studied in emerging economies.

Neumeyer and Perri (2005) show that real interest rates are countercyclical and that they lead the business cycles in emerging economies. Moreover, as stated in Neumeyer and Perri (2005), there is a strong correlation between real interest rates and the ups and downs of emerging economies. To the role of interest rates, they add "working-capital constraint" to modify the real business-cycle model, as suggested by Oviedo (2005). Neumeyer and Perri assume that firms have to borrow a pre-determined amount in advance to finance their payrolls. If there is a working-capital constraint in the economy, real interest-rate shocks will impact the firm's hiring decisions and thus its labor costs.

Besides working-capital requirements, they assume that the domestic interest rate in emerging economies is a function of both the world interest rate and a country-risk premium. In their model, the world interest rate is expressed as an international gross real interest rate, while the risk premium is expressed as a gross spread over the international real interest rate. Thus, the domestic interest rate may differ from the international interest rate due to the risk premium. They find that the model with a country-induced risk premium connected with domestic fundamentals performs better than the model without a risk premium. Another result of theirs is that the model generates countercyclical real interest rates when the working-capital constraint is added to it. However, if the model is simulated without a working-capital constraint, interest rates are procyclical.

The role of risk premium is also discussed in Uribe and Yue (2006), who underlined country-risk premiums, world interest rates, and financial frictions in explaining fluctuations in emerging economies. They find that real interest-rate shocks—both domestic and worldwide—affect domestic real variables with one period lag. Based on a variance-decomposition exercise, they conclude that shocks to the US interest rate bring about instability in emerging economies to a greater degree than do any shocks to the domestic interest rate.

Another paper considering the effects of world interest-rate shocks on business cycles is that of Lubik and Teo (2005). Using Bayesian techniques, they estimate an RBC model with terms-of-trade, world real interest-rate, and productivity shocks for five countries. Their findings indicate that the terms of trade shocks have a relatively minor effect, whereas world real interest rates and productivity have more influence.

In an attempt to explain the lost decade of the 1980s, Kydland and Zarazaga (2002) came up with an RBC model for Argentina and found that the standard RBC model was successful in explaining it. In an influential paper, Aguiar and Gopinath (2007) extended this by considering both permanent and transitory productivity shocks. They pointed out that, in contrast to developed economies, emerging economies tend to have more volatile long-run growth rates and countercyclical current accounts. Their empirical results suggested that an RBC model with a permanent productivity shock could explain business-cycle features in an emerging economy (Mexico).

However, their interpretation has been challenged by Garcia Cicco et al. (2010), as well as Chang and Fernandez (2010, 2013). The latter argued instead for an augmented RBC model with interest-rate shocks and financial frictions, in addition to the two productivity shocks: they claimed this offered a superior explanation for Mexico's economic travails. For their part, Garcia Cicco et al. (2010) maintain that the standard RBC model fails to capture observed characteristics of macroeconomic variables and produces a near random-walk behavior in the trade balance. They propose an alternative model, one in which three additional exogenous shocks account for the fluctuations in consumer preferences, country-risk premiums, and aggregate domestic spending. They conclude that their augmented RBC model is superior for replicating stylized facts about Mexico and Argentina.

Discussions in the literature predominantly focus on data from Mexico and Argentina. The number of studies focusing on other emerging economies is rather low. Among these, Araujo (2012) analyzes the sources of economic changes in Brazil and concludes that the model with investment-specific shocks is more precise than the standard two-shock RBC model. Bolanos and Wishart (2012) estimate the standard and extended RBC models using data from 12 emerging and 12 developed small open economies. They report that permanent productivity shocks are relatively more powerful in emerging economies, and the addition of financial frictions to the mix improves the fit of the model. Bhattacharya et. al. (2013) run the canonical RBC model with productivity shocks and terms-of-trade shocks for the Indian economy. They find that when the terms-of-trade shocks are put into the model, business-cycle volatility decreases, and the model does well in matching the features of the data by replicating the higher relative-consumption volatility and the countercyclical trade balance.

The number of studies focusing on the Turkish economy is also small. Özbilgin (2009) investigates the effects of financial-market participations on a standard open-economy real business-cycle model for the Turkish economy for the period from 1987 to 2004. Özbilgin (2009) emphasizes that the model gets better results than the standard RBC model; it generates higher consumption volatility, and the trade-balance-output correlation is in line with the data. Tiryaki (2010) investigates the effects of interest rates on the Turkish economy and states that the gyrations in the country's spread account for less than 9% percent of output volatility; moreover, the volatility of macroeconomic variables changes with the working-capital requirement parameter and the persistence of the productivity shocks. Taştan (2013) offers an augmented RBC model, with Bayesian methods that is inspired by Garcia Cicco et al. (2010) and incorporates data from Turkey's post-liberalization period. His results imply that the extended model, complete with financial frictions and additional shocks, is relatively more successful than the standard RBC model.

3. Alternative Models

The standard small open-economy real business-cycle model was developed by Mendoza (1991). Given the empirical failures of this model, Aguiar and Gopinath (2007) extended it with random labor-augmenting growth. Other permutations of the standard model include interest-rate shocks and financial frictions, as discussed in Neumeyer and Perri (2005) and Uribe and Yue (2006). Stochastic trends and financial frictions are embedded and estimated in Chang and Fernandez (2010) as well. In this section, we briefly discuss these models.

3.1 The Stochastic Trend Model

The production technology for the final good is given by

$$Y_t = a_t F(K_t, \Gamma_t h_t) = a_t K_t^{1-\alpha} (\Gamma_t h_t)^{\alpha} , \quad (1)$$

where Y_t denotes output, K_t denotes capital, h_t denotes hours worked, α is the labor's share of income, and F is a neo-classical production function. a_t is a shock to total factor productivity, and Γ_t allows for labor- augmenting productivity growth. The capital letters represent variables that have trends in equilibrium, and the lower -case letters represent variables with no trend in equilibrium. The total productivity shock is assumed to follow a stationary first- order autoregressive process in logarithms. That is,

$$log a_t = \rho_a log a_{t-1} + \varepsilon_t^a, \quad (2)$$

where $|\rho_a| < 1$ and $\varepsilon_t^a \sim iid\, N(0, \sigma_a^2)$. Labor-augmenting productivity growth is assumed to follow a stochastic trend with

$$\Gamma_t = g_t \Gamma_{t-1}, \quad (3)$$

where g_t is the gross growth rate of the Γ_t. It is assumed that the natural logarithm of g_t follows a first-order autoregressive process:

$$\ln(g_{t+1}/\mu) = \rho_g \ln(g_t/\mu) + \varepsilon_{t+1}^g, \quad (4)$$

with $|\rho_g| < 1$ and $\varepsilon_t^g \sim iid\, N(0, \sigma_g^2)$. μ represents the long-run mean growth rate of labor productivity. Note that a positive growth shock implies a permanently higher level of output. This, in turn, implies higher levels of permanent consumption, leading to less savings and current-account deficits.

The representative household faces the following budget constraint:

$$W_t h_t + u_t K_t + q_t D_{t+1} = C_t + I_t + D_t, \quad (5)$$

where W_t denotes the wage rate, u_t denotes the rental rate of capital, C_t denotes consumption, I_t denotes investment, q_t is the time t price of debt, while D_{t+1} is the stock of debt issued in period t. The capital accumulation can be written as

$$K_t = (1-\delta)K_t + I_t - \frac{\phi}{2}(\frac{K_{t+1}}{K_t} - \mu)^2, \quad (6)$$

where δ represents the rate of depreciation. The last term allows for quadratic capital-adjustment costs, and ϕ is the adjustment-cost parameter.

The representative household maximizes the expected utility function given by

$$E\sum_{t=0}^{\infty}\beta^t U(C_t, h_t, \Gamma_{t-1}) = E\sum_{t=0}^{\infty}\beta^t \frac{(C_t - \tau\Gamma_{t-1}h_t^{\omega})^{1-\sigma}}{1-\sigma} \quad (7)$$

where β is the discount factor, *U (.)* denotes the utility function, and *E* is the expectation operator. Households try to maximize the utility function subject to the production function, budget constraint, and the capital accumulation.

The interest rate (the inverse of q_t) on foreign borrowing for the households in this model can be written as follows:

$$\frac{1}{q_t} = R^* + \psi\left[exp\left(\frac{\widetilde{D}_{t+1}}{\Gamma_t} - \bar{d}\right) - 1\right] \quad (8)$$

where R^* denotes the constant world interest rate, and $\widetilde{D}_{t+1}$ is the country's external debt, which is equal to the household's debt D_{t+1} in equilibrium (Garcia-Cicco et al., 2010, Taştan, 2013). Households take $\widetilde{D}_{t+1}$ as exogenous. $\bar{d}$ denotes the steady-state level of normalized debt. It is assumed that the interest rate borne by households is sensitive to the total debt in order to ensure that there is a well-defined non-stochastic steady state. As shown by Schmitt-Grohe and Uribe (2003), the specification in the interest-rate equation guarantees that the steady state is well defined and independent of initial conditions.

3.2 The Financial-Friction Model

Random world interest rates and financial frictions are prime factors in pushing the business cycles in emerging countries. In these countries, economic booms are generally associated with cheap foreign credit. Additionally, as the country-risk premium increases, foreign capital stops flowing in, resulting in a current-account crisis (the so-called "sudden stop" phenomenon of Calvo (1998)). The theoretical framework proposed in Neumeyer and Perri (2005) and Uribe and Yue (2006) is designed to reproduce these stylized facts in emerging economies. The interest rate on foreign borrowing for the households (8) can be modified for the financial-friction model as follows:

$$\frac{1}{q_t} = R_t + \psi \left[exp\left(\frac{D_{t+1}}{\Gamma_t} - d\right) - 1\right], \tag{9}$$

where R_t is the country-specific interest rate, which is given as

$$R_t = S_t R_t^*, \tag{10}$$

where R_t^* is the world interest rate and S_t is the country-specific spread. In this model, the world interest rate is random and follows a stationary first-order autoregressive process in logarithms:

$$\ln(R_t^*/R^*) = \rho_R \ln(R_{t-1}^*/R^*) + \varepsilon_t^R, \tag{11}$$

where R^* is the world interest rate's long-run value and $|\rho_R| < 1$ with $\varepsilon_t^R \sim iid\ N(0, \sigma_R^2)$.

The process for the country-specific spread (S_t) can be written as follows:

$$\log(S_t/S) = -\eta E_t log\ a_{t+1}. \tag{12}$$

In this formulation, the country spread is in deviation form from its long-run level, and it depends on the expected future productivity.

Another financial friction is the so-called "working-capital requirement" proposed by Oviedo (2005), in which a fraction of the wage bill must be financed by companies. This friction was developed by Neumeyer and Perri (2005), in which the equilibrium in the labor market can be written in the following form:

$$W_t[1 + \theta(R_{t-1} - 1)] = a_t F_2(K_t, \Gamma_t h_t)\Gamma_t. \tag{13}$$

In this specification, world interest rates have direct effects on production by affecting the cost of labor.

3.3 The Encompassing Model

The stochastic trend and financial-friction models are generally tested separately in the real business-cycle model literature. Chang and Fernandez (2010) evaluate these two models within a framework they call the "encompassing model." The encompassing model differs from the stochastic model in two dimensions. First, it includes financial frictions and working-capital requirements. The spread is embedded in the parameter η, and working-capital requirements are assigned tothe parameter θ. Second, the spread is affected not only by the transient technology shocks, as in the stochastic growth version, but also by the permanent shocks in the encompassing model. An endogenous spread is introduced on the grounds that the default risk can fall with expected productivity, and the type of shock does not matter. The country spread is formulized as follows:

$$log(S_t/S) = -\eta E_t log(SR_{t+1}/SR) \tag{14}$$

where SR_t is the Solow residual, $SR_t = a_t g_t^a$. SR is the mean value of the Solow residual and can be written as SR $=\mu^{\alpha}$. In this model, "it is assumed that the spread is given by (12), except that the temporary productivity shock a_{t+1} is replaced by the total factor productivity (Solow Residual)" (Chang and Fernandez (2010), p. 10).

3.4 The Augmented RBC Model

Following Garcia-Cicco et al. (2010), we augment the encompassing model with preference shock and domestic-spending shock. In this model, a representative household maximizes

$$E_0 \sum_{t=0}^{\infty} \epsilon_t \left(\frac{(C_t - \tau \Gamma_{t-1} h_t^{\omega})^{1-\sigma}}{1-\sigma} \right), \tag{15}$$

subject to the budget constraint:

$$W_t h_t + u_t K_t + q_t D_{t+1} = C_t + I_t + D_t + B_t, \tag{16}$$

where ϵ_t denotes preference shock, and B_t denotes domestic-spending shock. It is assumed that preference and domestic-spending shocks follow a stationary AR (1) process:

$$log(\epsilon_{t+1}) = \rho_\epsilon \log(\epsilon_t) + \varepsilon_{t+1}^{\epsilon} \tag{17}$$

$$log(B_{t+1}/\mu_b) = \rho_b log(B_t/\mu_b) + \varepsilon_{t+1}^{b}, \tag{18}$$

where $|\rho_\epsilon| < 1$ and $\varepsilon_t^{\epsilon} \sim iidN(0, \sigma_\epsilon^2)$; $|\rho_b| < 1$ and $\varepsilon_t^{b} \sim iid\ N(0, \sigma_b^2)$.

4. Empirical Methodology

In this section, we briefly outline the Bayesian estimation methodology. More detailed treatments can be found in An and Schorfheide (2007), DeJong and Dave (2007), and Canova (2007).

Let Y_T denote the vector of observed data, Ψ^M denote the model-specific vector of parameters, and M denote the number of models. The purpose of the Bayesian estimation is to obtain posterior distribution of the structural parameters, given data:

$$p(\Psi^M|Y_T) = \frac{p(Y_T|\Psi^M)p(\Psi^M)}{p(Y_t)}, \tag{19}$$

where $p(\Psi^M|Y_T)$ is the posterior distribution, $p(Y_T|\Psi^M)$ is the likelihood function, $p(\Psi^M)$ is the prior distribution, and $p(Y_T)$ is the marginal density of the data for the model M. The likelihood function can be written as

$$p(Y_T|\Psi^M) = p(Y_0|\Psi^M)\prod_{t=1}^{T} p(Y_t|Y_{t-1},\Psi^M). \tag{20}$$

Our earlier beliefs about the distribution of the parameter vector are expressed in the prior distribution $p(\Psi^M)$. The marginal density of the data for the model M can be written as follows:

$$p(Y_t) = \int p(\Psi^M, Y_T)d\Psi^M \tag{21}$$

The posterior distribution of the models can be computed using the Metropolis-Hastings Algorithm, which is a Markov Chain Monte Carlo (MCMC) method. This method allows the drawing of any sequences from distribution. All the information about Ψ^M from the data can be obtained from the approximation of the posterior kernel.

$$p(Y_T|\Psi^M) \propto p(Y_T|\Psi^M)p(\Psi^M) \tag{22}$$

To get the posterior kernel, the marginal data density integrates to a constant. The Metropolis-Hastings algorithm generates a sequence of samples and draws from the posterior kernel

$$log\big(p(Y_t|\Psi^M)\big) + log\big(p(\Psi^M)\big) \tag{23}$$

Then, a Gaussian approximation around the posterior kernel mode is derived from that algorithm. We generate five independent chains for this algorithm. Each of these chains is composed of one million draws, and the first half of the draws are burned to get independence of initial conditions.[1]

5. Data, Calibration, and Priors

We collect quarterly data on GDP, private consumption, private investment, and net exports from International Financial Statistics (IFS) for the two periods: 1988q1-2013q3 and 2002q1-2013q3. Variables are seasonally adjusted with the Census X-12 method. Real variables are obtained by dividing nominal variables by the GDP deflator. Per capita variables are derived by

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[1] We use the DYNARE MATLAB toolbox to estimate and simulate the models (see Adjemian et al., 2011). For more information, visit: http://www.dynare.org/

dividing real variables by population for the ages 15-64. The population variable comes from the Turkish Statistical Institute. Growth rates of GDP, private consumption, and private investment are computed as log differences. Net exports are divided by GDP and computed as a difference. We collect real interest-rate data from theTurkish Data Monitor covering the period from the third quarter of 1996 to the third quarter of 2013.

Following Chang and Fernandez (2010), we always estimate parameters related to structural shocks and the capital-adjustment cost parameter. The structural parameter vector for the stochastic model is given by

$$\Theta = \left[\rho_a \; \rho_g \; \sigma_a \; \sigma_g \;\; \phi \;\; \sigma_{gy} \; \sigma_{gc} \; \sigma_{gi} \;\; \sigma_{dnx}\right]^T,$$

where σ_{gy}, σ_{gc}, σ_{gi}, σ_{dnx} are the standard deviations for the four nonstructural measurement errors. The structural parameter vector for the financial-friction model is given by

$$\Theta = \left[\rho_a \; \rho_R \; \sigma_a \; \sigma_R \;\; \phi \;\; \theta \;\; \eta \;\; \sigma_{gy} \;\; \sigma_{gc} \; \sigma_{gi} \;\; \sigma_{dnx}\right]^T$$

The structural parameter vector for the encompassing model is given by

$$\Theta = \left[\rho_a \; \rho_R \; \rho_g \; \sigma_a \; \sigma_R \; \sigma_g \;\; \phi \;\; \theta \;\; \eta \;\; \sigma_{gy} \; \sigma_{gc} \; \sigma_{gi} \;\; \sigma_{dnx}\right]^T$$

Finally, the structural parameter vector for the augmented model is given by

$$\Theta = \left[\rho_a \;\; \rho_R \;\; \rho_g \;\; \rho_\epsilon \;\; \rho_S \;\; \sigma_a \;\; \sigma_R \;\; \sigma_g \; \sigma_\epsilon \; \sigma_S \;\; \phi \;\; \theta \;\; \eta \right]^T$$

The rest of the parameters are calibrated as summarized in Table 1. Some of the parameters are from related literature when exact data has not been available; some others are data averages when data has been available; and certain parameters are from steady-state representations of the models. The long-run productivity growth (μ) is calculated from the average growth rate of real GDP per capita and set at 1.005. The depreciation rate (δ) is 0.025.

The discount factor is set to 0.9864 for the financial-friction, encompassing, and augmented RBC models. We calibrate the real interest rate to 1.024 from the Turkish Data Monitor. We set intertemporal elasticity of substitution to 2.00, following Aguiar and Gopinath (2007), Garcia-Cicco et al. (2010), and Chang and Fernandez (2010). The labor-supply elasticity parameter (ω) is set to 1.6, as in Mendoza (1991), Schmitt-Grohe and Uribe (2003), Aguiar and Gopinath (2007), and Chang and Fernandez (2010). This term is related to the labor-supply elasticity, and it is given by ($\frac{1}{1-\omega}$). The labor-share (α) parameter takes the value of 0.60 for the stochastic model, and 0.6059 for the financial-friction, encompassing, and augmented models. The value of the labor-share parameter (α) is commonly used in the related literature for the stochastic model. The value of this parameter for the other models is equal to $\alpha = labor\ share * (1 + (R - 1) * \theta)$, where the labor share is 0.

Table 1. Calibrated Parameters

Parameters	**Description**	**Value**
σ	Intertemporal Elasticity of Substitution	2
ω	Labor-Supply Elasticity $\left(\frac{1}{\omega-1}\right)$	1.6
$\alpha^{\#}$	Labor Share of Income	0.6059
R^{*}	Gross Foreign Interest Rate	1.002
μ	Long-Run Productivity Growth	1.005
$\tau^{\#}$	Labor Parameter	1.8145
ψ	Debt Elastic Interest-Rate Parameter	0.001
$\beta^{\#}$	Discount Factor	0.9864
S	Long-Run Gross Country Interest-Rate Premium	1.022
δ	Depreciation Rate of Capital	0.025
D	Debt-to-GDP Ratio (D/Y)	0.10
$R^{\#}$	Gross Country-Specific Interest Rate	1.024

Values of $\alpha, \tau, and\ \beta$ are the same for the Augmented, Encompassing, and Financial-Friction Models. $\alpha = 0.60$; $\tau = 2.95$; $\beta = 0.9871$ for the Stochastic Model
The Gross Country-Specific Interest Rate is taken as 1.017 for the 2002.Q1-2013.Q3 period.

Gross foreign interest rate is calculated from the US's three-month T- Bill rate, while the gross country-specific interest rate is calculated from the data provided by the Turkish Data Monitor. We set the debt-elastic interest-rate parameter to 0.001. In the real business-cycle model literature, this parameter is set to a small number to ensure that the adjustment-cost function does not drive the results (Schmitt-Grohe and Uribe (2003)). We set the debt-to-GDP ratio to 0.1, as in the related literature.

The prior distributions are summarized in Table 2. Our choice of priors generally reflects common practice in the related literature. When the number of endogenous (observable) variables is more than the number of shocks, we add uncorrelated measurement errors to avoid stochastic singularity.

Table 2. Prior Distributions of the Estimated Parameters

Parameters		Prior Distributions	Prior Mean	Prior Standard Deviations
ρ_a	AR(1) Coefficient of TFP Shock	Beta	0.80	0.1
ρ_g	AR(1) Coefficient of Permanent Shock	Beta	0.80	0.1
ρ_r	AR(1) Coefficient of Foreign Interest-Rate Shock	Beta	0.80	0.1
ρ_ϵ	AR(1) Coefficient of Preference Shock	Beta	0.80	0.1
ρ_b	AR(1) Coefficient of Domestic-Spending Shock	Beta	0.80	0.1
σ_a	Standard Deviation of TFP Shock	Inverse Gamma	0.02	0.02
σ_g	Standard Deviation of Permanent Shock	Inverse Gamma	0.02	0.02
σ_r	Standard Deviation of Foreign Interest-Rate Shock	Inverse Gamma	0.02	0.02
σ_ϵ	Standard Deviation of Preference Shock	Inverse Gamma	0.02	0.02
σ_b	Standard Deviation of Domestic-Spending Shock	Inverse Gamma	0.02	0.02
θ	Working-Capital Requirements	Beta	0.50	0.224
η	Spread	Gamma	1	0.101
ϕ	Capital-Adjustment Parameter	Uniform	0	10
σ_Y	Std. Dev. of GDP Measurement Error	Inverse Gamma	0.02	0.02
σ_C	Std. Dev. of Consumption Measurement Error	Inverse Gamma	0.02	0.02
σ_I	Std. Dev. of Investment Measurement Error	Inverse Gamma	0.02	0.02
$\sigma_{d(\frac{TB}{Y})}$	Std. Dev. of Trade-Balance Measurement Error	Inverse Gamma	0.02	0.02

6. Estimation Results for the Full Sample: 1988.Q1-2013.Q3

The posterior distributions of the parameters in the four models are given in Table 3. According to the estimation results, trend-growth shocks are more volatile than temporary shocks in all models. For example, the posterior mean of the variance of temporary shocks is 0.90, and the trend-growth shock is 2.47%, in the stochastic growth model. The ratio of standard devia-

Table 3. Posterior Estimation Results: Full Sample

Parameters	Priors	Posterior Means			
		Augmented Model	Encompassing Model	Financial-Friction Model	Stochastic Model
ρ_a	0.80	0.58 (0.47-0.69)	0.59 (0.49-0.70)	0.62 (0.56-0.67)	0.79 (0.64-0.94)
$100*\sigma_a$	2	0.85 (0.56-1.13)	0.82 (0.56-1.08)	1.47 (1.21-1.72)	0.90 (0.63-1.16)
ρ_g	0.80	0.30 (0.24-0.35)	0.33 (0.27-0.39)	-	0.57 (0.50-0.64)
$100*\sigma_g$	2	3.05 (0.56-1.13)	2.60 (2.12-3.10)	-	2.47 (2.00-2.97)
ρ_r	0.80	0.79 (0.74-0.85)	0.47 (0.34-0.61)	0.49 (0.36-0.64)	-
$100*\sigma_r$	2	0.45 (0.36-0.54)	0.51 (0.40-0.62)	0.52 (0.41-0.63)	-
ρ_ϵ	0.80	0.95 (0.92-0.98)	-	-	-
$100*\sigma_\epsilon$	2	14.73 (9.81-19.57)	-	-	-
ρ_b	0.80	0.98 (0.96-0.98)	-	-	-
$100*\sigma_b$	2	151.38 (133.20-169.45)	-	-	-
ϕ	5.00	9.82 (9.59-10.00)	9.75 (9.45-10.00)	9.76 (9.45-10.00)	9.06 (7.96-10.00)
θ	0.50	0.49 (0.13-0.86)	0.38 (0.05-0.70)	0.29 (0.02-0.55)	-
η	1.00	0.82 (0.68-0.97)	0.84 (0.70-0.99)	0.86 (0.71-1.00)	-
$100*\sigma_Y$	2	-	0.96 (0.65-1.26)	1.57 (1.25-1.90)	0.94 (0.64-1.24)
$100*\sigma_C$	2	-	2.74 (2.39-3.07)	3.13 (2.74-3.52)	2.62 (2.29-2.95)
$100*\sigma_I$	2	-	4.05 (3.18-4.91)	3.87 (2.86-4.87)	4.10 (3.47-4.72)
$100*\sigma_{d(\frac{TB}{Y})}$	2	-	1.27 (1.03-1.50)	1.30 (1.07-1.53)	1.21 (0.95-1.46)
Log-data density		773.4767	828.4998	816.6423	866.4131

Notes: Values in parentheses represent 90% of the highest posterior density intervals. Log data density is computed using Laplace approximation.

Average Acceptance Rate Per Chain:

Stochastic Model:	0.3651	0.3617	0.3622	0.3608	0.3608
Financial-Friction Model:	0.3713	0.3717	0.3717	0.3701	0.3712
Encompassing Model:	0.3426	0.3435	0.3421	0.3435	0.3431
Augmented RBC Model:	0.3249	0.3256	0.3239	0.3173	0.3238

tions, evaluated at the posterior means, is $\frac{\sigma_a}{\sigma_g} = 0.36$ in the stochastic growth model, 0.32 in the encompassing model, and 0.28 in the augmented model.

Thus, we can say that permanent shocks appear relatively more dominant than temporary ones. However, we note that when shutting down the trend shock and adding financial frictions, the volatility of temporary shocks increases significantly.

Focusing on the results from the encompassing model, we observe that the volatility of the innovations in the permanent component of trend productivity is still large in the presence of financial frictions. This is at odds with the view that the importance of trend shocks may be exaggerated if financial frictions are overlooked in models for emerging-market fluctuations. On the contrary, in an environment of random world interest rates, financial frictions—in the form of elastic country spreads and working-capital requirements—seem to play a leading role, even after accounting for both temporary and permanent productivity shocks. The elasticity of spread to expected movements in future productivity (η) has a posterior mean of around 0.84 in all models. This value is very close to those reported in the literature. The posterior mean of the working-capital parameter (θ) is less than 0.5 in all models, implying that some 30% to 40% of the wage bill may be kept as working-capital needs.

In contrast to volatility, the persistence of temporary shock dominates the permanent one in all models. For the stochastic growth model, the posterior means of temporary and trend shocks are 0.79 and 0.57, respectively. The values of the persistence of the shocks are 0.58 and 0.30, respectively, for the augmented model, and 0.59 and 0.33, respectively, for the encompassing model. The capital-adjustment cost parameter has a posterior mean value ranging from 9.06 to 9.8 in all models. We also note that, based on the ranking of log data density, the stochastic growth model performs better than the other models, followed by the encompassing model, the financial-friction model, and the augmented RBC model.

The values of the estimated parameters may not be sufficient criteria for evaluating the different models in real business-cycle models. The literature on this subject also considers some key moments of the model.

Table 4 summarizes selected second moments of the Turkish data and those implied by the alternative models. We observe that, in the data, the consumption and investment growth rates are relatively more volatile than the output growth, and the trade balance is countercyclical. All models successfully replicate the countercyclicality of the trade balance with varying degrees of success. However, the financial-friction model is not very successful in replicating the higher volatility of consumption growth.

Table 4. Selected Second Moments: Full Sample

Variables	Turkish Data	Augmented Model	Encompassing Model	Financial-Friction Model	Stochastic Model
	Standard Deviation (%)				
gy	2.95	3.44	3.00	2.55	2.84
gc	4.10	4.10	2.75	1.93	2.89
gi	6.95	9.31	8.06	8.31	5.71
dnx	1.72	2.42	1.36	1.31	1.21
	S.D.(x)/S.D.(gy)				
gc	1.39	1.19	0.92	0.76	1.02
gi	2.36	2.71	2.67	3.26	2.01
dnx	0.58	0.70	0.45	0.51	0.43
	Correlation with gy				
gc	0.73	0.73	0.98	0.98	0.97
gi	0.73	0.78	0.88	0.89	0.92
dnx	-0.37	-0.22	-0.57	-0.52	-0.48
	Correlation with dnx				
gc	-0.44	-0.37	-0.67	-0.64	-0.67
gi	-0.43	-0.51	-0.87	-0.85	-0.78
	Autocorrelations				
gy	-0.028	-0.22	-0.17	-0.14	-0.01
gc	-0.004	-0.09	-0.11	-0.13	-0.023
gi	0.102	-0.08	-0.22	-0.19	-0.002
dnx	-0.309	0.07	-0.17	-0.23	-0.004

The growth rate of GDP is highly correlated with consumption and investment growth rates (0.73) in the data. This stylized fact is more clearly seen in the augmented RBC model with five shocks, whereas other models imply much higher correlations above 0.88. All models imply negative correlations between the ratio of the trade balance to output and the growth rates of consumption and investment.

We note that there is virtually no persistence in the growth rates of output and consumption in the data, whereas the trade balance and the growth rate of investment are slightly autocorrelated. None of the models seems to be in line with this stylized fact. However, we should note that the stochastic growth model is successful in replicating the non-autocorrelation of *gy* and *gc*, but it fails for *gi* and *dnx*.

To assess the relative importance of exogenous shocks, we computed variance decompositions using alternative models. The results of the variance decomposition analysis are summarized in Table 5.

Table 5. Variance Decompositions: Full Sample

Augmented Model					
	$\boldsymbol{\varepsilon^a}$	$\boldsymbol{\varepsilon^g}$	$\boldsymbol{\varepsilon^{R^*}}$	$\boldsymbol{\varepsilon_t^{\epsilon}}$	$\boldsymbol{\varepsilon_t^s}$
Gy	16.12	83.38	0.28	0.12	0.10
Gc	6.14	48.38	1.16	26.36	17.96
Gi	15.17	48.48	34.39	1.17	0.79
dnx	1.06	6.66	48.23	28.96	34.39
Encompassing Model					
Gy	20.22	79.54	0.24	-	-
Gc	13.19	85.87	0.95	-	-
Gi	22.22	58.89	18.88	-	-
dnx	5.73	32.25	62.03	-	-
Financial-Friction Model					
Gy	99.80	-	0.20	-	-
Gc	98.12	-	1.88	-	-
Gi	81.28	-	18.72	-	-
dnx	29.62	-	70.38	-	-
Stochastic Model					
Gy	26.12	73.88	-	-	-
Gc	8.83	91.17	-	-	-
Gi	2.84	97.16	-	-	-
dnx	21.69	78.31	-	-	-

The most remarkable result is the small role played by the transitory shock relative to other shocks in causing variations in macroeconomic variables in all models but the financial-friction model. Recall that in the latter, there are no permanent shocks but a transitory productivity shock coupled with world interest-rate shocks and various frictions.

Although significant portions of the variations in the growth rates of output, consumption, and investment can be attributed to transitory shocks in the financial-friction model, once we allow for permanent productivity shocks, this is no longer the case in the encompassing model. Also we note that approximately 62% of the variations in the trade balance can be linked to world interest-rate shocks in the encompassing model, while this value is around 70% in the financial-friction model and 48% in the augmented RBC model.

The effect of world interest-rate shocks on the variance of output growth is virtually nil. This result is also valid for the encompassing and financial-friction models. These results are generally in line with those of Garcia-Cicco et al. (2010) and Chang and Fernandez (2010). However, our results showing the relative importance of the permanent productivity shocks stand in stark contrast to theirs. In general, our results imply that trend shocks are relatively more important in explaining variations in the growth rates of output, consumption, and investment. Indeed, approximately 80% of the variations in the growth rate of output can be attributed to permanent productivity shocks.

Results from the encompassing model imply that about 86% of the variations in the growth rate of consumption can be traced to the variations in the trend shock. This is even higher in the stochastic growth model but significantly lower (48%) in the augmented RBC model, where the rest of the variations can be ascribed to preference shocks and spending shocks.

7. Estimation Results for the Subsample: 2002.Q1-2013.Q3

We replicate our analysis for the subsample 2002.Q1-2013.Q3 in order to verify the robustness of our results in a period of relative stability. We summarize the posterior estimation results in Table 6.

In general, the results are qualitatively similar to the results from the full sample. The trend growth shocks are more volatile than the temporary shocks in all models. The ratio of the standard deviations of shocks, σ_a/σ_g, is slightly larger in the subsample than inthe full sample: 0.47 in the stochastic growth model, 0.37 in the encompassing model, and 0.32 in the augmented RBC model, respectively. As in the full sample, permanent shocks appear relatively more dominant than temporary ones.

Similarly, we note that by shutting down the trend shock in this subperiod and adding financial frictions, the volatility of temporary shocks rises markedly. Also, the parameters governing the extent of financial frictions generally have posterior mean values close to their full sample counterparts. The elasticity of spread to expected movements in the country fundamentals has a posterior mean of around 0.86 in all models.

The ranking of the models using the log data density is also the same in the subperiod: the stochastic growth model and the encompassing model are relatively more successful than the others.

Table 6. Posterior Estimation Results: Subsample 2002.Q1-2013.Q3

Parameters	**Priors**	**Posterior Means**			
		Augmented Model	**Encompassing Model**	**Financial-Friction Model**	**Stochastic Model**
ρ_a	0.80	0.59 (0.49-0.69)	0.60 (0.51-0.69)	0.62 (0.56-0.68)	0.92 (0.86-0.98)
$100 * \sigma_a$	2	0.97 (0.60-1.34)	0.92 (0.59-1.23)	1.50 (1.04-1.94)	1.00 (0.62-1.37)
ρ_g	0.80	0.31 (0.24-0.38)	0.37 (0.29-0.44)	-	0.52 (0.43-0.62)
$100 * \sigma_g$	2	3.03 (2.30-3.76)	2.46 (1.79-3.12)	-	2.12 (1.39-2.86)
ρ_r	0.80	0.55 (0.43-0.70)	0.47 (0.33-0.61)	0.48 (0.34-0.63)	-
$100 * \sigma_r$	2	0.61 (0.45-0.76)	0.53 (0.41-0.66)	0.55 (0.41-0.67)	-
ρ_ϵ	0.80	77.77 (63.35-99.29)	-	-	-
$100 * \sigma_\epsilon$	2	8.25 (5.87-10.09)	-	-	-
ρ_b	0.80	0.86 (0.76-0.96)	-	-	-
$100 * \sigma_b$	2	102.74 (85.01-119.81)	-	-	-
ϕ	5.00	9.71 (9.34-10.00)	9.70 (9.32-10.00)	9.68 (9.26-10.00)	8.77 (7.37-10.00)
θ	0.50	0.50 (0.13-0.86)	0.40 (0.05-0.73)	0.45 (0.10-0.81)	-
η	1.00	0.85 (0.70-0.99)	0.86 (0.72-1.01)	0.88 (0.73-1.03)	-
$100 * \sigma_Y$	2	-	0.86 (0.58-1.13)	1.46 (1.03-1.89)	0.81 (0.56-1.05)
$100 * \sigma_C$	2	-	1.79 (1.43-2.14)	2.36 (1.89-2.81)	1.73 (1.38-2.08)
$100 * \sigma_I$	2	-	3.95 (2.90-5.04)	4.27 (3.09-5.43)	3.69 (2.94-4.42)
$100 * \sigma_{(\frac{TB}{Y})}$	2	-	0.95 (0.67-1.27)	0.90 (0.63-1.15)	0.99 (0.76-1.22)
Log data density		391.1226	400.3024	389.7457	438.5589

Notes: Values in parentheses represent 90% of the highest posterior density intervals. Log data density is computed using Laplace approximation.

Average Acceptance Rate Per Chains:

Stochastic Model:	0.3197	0.3198	0.3197	0.3188	0.3201
Financial-Friction Model:	0.3949	0.3955	0.3967	0.3963	0.3970
Encompassing Model:	0.3307	0.3316	0.3303	0.3310	0.3301
Augmented RBC Model:	0.3430	0.3377	0.3378	0.3456	0.3349

Table 7 summarizes second moments of the data and those implied by the alternative models in the subsample. In general, second moments are qualitatively similar to the full sample. Although consumption and investment are still relatively more volatile than output growth, standard deviations are smaller in the subsample. According to the augmented model results, consumption growth and investment growth are more volatile than output growth, as expected. All models are successful in replicating the countercyclical behavior of the trade balance-to-output ratio, but the magnitude is overestimated in the encompassing, financial-friction, and stochastic growth models.

Table 7. Second Moments: Subsample 2002.Q1-2013.Q3

Variables	Data	Augmented Model	Encompassing Model	Financial-Friction Model	Stochastic Model
	Standard Deviation (%)				
Gy	2.57	3.47	2.90	2.59	2.60
Gc	3.18	3.60	2.74	2.01	2.56
Gi	5.78	8.95	8.21	8.75	4.74
Dnx	1.25	2.34	1.65	1.66	0.78
	S.D.(x)/S.D.(gy)				
Gc	1.24	1.04	0.95	0.78	0.98
Gi	2.25	2.58	2.83	3.38	1.82
Dnx	0.49	0.67	0.57	0.64	0.30
	Correlation with gy				
Gc	0.83	0.87	0.98	0.98	0.98
Gi	0.74	0.86	0.89	0.89	0.98
Dnx	-0.44	-0.38	-0.66	-0.62	-0.69
	Correlation with dnx				
Gc	-0.50	-0.57	-0.73	-0.70	-0.80
Gi	-0.36	-0.60	-0.92	-0.91	-0.81
	Autocorrelations				
Gy	0.19	-0.22	-0.15	-0.11	-0.03
Gc	-0.04	-0.16	-0.09	-0.05	-0.02
Gi	0.47	-0.12	-0.22	-0.20	-0.02
Dnx	0.11	0.02	-0.21	-0.23	0.09

According to the results of the financial-friction model, growth in output is more volatile than that in consumption growth; on the other hand, growth in investment is more volatile than that in output. The lower volatility of the consumption behavior conflicts with the Turkish data and the overall expectations for developing countries. The encompassing model is more successful than the financial-friction model in replicating such volatilities of observed variables.

The correlation between growth rates in consumption and in output on the one hand and investment growth and output growth on the other is high and positive (respectively, 0.83 and 0.74), as expected from the Turkish data. The encompassing model, financial-friction model, and stochastic model all overpredict the correlation between output and consumption, as well as that between output and investment.

Table 8 summarizes the variance-decomposition analysis for the subsample.

Table 8. Variance Decomposition: Subsample 2002.Q1-2013.Q3

Augmented Model					
	ε^a	ε^g	ε^{R^*}	ε_t^ϵ	ε_t^s
Gy	16.67	80.20	0.10	0.00	0.02
Gc	10.56	65.96	0.71	21.93	0.84
Gi	23.21	53.39	22.93	0.10	0.37
Dnx	4.63	12.49	38.52	21.98	22.39
Encompassing Model					
Gy	26.80	72.93	0.27	-	-
Gc	16.92	82.19	0.88	-	-
Gi	26.70	55.41	17.89	-	-
Dnx	9.45	39.32	51.23	-	-
Financial-Friction Model					
Gy	99.45	-	0.55	-	-
Gc	97.83	-	2.17	-	-
Gi	82.19	-	17.81	-	-
Dnx	42.73	-	57.27	-	-
Stochastic Model					
Gy	35.28	64.72	-	-	-
Gc	19.79	80.21	-	-	-
Gi	22.27	77.73	-	-	-
Dnx	1.28	98.72	-	-	-

As in the full sample, transitory productivity shock has a minor role in inducing the variations in macroeconomic variables. Almost 73% of the variations in output growth can be attributed to permanent shocks in the encompassing model, 65% in the stochastic growth model, and about 80% in the augmented model. When we exclude the permanent shocks and include financial frictions, almost all of the variations in output growth are attributed transitory shocks.

Similar to the full sample results, once we allow for permanent productivity shocks, this is no longer the case in the encompassing model. Also we note that roughly 51% of the variations in the trade balance can be linked to world interest-rate shocks in the encompassing model, whereas this value is close to 57% in the financial-friction model and 39% in the augmented RBC model.

8. Conclusion

Although it is difficult to choose a single model as the most successful among the alternative models, we can draw several conclusions from this exercise. First, (permanent) trend-growth shock has a dominant role in the volatility of macroeconomic variables. The role of this shock for the Turkish economy is compatible with Aguiar and Gopinath (2007), supporting their "the cycle is trend" argument. However, we also note that a model with transitory shocks coupled with several financial frictions might also explain macroeconomic fluctuations.

Furthermore, once we allow for a permanent productivity shock in the financial-friction model (the encompassing model a la Chang and Fernandez, 2013), the role of transitory shocks diminishes, with the financial frictions remaining equally important. Second, all alternative models are successful in replicating a countercyclical trade balance and producing strong correlations with output growth and a higher volatility of consumption. However, they generally fail in replicating the persistence in the trade balance-to-output ratio.

Although one may be tempted to choose the stochastic growth model, on the grounds of parsimony (Occam's razor), we should note that it fails in replicating stylized facts in several dimensions. Third, our results are generally robust in the relatively stable subperiod covering 2002.Q1-2013.Q3. Similar to the full sample results, trend growth shocks seem to have a dominant effect on macroeconomic variables.

Overall, once we include a nonstationary productivity shock in an otherwise standard stochastic growth model, it accounts for the largest portion of the variations in the macroeconomic variables. This is generally robust to the presence of various financial frictions. However, this result does not imply that financial frictions are a minor factor in business cycles. On the contrary, permanent productivity shocks coupled with several micro-frictions might have more to do with macroeconomic fluctuations. These results indicate that decision-making authorities should be concerned about crafting policies that will lessen the impact of financial frictions on macroeconomic variables.

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