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A New Keynesian Model of the Armenian Economy

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Abstract

This paper develops a small open economy dynamic stochastic general equilibrium (DSGE) model of the Armenian economy. The structure of the model is largely motivated by recent developments in DSGE modeling, with key extensions to incorporate specific structural characteristics of the Armenian economy. The resultant model can be used to simulate monetary policy paths and help analyze the robustness of policy conclusions. The paper tests the model's properties on Armenian data, demonstrating that the main stylized features relevant for monetary policy making are well captured by the model.

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I.

INTRODUCTION

During the past decade, central banks have increasingly focused on dynamic stochastic general equilibrium (DSGE) models for analyzing macroeconomic fluctuations and to use these models for quantitative policy analysis. These models—often referred to as New Keynesian—typically incorporate imperfect competition and nominal rigidities in the analysis of monetary policy transmission and its response to shocks.[1] Key aggregate relationships in these models are derived from micro-foundations with optimizing agents and rational expectations.

The Armenian Central Bank adopted inflation targeting in 2006. To support the implementation of monetary policy, an analytical framework was established around a small open economy quarterly projections model (QPM).[2] The QPM captures highly aggregated and stylized relations in the Armenian economy necessary to explain fluctuations in output, inflation, the exchange rate, and interest rate. The model consists of simple structural equations, and largely deals with deviations of the main macroeconomic variables from their long-term trends ("gap" model). While the simplicity of this framework facilitates communication and strengthens forecast organization, it lacks rigorous theoretical underpinnings. In this paper, we extend this basic model by developing a New Keynesian-type small open economy model with microeconomic foundations.

The design of our model builds extensively upon previous work done in this areas, notably by Smets and Wouters (2004), Gali and Monacelli (2002), Svensson (2000), Justiano and Preston (2004), and Monacelli (2005). These papers develop models with an explicit structure for agents, markets, technologies and preferences, and provide a mapping to the economy's deep parameters. We extend this framework to capture certain structural features specific to the Armenian economy that are pertinent from the point of view of monetary policy implementation.[3]

One important structural characteristic of the Armenian economy is the low responsiveness of imported goods prices to exchange rate movements. Many of the above-mentioned papers assume the presence of nominal rigidities in the imported goods sector arising from inefficient distribution networks and monopolistic retailers. This *law of one price gap* (LOP gap) commonly cited in the literature can be regarded as the wedge between the world price of goods in domestic currency and the domestic price of the same imported goods. It results in an incomplete exchange rate pass-through in the short run, implying also that changes in world prices of imported goods have a gradual affect on the domestic economy. Our model has this feature, but, in addition, we assume that importing firms take into account domestic unit labor costs in their pricing decisions. Specifically these firms distribute imported goods to consumers using

[1] See Christiano et al (2005), Clardia et al. (1999, 2001) and references therein for the theoretical underpinnings, and Bucncic et al (2007), Liu (2006), Osvald and Musil (2006) for applications of such New Keynesians models to other small open economies such as Australia, New Zealand, and the Czech Republic.

[2] Tibor Hledik and Jan Vlcek of the Czech National Bank provided considerable support for building and developing the QPM model for the Armenian economy.

[3] The data and analysis in the paper covers the period 2001 - 2007and predates the recent global economic crises.

domestic labor as an input. As a result, domestic unit labor costs play an influential role in the pricing behavior of these firms.

Incorporating this feature makes imported good prices even less responsive to exchange rate movements than in the standard literature. This is important because during the period 2004-2007, the nominal exchange rate appreciated by more than 40 percent but was accompanied by a less than 5 percent decline in imported good prices. Since the imported goods sector uses labor services, this assumption also implies that demand for imported goods influences domestic output through its affect on labor demand. This is in line with stylized evidence for the Armenian economy. During the period of sustained exchange rate appreciation, the higher demand for imported goods translated into an increase in labor employed in the imported good distribution sector at the expense of employment in the export sector.

The model also incorporates the key role played by remittances in stimulating domestic demand in Armenia and in fueling the exchange rate appreciation. Specifically, remittance inflows are modeled as a foreign consumption shock that affects the domestic economy. This is done by including a preference shock parameter in the foreign households utility function. Shocks to this parameter induce foreign households to remit income to the domestic economy, thereby affecting domestic demand, and through the uncovered interest parity condition the exchange rate, capturing the capital inflow character of remittances.

The model is calibrated to the Armenian economy and impulse response functions are presented to provide a qualitative way of understanding the dynamic behavior of the economy in response to various shocks. We also utilize a variety of approaches to assess whether the model is capable of replicating key business cycle patterns of Armenian economy.

The paper is organized as follows. Section II describes stylized facts about the transmission mechanism in the Armenian economy, providing the background for evaluating the properties of the model. Section III lays out the model environment. In Section IV, we examines the model's behavior in response to shocks and evaluate the correspondence between the model and actual data. Section V concludes.

II. Stylized Facts About the Armenian Economy

In this section, we discuss Armenia's recent monetary experience, including details about the monetary transmission mechanism, as well as stylized features of the economy that are most relevant for the purposes of modeling. We first describe recent economic and institutional developments and then characterize some of the long- and medium-term phenomena. This approach allows us to examine the properties of the data and to focus on specific features of the economy before turning to the structural model.

Successful disinflation and double-digit economic growth characterize Armenia's recent economic history, especially since 2001. The fiscal and quasi-fiscal consolidation undertaken in the late 1990s played a critical role in reducing inflation to single-digit levels. A largely

independent central bank ensured the support of tight monetary policies.[4] Exchange rate flexibility and a clear focus on price stability gave the authorities the necessary control over the money supply in an environment of free capital mobility, and real and nominal interest rates fell in response to macroeconomic stability.

Since end-2003, the country was buffeted by large external shocks in the form of sizeable remittance inflows. The persistence of these inflows as well as other nominal shocks (i.e. money demand shocks in the presence of dollarization) made it increasingly impractical to use broad money aggregates as credible intermediate targets. Prudent fiscal policy together with institutional changes in early 2000s, paved the way for the gradual introduction of an implicit inflation targeting regime.[5] Since 2006, short-term inflation targets, using the interest rate as a policy instrument, have complemented monetary targets in the context of an IMF program.

A. Stylized Facts on Long-Term Trends

In this sub-section, we review long trends for the Armenian economy that are most relevant from a modeling perspective. Within the period under examination (2001–07), all real variables exhibit persistent growth. On average, GDP grew by 11.6 percent, consumption grew by 8.5 percent, while productivity growth averaged 12 percent. The growth rate of consumption was lower then GDP growth, due to a decline in consumption shares from 92 percent in 2001 to 72 percent in 2007, and a corresponding increase in private investment. We note that two types of essential changes took place over this period. Government expenditures grew rapidly in 2002–03 before stabilizing at more moderate levels, while the second half of 2004 onwards saw a sharp increase in remittance inflows. For instance, remittances grew on average by 20 percent in 2001–03, and by an average of 38 percent from 2004 onwards.

The real exchange rate depreciated during 2002–03 in line with the large increase in government expenditures, but showed a permanent appreciating trend thereafter following an acceleration in remittance inflows. Interest rates showed a declining trend over the period under consideration, associated largely with financial market deepening, foreign bank entry, and increases in bank capital. Inflation over this period remained low, averaging 3.4 percent during 2001–07. But domestic inflation was higher then imported good inflation (4.3 percent and 1.7 percent , on average, respectively), reflecting the Balassa-Samuelson effect working through higher productivity in the tradable relative to the nontradable goods sector.

In summary, the Armenian economy during 2001–07 exhibited long term growth in productivity, remittances, and output, a sustained real exchange rate appreciation from the second half of 2004, and declining interest rates. However, understanding the determinants of inflation requires an analysis of business cycle patterns.

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[4] Monetary policy followed strict targets on the net domestic assets of the CBA and minimal accumulation of bank credit to the government. For a detailed discussion of the changes in the monetary policy framework since the early years of transition, see Dabla-Norris and others (2007), and Dabla-Norris and Floerkemeier (2006).

[5] The CBA was given legal and operational independence to pursue the primary objective of achieving and maintaining price stability, and formal mechanisms for accountability to the inflation target strengthened.

B. Business Cycle Fluctuations

In contrast to long-term patterns, medium-term fluctuations in the data are related to the monetary policy transmission mechanism, and its importance in controlling inflation over a business cycle. At the same time, the presence of nominal rigidities in price setting behavior can influence the path of inflation in the short term. Analysis of business cycle patterns is, therefore, important for providing structure to a model of the Armenian economy. In what follows, we characterize business cycle patterns in Armenia by examining deviations for detrended data (calculated using the HP filter) from longer-term trends (Figure 1).

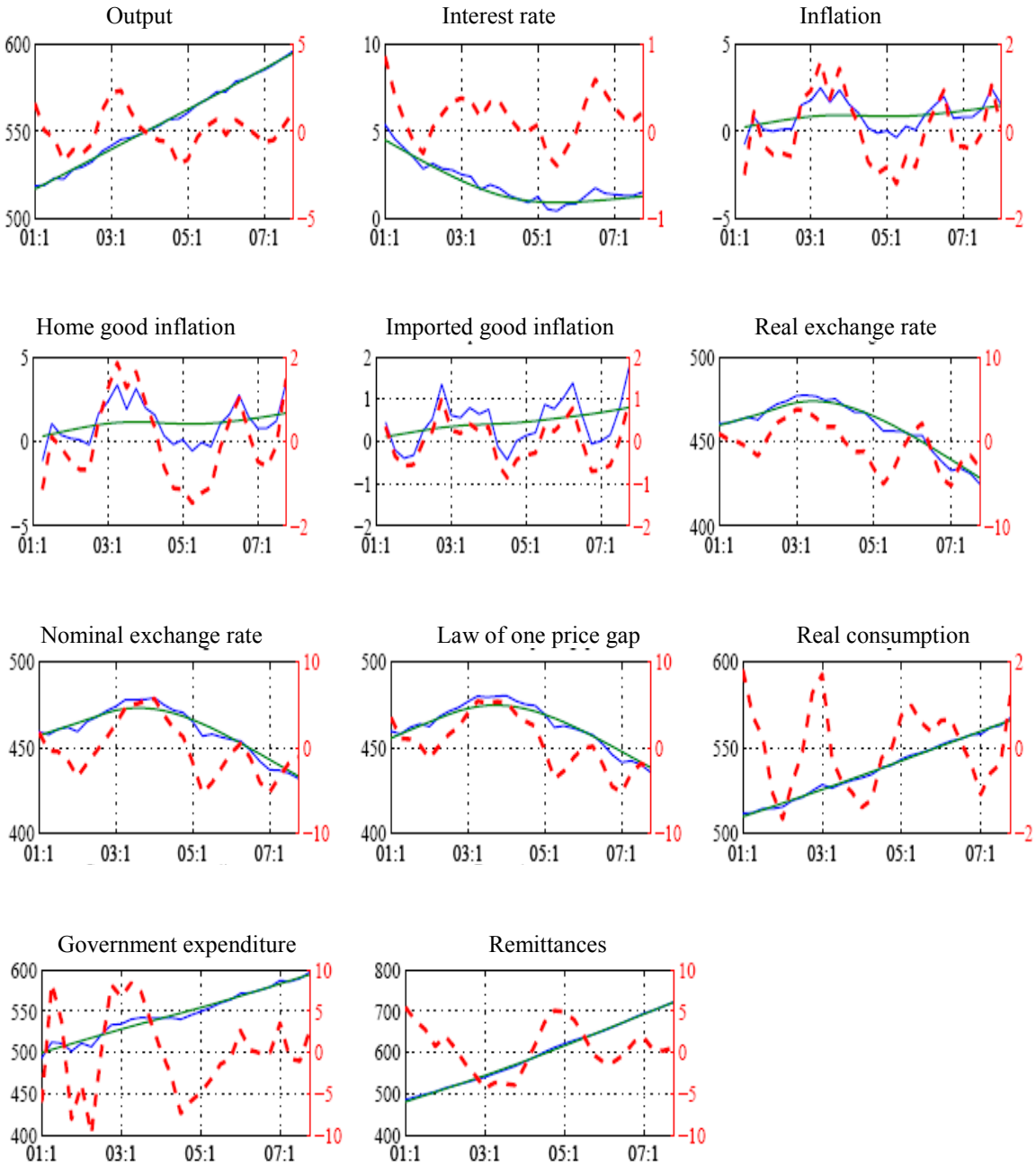
The positive output gap between 2002Q4 and 2003Q4 is associated with the large increase in government expenditures and a real exchange rate depreciation discussed above. Home good inflation increased with the positive output gap, while the co-movement between imported good inflation and the nominal exchange rate depreciation over this period is very small, suggesting that the impact of exchange rate movements in determining imported good inflation was limited. The next important period is 2004Q3 to 2005Q3 when private remittance inflows surged. This was associated with a nominal and real exchange rate appreciation, and a negative output gap. While overall inflation declined, imported goods prices declined by significantly less than the nominal exchange rate appreciation. This again suggests a low correlation between imported goods inflation and fluctuations in the exchange rate.

Since 2005, there was also increasing dedollarisation in the economy which fueled further appreciation pressures. This, in part, explains why the nominal and real appreciation of the exchange rate was not only influenced by the surge in remittances and the interest rate differential. The real exchange rate appreciation resulted in a negative output gap and deflation during this period.

The cyclical behavior of the interest rate (deviation from the trend) over this period suggests that for the most part, the interest rate responded to changes in the output gap and inflation. Prior to 2006, when a monetary targeting strategy was followed, the correspondence of co-movements indicates that monetary policy was largely countercyclical. Starting from 2006, when an implicit inflation targeting strategy was adopted, the interest rate was the key policy lever of the central bank and moved mainly in line with inflation developments.

A visual inspection of business cycle correlations between the pertinent variables (Figure 2) shows important regularities and correlations between cyclical patterns on the expenditure side with relative prices. The data suggest a negative relationship between consumption and the real interest rate, providing evidence of the transmission from interest rates to consumption. The impact of the real exchange rate on the output gap is evident from the cyclical patterns in the data, but started to weaken from 2005. This suggests that the LOP gap (defined in detail in Section III) is an endogenous variable and has an influential impact on the transmission mechanism. This is confirmed when we examine the graph of changes in the nominal exchange rate and imported good inflation. The cyclical patterns in home good inflation show the correct co-movement with the output gap, indicating that the output gap is an important determinant of variability in home good inflation.

Figure 1. Long-Term Trends and Business Cycle Movements from Trends
(Series detrended using HP filter)



As discussed above, the limited role of the exchange rate in affecting imported good inflation in Armenia suggests that the exchange rate pass-through is muted. This can be explained by the fact that distributive trade accounts for an important share of retail imported goods because of the need for local labor-intensive distribution services. As a result, domestic unit labor costs play an influential role in pricing behavior of importer firms. In this case, even if imported goods prices were flexible and distribution networks efficient, incomplete exchange rate pass-through would hold due to the movement of nominal marginal costs. Therefore, in capturing the short-term dynamics of monetary policy transmission in Armenia, the model should account for this feature.

III. MODEL ENVIRONMENT

In this section we lay out the derivation of the key structural equations implied by the model proposed by Gali and Monacelli (2005) and Monacelli (2005) adding some features that are relevant to the Armenian economy. The model's dynamics are enriched by allowing for adjustment costs, habit formation, and indexation of prices, as in Furher (2000), Justiano and Preston (2004), and Svensson (2000).

A. Households

The economy is populated by a representative household who seeks to maximize the expected present discount value of utility:

$$E_t \sum_{i=0}^{n} \beta^i \left\{ \frac{(C_{t+i} - hC_t)^{1-\sigma}}{1-\sigma} - x\frac{N_{t+i}^{1+\eta}}{1-\eta} \right\} \tag{1}$$

where σ is the inverse elasticity of intertemporal substitution, η is the inverse elasticity of labor supply, N_t denotes labor supply, and hC_t represents external habit formation for the household, for $h \in (0,1)$. C_t is a composite consumption index of foreign and domestically produced goods defined as:

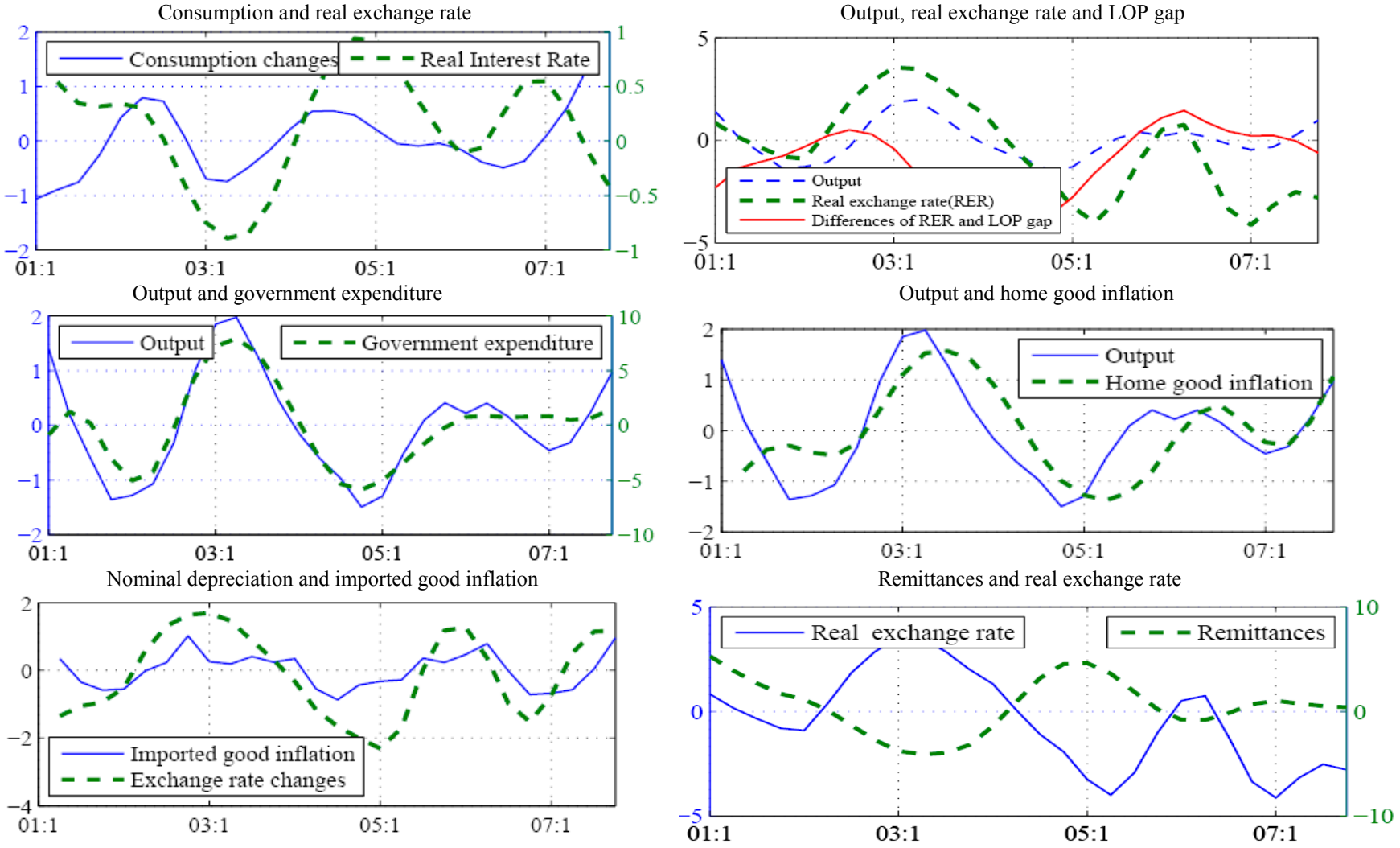
$$C_t = \left\{ (1-\gamma)^{\frac{1}{a}} C_t^{h\ \frac{a-1}{a}} + \gamma^{\frac{1}{a}} C_t^{m\ \frac{a-1}{a}} \right\}^{\frac{a}{a-1}} \tag{2}$$

where $\gamma \in [0,1]$ is the degree of openness as measured by import share in consumption, and $a > 0$ is the elasticity of substitution between home and imported goods. The aggregate consumption indices of domestic (C_t^h) and foreign (C_t^m) produced goods are given by the CES functions:

$$C_t^h = \left\{ \int_0^1 C_{jt}^{h\ \frac{\theta-1}{\theta}} d_j \right\}^{\frac{\theta}{\theta-1}} \text{ and } C_t^m = \left\{ \int_0^1 C_{jt}^{m\ \frac{\theta-1}{\theta}} d_j \right\}^{\frac{\theta}{\theta-1}}$$

where $\theta > 0$ is the elasticity of substitution between different varieties of goods.

Figure 2. Business Cycle Fluctuations of Detrended Series



The household maximizes its utility function subject to a sequence of budget constraints of the form:

$$\int_0^1 \left\{ P_{jt}^h C_{jt}^h \; + \; P_{jt}^m C_{jt}^m \right\} d_j \; + \; E_t \left\{ Q_{t,t+1} D_{t+1} \right\} \leq \; D_t \; + \; W_t N_t \; + \; T_t, \tag{3}$$

for $t = 0, 1, 2, ...,\infty$

where P_{jt}^h and P_{jt}^m denote prices of the domestic and foreign good (expressed in domestic currency) j, respectively, D_{t+1} is the nominal payoff in period t+1 of the portfolio held at the end of period t, W_t is the nominal wage, and T_t denotes lump-sum taxes. $Q_{t,t+1}$ is the stochastic discount factor for a one-period ahead nominal payoff on a portfolio relevant to the domestic household.

The optimal allocation of any given expenditures for good i is given by the demand functions:

$$C_t^h(i) \; = \; \left(\frac{P_t^h(i)}{P_t^h} \right)^{-\theta} C_t^h \qquad \text{and} \qquad C_t^m(i) \; = \; \left(\frac{P_t^m(i)}{P_t^m} \right)^{-\theta} C_t^m \tag{4}$$

where

$$P_t^h \; = \; \left(\int_0^1 {P_{jt}^h}^{1-\theta} d_j \right)^{\frac{1}{1-\theta}} \qquad ; P_t^m \; = \; \left(\int_0^1 {P_{jt}^m}^{1-\theta} d_j \right)^{\frac{1}{1-\theta}}$$

and P_t^h and P_t^m are the price indices of domestically produced and imported goods (expressed in domestic currency), respectively. Assuming symmetry across goods, the optimal allocation of expenditure between domestic and imported goods is given by

$$C_t^h \; = \; (1-\gamma) \left(\frac{P_t^h}{P_t} \right)^{-a} C_t \qquad \text{and } C_t^m \; = \; \gamma \left(\frac{P_t^m}{P_t} \right)^{-a} C_t \tag{5}$$

where

$$P_t \; = \; \left\{ (1-\gamma) {P_t^h}^{1-a} \; + \; \gamma {P_t^m}^{1-a} \right\}^{\frac{1}{1-a}} \tag{6}$$

is the overall consumer price index (CPI). Total consumption expenditures by domestic households can then be written as $P_t C_t \; = \; P_t^h C_t^h \; + \; P_t^m C_t^m$. Thus, the period budget constraint (3) can be rewritten as:

$$P_t C_t \; + \; E_t \left\{ Q_{t,t+1} D_{t+1} \right\} \leq \; D_t \; + \; W_t N_t \; + \; T_t \tag{7}$$

Solving the household's optimization problem subject to (7) yields the following first order conditions (FOCs):

$$(C_t - hC_{t-1})^{-\sigma} = \beta(1+i_t) E_t \left(\frac{P_t}{P_{t+1}} \right) (C_{t+1} - hC_t)^{-\sigma} \tag{8}$$

$$\frac{x N_t^{\eta}}{(C_t - hC_{t-1})^{-}\sigma} = \frac{W_t}{P_t} \tag{9}$$

where $(1+i_t)$ is the nominal rate of return on a riskless one-period bond maturing in $t+1$. Equation (8) is the conventional stochastic Euler equation for inter-temporal consumption, while equation (9) states that the marginal utility of consumption equals the marginal value of labor at any point of time.

We assume that households in the foreign economy face a similar optimization problem, have the same elasticity of substitution, and that the influence from the domestic economy is minimal. However, given the existence of a large Armenian Diaspora who may have a motive to remit income to Armenia, we modify the utility function of the foreign household by adding an exogenous preference parameter. Specifically, to capture the observed importance of remittances to the Armenian economy, we assume that the utility function of the foreign household is of the form:

$$E_t \sum_{i=0}^{n} \beta^i \left\{ \frac{e^{-\xi_t}(C_t^* - hC_{t-1}^*)}{1-\sigma} - x\frac{N_{t+i}^{1+\eta^*}}{1-\eta} \right\} \tag{10}$$

where ξ_t represents an exogenous consumption (or investment) preference parameter for the foreign household.

The negative sign implies that the foreign household derives utility from a motive to remit income or to invest in the domestic economy at the expense of its own consumption. While we do not explicitly model altruism on the part of the foreign household, the underlying idea is that an increase in ξ_t increases the utility of Diaspora Armenians from sending funds to domestic households or investing in the domestic economy. In this respect, this ad hoc assumption can be viewed as capturing both altruistic and self-interested motives to remit income to domestic economy, since remittances also behave as capital inflows.[6] Assuming that the domestic economy is very small relative to the foreign economy, we assume that changes in the preference parameter have no significant influence on the foreign economy.

The Euler equation for the foreign household can then be written as:

$$e^{-\xi_t}(C_t^* - hC_{t-1}^*)^{-\sigma} P_{t+1}^* = \beta(1+i^*)\{e^{-\xi_{t+1}}(C_{t+1}^* - hC_t^*)^{-\sigma} P_{t+1}^*\}$$

Foreign demand for imported goods is given by:

$$C_t^{h*} = \gamma\left(\frac{S_t P_t^*}{P_t^h}\right)^{-a*} C_t^* \tag{11}$$

[6] The literature on remittances highlights different motivation for remitters, ranging from an altruistic one to that driven by self-interest, including exploitation of investment opportunities (Acosta et al, 2007). In the case of the former, remittances can be viewed as providing an additional source of income for domestic households. In the latter case, domestic households can be viewed as merely intermediaries that channel funds from foreign residents who use their savings to take advantage of local investment opportunities, thereby having no direct impact on the domestic household's budget constraint (Lucas and Stark, 1985).

where C_t^{h*} is foreign demand for domestic goods, S_t is the nominal exchange rate, P_t^* is the foreign price level, $a^* > 0$ is the elasticity of substitution between domestically produced and imported goods for the foreign economy, and C_t^* is the foreign consumption index.

Log-linear approximation of (2), (5) - (6), the two FOCs (8) - (9), and (11) yield:

$$c_t = (1-\gamma)c_t^h + \gamma c_t^m \tag{12}$$
$$c_t^m = -a(1-\gamma)(p_t^m - p_t^h) + c_t \tag{13}$$
$$c_t^h = a\gamma(p_t^m - p_t^h) + c_t \tag{14}$$
$$p_t = (1-\gamma)p_t^h + \gamma p_t^m \tag{15}$$
$$c_t^{h*} = \gamma(s_t + p_t^* - p_t^h) + c_t^* \tag{16}$$
$$c_t - hc_{t-1} = E_t(c_{t+1} - hc_t) - \frac{1-h}{\sigma}(i_t - \pi_{t+1}) \tag{17}$$
$$\frac{\sigma}{(1-h)}(c_t - hc_{t-1}) + \eta n_t = w_t - p_t \tag{18}$$

where lower case letters denote the percentage deviations of the relevant variables from the steady-state, and $\pi_t = \ln p_t - \ln p_{t-1}$ is CPI inflation.

Inflation, the real exchange rate, and the terms of trade

In this subsection, we outline the key relationships between inflation, the real exchange rate, and the terms of trade. We define the terms of trade (TOT) as:

$$\Delta_t = \frac{P_t^m}{P_t^h}$$

where Δ_t is the terms of trade, P_t^m and P_t^h are the domestic price of imported and home goods, respectively. The terms of trade can, therefore, be regarded as the price of the foreign good per unit of the home good. Log-linearizing the TOT and using the log-linearized CPI equation we can obtain links between domestic goods inflation, CPI inflation, and changes in the TOT.

$$\pi_t = \pi_t^h + \gamma\Delta\delta_t \tag{19}$$
$$\delta_t = p_t^m - p_t^h, \text{ and } \Delta\delta_t = \pi_t^m - \pi_t^h \tag{20}$$

where δ_t is the percentage deviations of the TOT from the steady-state and Δ denotes the first difference. Equation (19) suggests that the difference between the overall CPI and domestic goods inflation is proportional to the change in the TOT. Moreover, the higher the degree of openness (γ) of the economy, the stronger is this relationship.

Throughout the paper, we assume that the *law of one price* (LOP) holds for the export sector, but there is incomplete pass-through in the import sector (LOP gap). There are two reasons as to why this is an appropriate assumption for the Armenia economy. First, while prices of Armenian exports are set in international markets, on the import side, rigidities arising from monopolistic retailers in the imported goods distribution sector allow domestic prices of imported goods to deviate from world prices. Therefore, while the LOP holds at the wholesale level for imports, it fails to hold at the retail level for domestic imports. Second, as mentioned in the previous

section, distributive trade accounts for an important share of retail imported goods because of the need for local labor-intensive distribution services. We model this by assuming that nominal marginal costs in the domestic economy influence optimal pricing decisions of distributors. In this case, even if imported goods prices were flexible and distribution networks efficient, incomplete pass-through would hold due to the movement of nominal marginal costs.[7]

The LOP gap and real exchange rate can be defined as follows:

$$\Psi_t = \frac{S_t P_t^*}{P_t^m} \tag{21}$$

$$Q_t = \frac{S_t P_t^*}{P_t} \tag{22}$$

where Q_t is the real exchange rate, S_t is the nominal exchange rate and P_t^* is the foreign price index.[8]

Log-linearizing these two equations around the steady state and using equation (19) gives:

$$q_t = s_t + p_t^* - p_t = \psi_t + (1-\gamma)\delta_t \tag{23}$$

$$\psi_t = s_t + p_t^* - p_t^m \tag{24}$$

where $\psi_t = ln(\Psi_t)$. Equations (23) imply that the LOP gap is positively related to the real exchange rate and negatively to the degree of international competitiveness of the domestic economy.

International risk sharing and uncovered interest parity

Under the assumption of complete international financial markets and perfect capital mobility, the expected nominal return (expressed in domestic currency) from risk-free bonds in the domestic and foreign economy must be the same, that is, $E_t R_{t,t+1} = E_t\left(R^*_{t,t+1}\frac{S_{t+1}}{S_t}\right)$ where $R_{t,t+1} = 1 + i_t$ is the nominal rate of return on a domestic bond and $R^*_{t,t+1} = 1 + i^*_t$ is the return on a foreign bond.

The assumptions of perfect capital mobility and complete international financial markets may not be entirely applicable to the Armenian economy. However, we can partially justify this assumption on the grounds of the existence of a large Armenian Diaspora with a motivation to send remittances to Armenia. As discussed earlier, an increase in the foreign households preference to remit income to the domestic economy (ξ_t) will result in an inflow from the

[7] Strong evidence of the importance of distribution services for the retail price of consumption goods has been found for other countries as well (Burstein et. al, 2003). Goldberg and Verhoven (2001) based on data for automobile prices in five European countries estimate that local costs account for up to 35 percent of the price of a car due to distribution services provided by local dealers.

[8] Note that if LOP holds (i.e. if Ψ_t=1), then the import price index is simply the domestic currency price of the foreign price index.

international risk sharing condition. Therefore, we can equate the intertemporal optimality conditions for the domestic and foreign households' optimization problems as follows:

$$E_t(\frac{S_t}{S_{t+1}})\beta E_t\left\{\frac{P_t^*}{P_{t+1}^*}\left(\frac{e^{-\xi_{t+1}}(C_{t+1}^*-hC_t^*)}{e^{-\xi_t}(C_t^*-hC_{t-1}^*)}\right)^{-\sigma}\right\}=\beta E_t\left\{\frac{P_t}{P_{t+1}}\left(\frac{C_{t+1}-hC_t}{C_t-hC_{t-1}}\right)^{-\sigma}\right\} \tag{25}$$

However, to close the model we assume that the foreign economy is exogenous to the small open economy, so that the remittance parameter in the foreign households Euler equation is an exogenous stochastic variable. Specifically, we assume that the foreign household's bias for remitting income to Armenian, ξ_t, follows an AR(1) process, that is $\xi_t=\rho_\xi\xi_{t-1}+\varepsilon_t^\xi$, where $0\le\rho_\xi\le 1$ is a parameter of persistence and ε_t^ξ is an *i.i.d* shock.

Rearranging equation (25) we get

$$C_t-hC_{t-1}=E_t\left\{\frac{(e^{\xi_{t+1}})^{\frac{1}{\sigma}}}{Q_{t+1}^{\frac{1}{\sigma}}}\frac{(C_{t+1}-hC_t)}{(C_{t+1}^*-hC_t^*)}\right\}(C_t^*-C_{t-1}^*)Q_t^{\frac{1}{\sigma}}(e_t^\xi)^{\frac{1}{\sigma}} \tag{26}$$

In equilibrium, the following relationship must hold

$$C_t-hC_{t-1}=\vartheta(C_t^*-C_{t-1}^*)Q_t^{\frac{1}{\sigma}}(e_t^\xi)^{\frac{1}{\sigma}} \tag{27}$$

where ϑ is a constant depending on the relative initial assets positions. This assumption is a necessary condition needed to close the model (see Schmitt-Grohe and Uribe, 2003). Log-linearizing the above equation around the steady state yields

$$c_t-hc_{t-1}=y_t^*-hy_{t-1}^*+\frac{1-h}{\sigma}q_t+\frac{1-h}{\sigma}\xi_t \tag{28}$$

The above equation links domestic consumption to world consumption, the real exchange rate, and remittances to the domestic economy.

The assumption of complete markets at the international level also allows us to obtain a version of the uncovered interest parity condition, which relates domestic and foreign real interest rates. Assuming that the domestic economy is very small relative to the foreign economy and that preferences for remittances do not influence the foreign economy, as the Armenian Diaspora is small compared to the rest of the world, yields the following real uncovered interest parity condition:[9]

$$q_t=E_tq_{t+1}-rr_t+rr_t^*-(\xi_t-\xi_{t+1}) \tag{29}$$

[9] This equation is obtained by combining the consumption Euler equations for both the domestic and foreign economy (excluding the preference shock) with the risk sharing condition (25) and equation (19) which relates domestic inflation to CPI inflation.

where $rr_t = i_t - \pi_{t+1}$ is the domestic CPI based real interest rate, and $rr_t^* = i_t^* - \pi_{t+1}^*$ is the foreign real interest rate. Thus, we get an uncovered interest parity condition which depends on the current real interest rate differentials as well as remittance inflows. In our model, the last term in the above equation is akin to introducing an exogenous stochastic risk premium term (see Kollman, 2001).

B. Firms

There is a continuum of identical monopolistically-competitive firms which have the following production function.

$$Y_t(j) = Z_t N_t(j) \tag{30}$$

where Y_j is a differentiated good, Z_t is total productivity, and $z_t = log(Z_t)$ is assumed to follow an AR(1) process, that is $z_t = \rho_z z_{t-1} + \xi_t^z$, where $0 \leq \rho_z \leq 1$ is a parameter of persistence and ξ_t^z is an *i.i.d* shock.

Assuming a symmetric equilibrium for all *j* firms, the log-linear approximation of aggregate production can be written as

$$y_t = n_t + z_t \tag{31}$$

From the firms' cost minimization problem, we can derive the real marginal cost for all firms as.

$$MC_t = \frac{W_t}{P_t^h Z_t},$$

Log-linearizing the above equation yields

$$mc_t = w_t - p_t^h - z_t$$

and using (18) and (23), we obtain:

$$mc_t = w_t - p_t + \gamma\delta_t - z_t = \frac{\sigma}{1-h}(c_t - hc_{t-1}) + \eta y_t + \frac{\gamma}{1-\gamma}(q_t - \psi_t) - (1+\eta)z_t \tag{32}$$

From equation (32), it is evident that the existence of the LOP gap reduces the influence of the real exchange rate on firms' real marginal costs. This is because changes in the nominal exchange rate do not fully translate into changes in imported goods prices. Therefore, if firms optimally insulate local prices from exchange rate movements, the exchange rate has a smaller impact on relative prices of domestic and foreign goods than would be the case otherwise. Moreover, real marginal costs are an increasing function of domestic output and are inversely related to the level of labor productivity.

Price-setting behavior and incomplete pass-through

In the domestic goods market, monopolistic firms are allowed to set prices in a Calvo-staggered manner. In every period *t*, only $1 - w_h$, where $0 \leq w_h \leq 1$, of domestic firms are able to reset their prices optimally, while a fraction w_h can not. Let $\overline{P}_t^h$ denote the price level that optimizing firms set each period. We only consider the case of a symmetric equilibrium where

$P^h_{t,j} = P^h_{t,k} \ \forall j,k$ so we can drop the index j. The aggregate domestic price level then evolves according to:

$$P_t^{h^{1-\theta}} = w_h P_{t-1}^{h^{1-\theta}} + (1-w_h)\overline{P}_t^{h^{1-\theta}}$$

When setting a new price, $\overline{P}^h_t$, in period *t*, an optimizing firm seeks to maximize the current value of its dividend stream subject to a sequence of demand constraints. In aggregate, therefore, the following function is maximized:

$$\max_{\overline{P}^h_t} \sum_{k=0}^{\infty} w_h^k E_t\{\beta^k Q_{t,t+k}[Y_{t+k}(\overline{P}^h_t - MC^N_t)]\}$$

s.t.
$$Y_{t,t+k} \le \left(\frac{\overline{P}^h_t}{P_t}\right)^{-a}(C^h_t + C^{h*}_t)$$

where $Q_{t,t+k} = \left(\frac{C_{t+k}}{C_t}\right)^{-\sigma}\frac{P_t}{P_{t+k}}$ is the discount factor, and MC^N_t is the nominal marginal cost of firms.

The optimal price-setting strategy for a typical firm resetting its price in period *t* can be approximated by the (log-linear) rule[10]:

$$\pi^h_t = \beta E_t \pi^h_{t+1} + \lambda_{\pi^h} mc_t \tag{33}$$

where $\lambda_{\pi^h} = \frac{(1-w_h)(1-w_h\beta)}{w_h}$, mc_t is the deviation of real marginal costs from the steady state, β is the discount factor, and w_h measures the degree of rigidity in price-setting. We also assume that the presence of adjustment costs and habits formations can lead to partial price adjustment, as is done by Svensson (2000), including a backward looking component for inflation.

$$\pi^h_t = \beta_h \pi^h_{t-1} + (1-\beta_h)\beta E_t \pi^h_{t+1} + \lambda_{\pi^h} mc_t$$
$$\text{where } 0 < \beta_h < 1$$

Following a similar Calvo-type pricing procedure we can derive the price setting behavior for domestic importers, assuming that $1 - w_m$ of importers are able to change their prices, while a fraction w_m can not.[11] As mentioned earlier, the imported goods sector in Armenia uses distribution services. Here we are assuming that monopolistic local importer firms import goods and distribute them in the retail market to consumers using domestic labor as an input. As a result, domestic unit labor costs play an influential role in the pricing behavior of these firms.[12] Taking this into account, the cost function of an importing firm can be written as

[10] The detailed derivation of the price setting rule is presented in Galí and Monacelli (2004) and Walsh (2003).

[11] The Philips curve for importers is derived in Monacelli (2005) and Liu (2006).

[12] This assumption differs from Erceg and Levin (1995) and Burstein et. al (2000) who assume that bringing one unit of traded goods to consumers requires some units of nontraded goods. Our model does not make a distinction between tradable and nontradable goods. Instead, we assume that bringing one unit of the imported good to consumers requires labor input.

$$C_t^M(j) = M_t(j)S_tP_t^*(j) + W_tN_t(j) \tag{34}$$

where $M_t(j)$ is the volume of the j goods imported by the firm, $S_tP_t^*(j)$ is the cost of importing good *j*, W_t is the domestic economy wage, and $N_t(j)$ is number of employees required for selling $M_t(j)$ amounts of the imported good. We assume that demand for employees $N_t(j)$ is a function of volume of imported goods sold $M_t(j)$ and the productivity of employees. For analytical tractability, we assume that the productivity of employees in the imported good sector is identical to that of the domestic economy Z_t.

$$N_t(j) = \frac{M_t(j)}{Z_t}$$

Using this relationship, the cost function of the importer firm can be written as:

$$C_t^M(j) = M_t(j)S_tP_t^*(j) + \frac{W_tM_t(j)}{Z_t}$$

Dividing both side of the above equation by $M_t(j)$, the nominal marginal cost of importer firm can be written as

$$MC_{m,t}^N(j) = S_tP_t^* + MC_t^N \tag{35}$$

where $MC_{m,t}^N \; and \; MC_t^N$ are the nominal marginal costs of importers and domestic producers, respectively. This specification assumes that the LOP holds at the wholesale level for imports. However, a wedge is introduced between world and domestic import prices in the imported good sector on two accounts: (i) due to inefficiencies in distribution channels and monopolistic retailers which keep domestic prices above marginal cost (LOP gap), and (ii) the assumption that the costs of importers depend upon nominal marginal costs in the domestic economy because of the need for domestic labor-input intensive distribution services.

Following a similar Calvo-type pricing procedure discussed earlier, an importer firm *j* setting a new price in period *t* seeks to maximize the present value of its dividend stream subject to the demand constraints:

$$\max_{\overline{P}_t^m} \sum_{k=0}^{\infty} w_m^k E_t\{\beta^k Q_{t,t+k}[C_{t+k}^m(j)(\overline{P}_t^m(j) - S_{t+k}P_{t+k}^*(j) - MC_t^N)]\}$$

$$\text{s.t.} \quad C_t^m(j) = \gamma\left(\frac{\overline{P}_t^m(j)}{P_t}\right)C_t^m$$

where $\overline{P}_t^m$ is the optimal price set by firms adjusting their price in period *t*. The aggregate price level of the imported good then evolves according to:

$$P_t^{m^{1-\theta}} = w_m P_{t-1}^{m^{1-\theta}} + (1 - w_m)\overline{P}_t^{m^{1-\theta}}$$

The FOC results to following expression

$$\sum_{k=0}^{\infty} w_m^k E_t\{\beta^k Q_{t,t+k}[C_{t+k}^m(j)(\overline{P}_t^m(j) - \frac{a}{1-a} MC_{m,t}^N)]\} = 0$$

Log-linearization of the first-order condition around the steady state and log-linearization of the equation for imported good inflation gives us:[13]

$$\pi_t^m = \beta E_t \pi_{t+1}^m + \lambda_{\pi^m} \psi_t^m \tag{36}$$

where $\lambda_{\pi^m} = \frac{(1-w_m)(1-w_m\beta)}{w_m}$, and $\Psi_t^m = \frac{MC_{m,t}^N}{P_t^m} = \frac{S_t P_t^* + MC_t^N}{P_t^m}$ is the real marginal cost of importer firms. Log-linearizing around the steady state gives us

$$\psi_t^m = (1-\gamma_\psi)(p_t^h + mc_t) + \gamma_\psi(s_t + p_t^*) - p_t^m = (1-\gamma_\psi)mc_t - \frac{1-\gamma_\psi}{1-\gamma} q_t + \frac{1-\gamma\gamma_\psi}{1-\gamma}\psi_t \tag{37}$$

where $(1\text{-}\gamma_\psi)$ is the share of employee compensation in the total cost of the imported good distribution sector. Equations (36) and (37) imply that in setting the new price of imports, domestic retailers are concerned about the future path of imported good inflation, the LOP gap, as well as nominal marginal costs in the domestic economy. The latter two features of the model provide a mechanism for incomplete pass-through of import prices in the short run. As a result, large movements in the nominal and real exchange rates translate into small changes in consumption, employment, and price levels.

The key difference between the above equations and those in Monacelli (2005) and Liu (2006) is the introduction of domestic nominal marginal costs in the importers' cost function.[14] This assumption implies that changes in world import prices have an even more gradual impact on the domestic economy than in the above-mentioned papers. As a result, the aggregate price level and wages and, hence, real marginal costs are even less responsive to movements in the real exchange rate.

As in the case of the home goods inflation equation, we introduce adjustment cost and habit formations in the imported goods inflation equation.

$$\pi_t^m = \beta_m \pi_{t-1}^m + (1-\beta_m)\beta E_t \pi_{t+1}^m + \lambda_{\pi^m}\psi_t^m$$

where $0 < \beta_m < 1$. Log-linearizing the definition of CPI and taking the first difference yields the following relationship for overall inflation

$$\pi_t = (1-\gamma)\pi^h + \gamma\pi^m$$

[13] The detailed derivation of equation (36) is similar to that for home good inflation equation.

[14] In the mentioned papers, the LOP gap and real marginal cost of importer firms are identical.

where π_t is overall inflation in the economy.

C. Equilibrium

Demand block

Goods market clearing in the domestic economy requires that domestic output is equal to the sum of domestic and foreign consumption of home produced goods (domestic exports) and consumption of distribution services :

$$y_t = k_1 c_t^h + k_2 c_t^m + (1 - k_1 - k_2) c_t^{*h} \tag{38}$$

where k_1 is the share of domestic consumption, and $k_2 = \frac{C^m}{Y}(1 - \gamma_\psi)$ is the share of the imported good distribution sector demand for home-produced goods. The underlying idea behind this specification is that imported goods consumption includes a part of the domestically-produced good as a distribution service. This distribution service is purchased together with the imported good. In equilibrium, therefore, changes in demand for the imported good result in changes in the aggregate demand for domestically produced goods.[15]

Assuming the same productivity for the whole economy and using equations (13) - (16), (20), and (23), we can write the goods market clearing condition for the domestic economy as:

$$\begin{aligned} y_t = {} & [k_1 a\gamma - a k_2 (1-\gamma) + (1 - k_1 - k_2) a^*] \delta_t + (1 - k_1 - k_2) a^* \psi_t \\ & + (1 - k_1 - k_2) y_t^* + (k_1 + k_2) c_t \end{aligned} \tag{39}$$

Simplifying the above equation and expressing it in terms of the real exchange rate, we get

$$y_t = d_1 q_t - d_2 \psi_t + (k_1 + k_2) c_t + (1 - k_1 - k_2) y_t^* \tag{40}$$

where $d_1 = \frac{k_1 a\gamma}{1-\gamma} - a k_2 + \frac{(1-k_1-k_2)a^*}{1-\gamma}$, $d_2 = \frac{k_1 a\gamma}{1-\gamma} - a k_2 + \frac{(1-k_1-k_2)\gamma a^*}{1-\gamma}$, and q_t is the real exchange rate.

Monetary policy rule

To complete the small open economy model, we need to introduce an equation of an endogenously determined interest rate as a monetary policy rule. The operational procedure of the central bank is to manage the short-term interest rate to stabilize both output and inflation in order to fully restore the flexible price equilibrium (see Svensson, 2005). We use a simple rule rather the optimal rule under commitment and discretion because the latter is more complicated and difficult to communicate to the public. Moreover, as the Armenian economy is at an early stage of implementing inflation targeting, a simple well-understood monetary policy rule is more applicable.

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[15] Our specification of the distribution sector is in the spirit of a remark made by Tirole (1995, page 175) that "production and retailing are complements, and consumers often consume them in fixed proportions"

We rely on the rule used by Benes et al. (2007), distinguishing central bank responses to movements in home and imported good inflation. Specifically, we assume the following reaction function:

$$i_t = \mu_i i_{t-1} + (1-\mu_i)(\mu_{\pi_h}\pi_t^h + \mu_{\pi_m}\pi_t^m) \tag{41}$$

where μ_i denotes the degree of the central bank's willingness to smooth the interest rate, and μ_{π_h} and μ_{π_m} are the relative weights on the reaction of the interest rate to home and imported good inflation.

Appendix A provides a summary of the linearized model consisting of equations for the endogenous variables and the exogenous process.

D. Model Calibration and Estimation

Data from 2002Q4 to 2007Q4 for Armenia is used in the analysis. All variables are re-scaled to have a mean of zero and can be interpreted as an approximate percentage deviation from the mean. See Appendix B for a more detailed description of the data transformations.

We use a combination of estimation and less formal calibration approaches in parameterizing the model. Specifically, we distinguish between three basic groups of parameters: (i) steady-state values of the observed macroeconomic variables; (ii) autoregressive coefficients, and (iii) behavioral parameters. The first set of coefficients are parameterized using data for the Armenian economy. The autoregressive coefficients or parameters that describe the properties of the stochastic process are estimated using OLS. Finally, we use a Bayesian approach to estimate the behavioral coefficients of the model.

We parameterize the steady-state parameters as follows. The ratio of government expenditure to GDP (k_3) is assumed to be 0.15 on the basis of observed fiscal ratios during the period 2002-2007. The ratio of exports to GDP for same period is 0.2. The imported good distribution sectors' share in total demand (k_2) is assumed to be in line with the ratio of retail trade employment in total employment (0.1 on average). Taking into account the ratio of imports to GDP for this period (0.38), we derive the coefficient of the share of nominal marginal costs in total costs of the importing firms as $1-\gamma_\psi = \frac{0.1}{0.38} = 0.26$, or $\gamma_\psi = 0.74$. The ratio of private expenditures to GDP (k_1) is then determined from the above as equal to 0.55. The share of imported goods in consumption (γ) is calculated from the CPI basket to be 0.25.

The behavioral parameters of the model are estimated using a Bayesian approach. The choice of priors for our estimation is guided by several considerations. Information on the structural characteristics of the Armenian economy and its institutional settings were all taken into account. In addition, the standard deviation of the priors and the shocks, which are important for Bayesian estimations, were taken from other research papers similar to ours. Given the large degree of uncertainty about the initial estimations of standard deviations, adjustments were made to parameter values to conform with features of the Armenian economy. In particular, adjustments to parameter values were made by matching business cycle properties implied by the model with those observed using actual data of Armenian economy, including a fitting of the historical forecast to actual data. A summary of the parameter values is provided in Table 1.

Table 1. Model Parameter Values

k_1	= 0.55	a^*	= 0.73	ρ_z	= 0.74
k_2	= 0.10	β_h	= 0.65	ρ_ξ	= 0.75
k_3	= 0.15	β_m	= 0.45	ρ_{gov}	= 0.63
β	= 0.99	β_q	= 0.25	ρ_{y^*}	= 0.75
h	= 0.65	ω_h	= 0.65	ρ_{π^*}	= 0.50
σ	= 1.86	ω_m	= 0.80	ρ_{i^*}	= 0.82
η	= 1.30	γ_ψ	= 0.26		
a	= 0.73	γ	= 0.25		

IV. MODEL PROPERTIES

A. Impulse Responses

In this section, we present the model's behavior in response to shocks.[16] In particular, we examine impulse response functions to a temporary shock—a unit increase change in the first period of simulation.

Domestic inflation shock (Figure 3)

A domestic inflation shock initially worsens domestic competitiveness by generating a real exchange rate appreciation. The monetary authority responds to the higher rate of inflation by raising interest rates, which generates a further real exchange rate appreciation. This eventually reduces output via a decline in export demand and consumption and by inducing a substitution effect away from the home good and towards imported goods. However, the existence of the LOP gap make changes in imported good prices less responsive to the exchange rate movements. As a result, the central bank increases interest rate by more than would have been the case with complete pass-through. Domestic output and consumption decline in response to the monetary tightening. An appreciation of the exchange rate due to monetary tightening also serves as another channel to bring inflation back to equilibrium 20 quarters later.

Imported inflation shock (Figure 4)

A positive imported good inflation shock initially improves domestic competitiveness, and induces expenditure switching towards domestically-produced goods. However, overall inflation is higher on impact, with higher import prices pushing up the cost of production. The monetary authority responds to the higher overall inflation by raising interest rates, which, in turn, causes consumption to fall and the real exchange rate to appreciate. These two factors outweigh the initial increase in demand for domestic goods due to improved competitiveness, and generate a reduction in output.

[16] The dynamic simulation was conducted by the Iris-toolbox which was kindly provided by Tibor Hledik and Jan Vlcek of the Czech National Bank.

Productivity shock (Figure 5)

A temporary productivity shock reduces real marginal cost of firms, enabling them to lower prices of domestically-produced goods. This, in turn, increases the degree of domestic competitiveness and will see domestic agents substitute out of foreign-produced goods into home-produced goods. The impulse analysis shows that consumption is higher on impact. However, output initially increases by less than the increase in productivity as agents' substitution between work and leisure dominates the lower cost of production. Inflation falls initially as the higher labor productivity reduces production costs. The monetary authority responds to deflation by lowering interest rates somewhat, taking into account the output-inflation tradeoff. Lower interest rates generate an exchange rate depreciation, which has limited impact on imported inflation due to rigidities in the imported good sector. The positive output gap reduces deflation in the future as interest rates gradually rise to restore equilibrium.

Remittance shock (Figure 6)

Following a remittance shock, the nominal and real exchange rate appreciate on impact. The resultant worsening in competitiveness initially lowers output. However, the existence of rigidities in the imported goods sector weakens the responsiveness of import prices to the exchange rate appreciation. On the other hand, domestic prices fall slightly in response to the lower output. As a result, the monetary authority responds to deflation by lowering interest rates, which generates a nominal depreciation. The risk sharing condition implies that remittances increase consumption due to an income effect, but the exchange rate appreciation serves to partially dampen consumption.

Foreign output shock (Figure 7)

A shock to foreign output increases both foreign and domestic consumption from the risk sharing condition. As a result, real marginal costs and domestic inflation increase. However, the higher foreign output increases demand for exports, which causes the nominal and real exchange rate to appreciate, but the presence of rigidities in the imported goods sector initially weakens the responsiveness of import prices. The monetary authority responds to the higher overall inflation by raising interest rates. While the nominal exchange rate appreciates on impact, it eventually depreciates on account of the permanent positive interest rate differential. The positive real interest rate and real exchange rate appreciation reduce output and lower overall inflation during the stabilization period.

In contrast to a shock to remittances, we now have higher domestic output and consumption in the first period. There are several reasons for this. First, a shock to foreign output influences domestic output through two different channels: (i) an increase in foreign demand for domestic exports; and (ii) an increase in consumption from the risk sharing condition, which implies that the higher foreign output is divided between foreign and home consumption. As remittances constitute direct income from abroad, domestic consumption is influenced by intertemporal consumption smoothing behavior. As a result, domestic consumption increases more on impact in the case of a foreign output shock, while in the case of remittances shock, it initially increases by less but remains positive over a longer period. Second, a remittances shock affects on exchange rate through the uncovered interest parity condition, which captures the capital inflow character of remittances. This implies that an inflow of remittances results in an appreciation of the domestic currency in the first instance.

Policy interest rate shock (Figure 8)

A one percent increase in the interest rate reduces consumption from the intertemporal substitution condition and sharply appreciates the nominal and real exchange rate. The latter, in turn, will see domestic agents substitute out of domestically-produced goods and into foreign-produced goods. Firms respond to the lower demand by reducing nominal wages and cutting costs of production, which causes prices of domestically-produced goods to eventually decline. Moreover, prices of imported goods decline somewhat in response to the real exchange rate appreciation. The monetary authority responds to the negative impact on output and inflation by lowering the nominal interest rate, such that the policy interest rate rises by less than percent. The exchange rate reacts positively to the monetary tightening before returning to equilibrium.

Figure 3. Home Good Inflation Shock

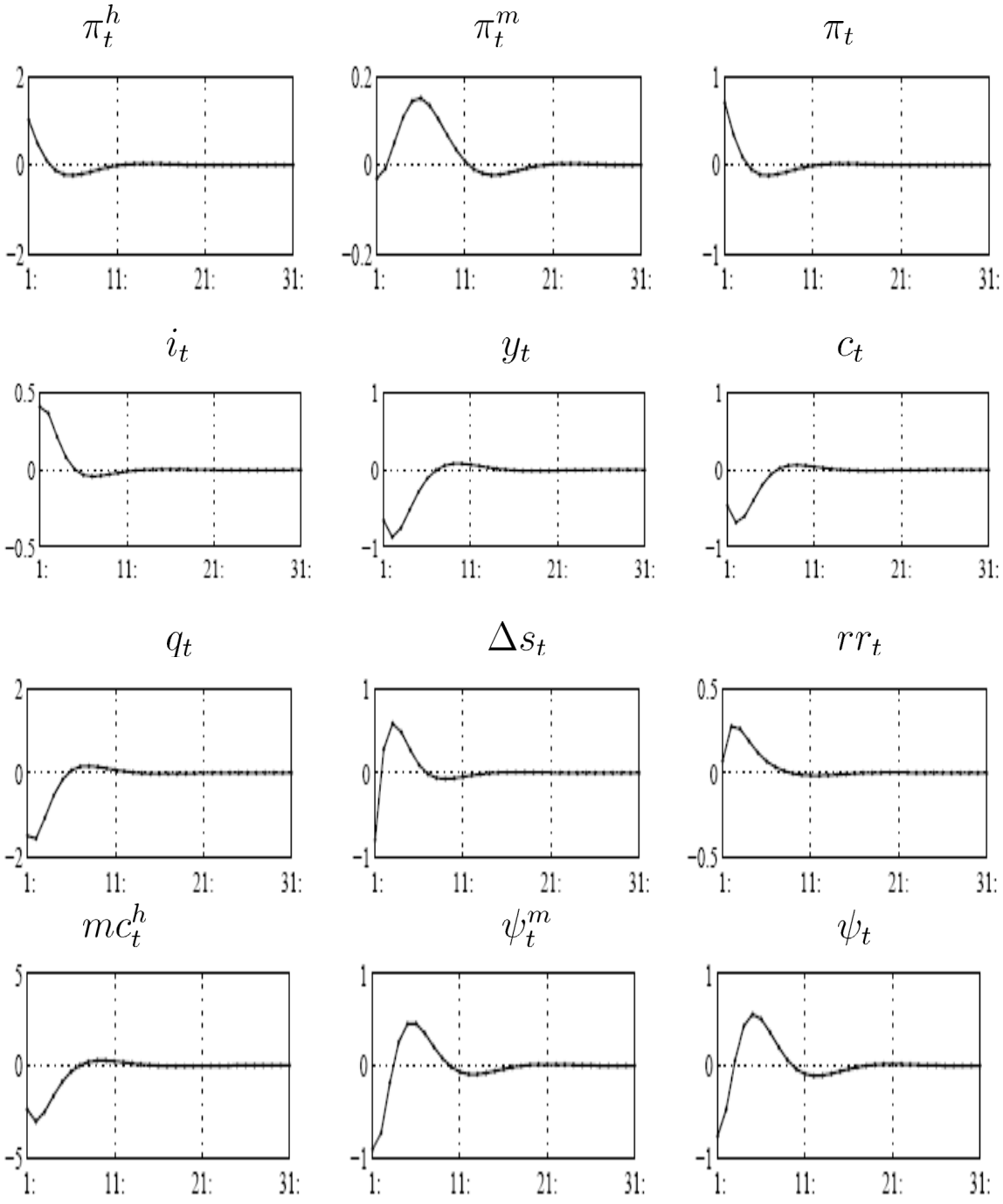


Figure 4. Imported Good Inflation Shock

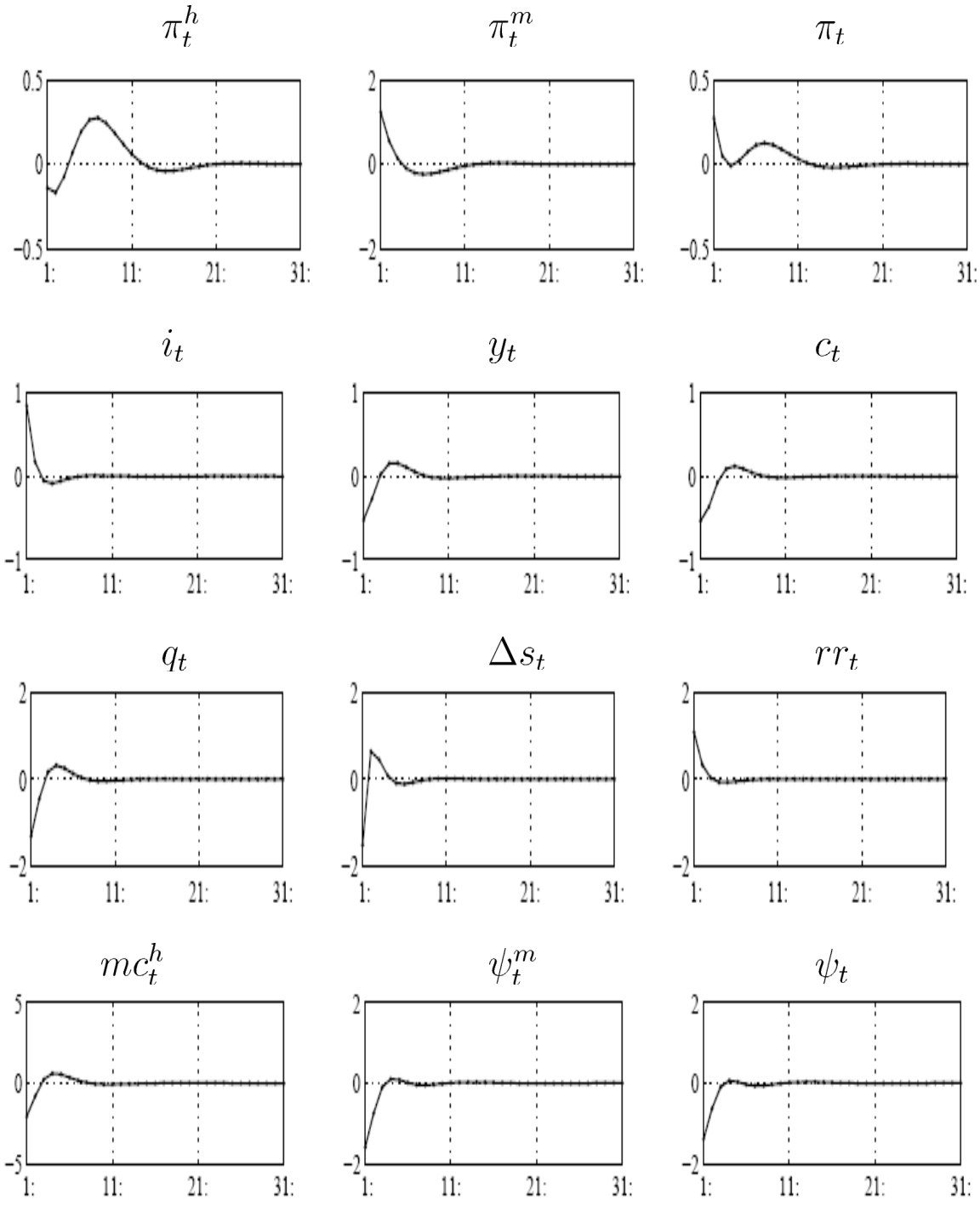


Figure 5. Productivity Shock

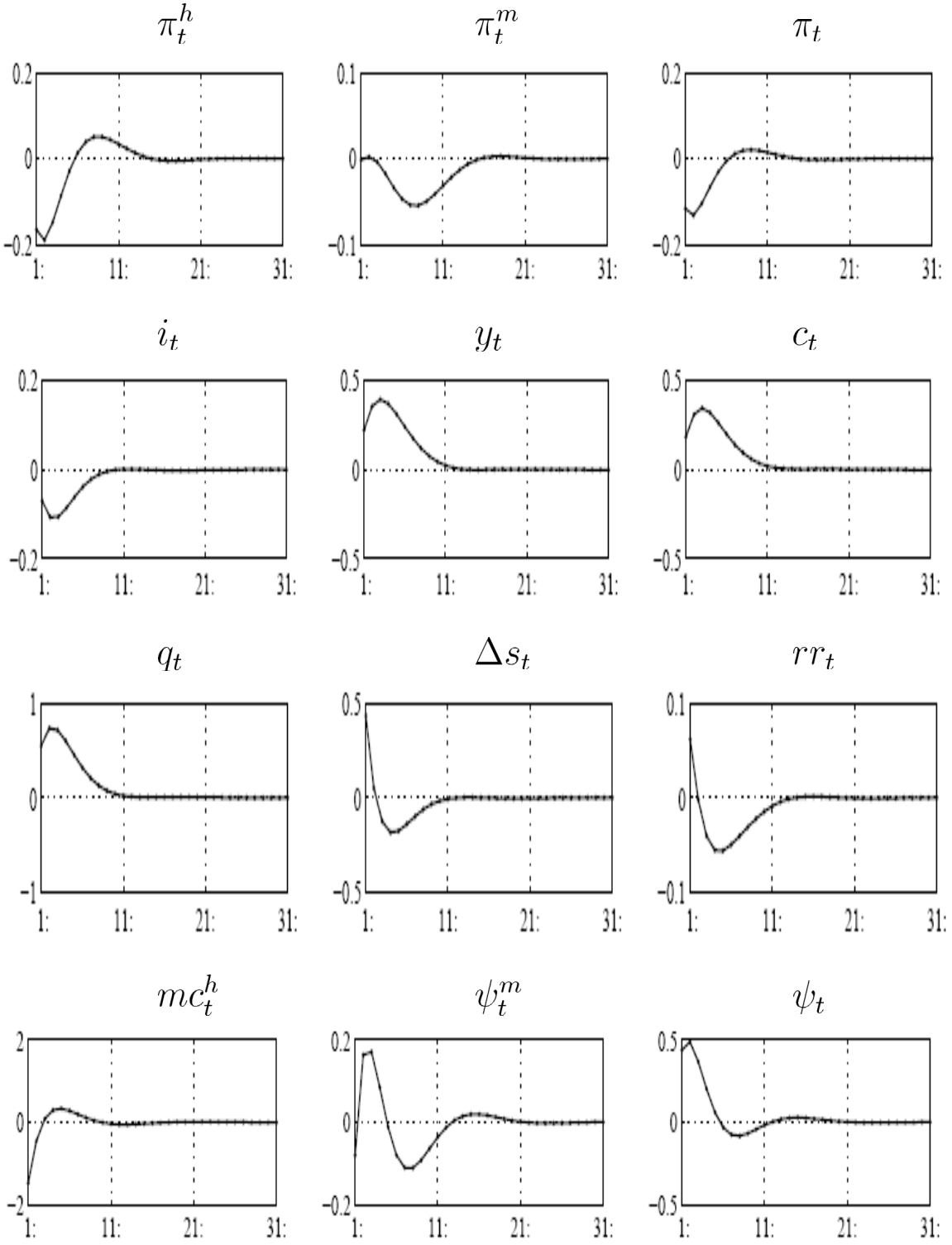


Figure 6. Remittances Shock

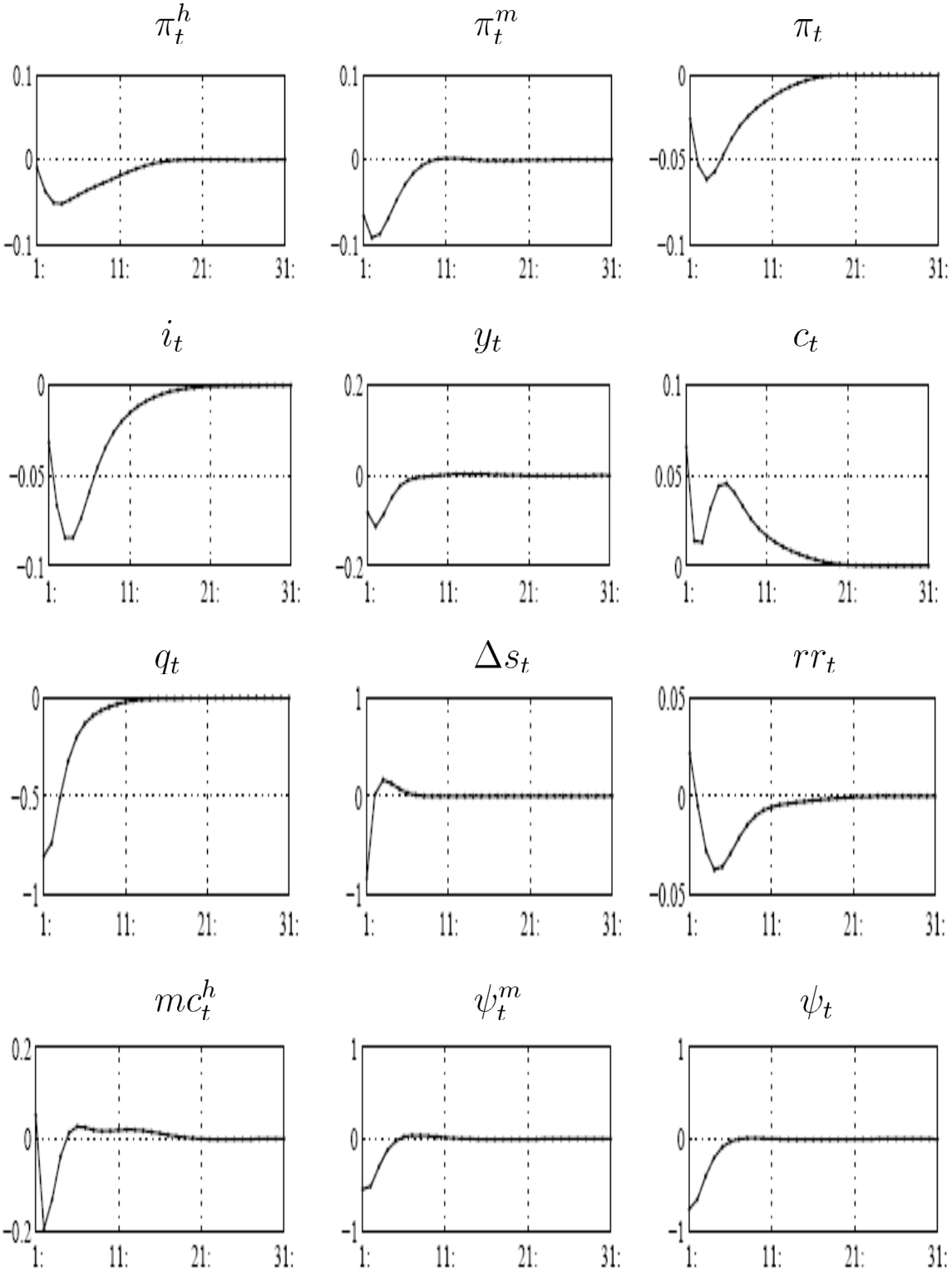


Figure 7. Foreign Output Shock

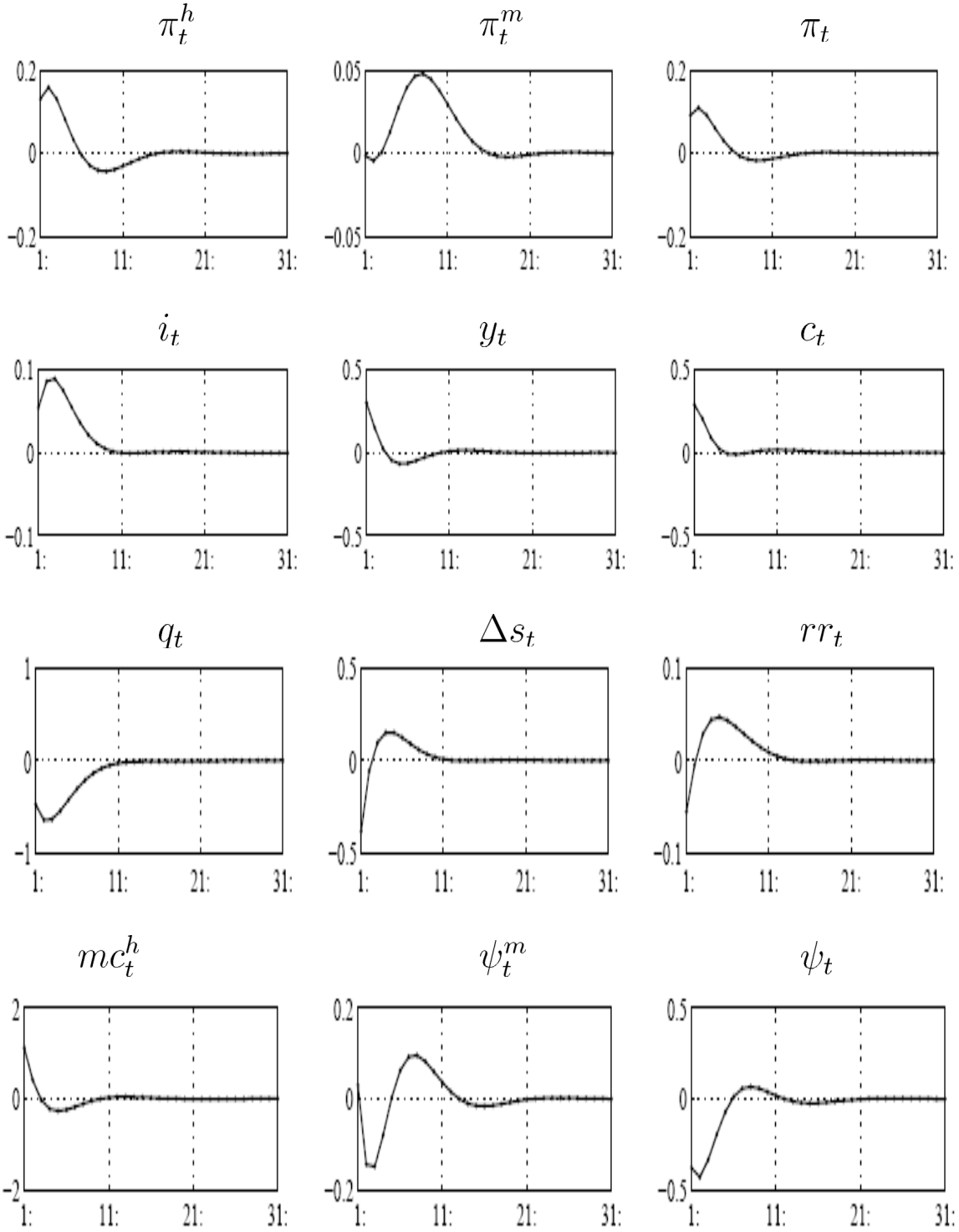
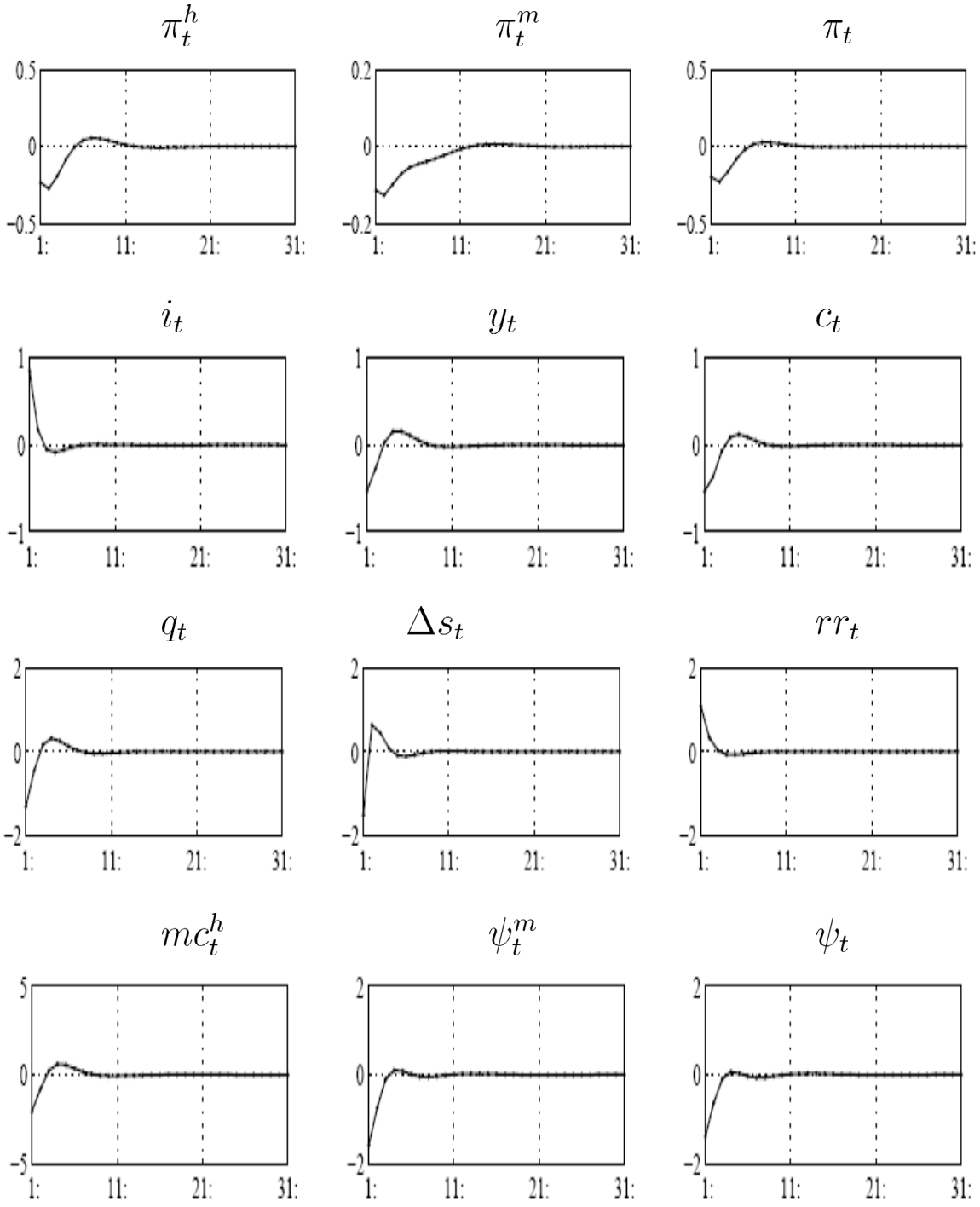


Figure 8. Policy Interest Rate Shock



B. Correspondence Between the Model and Observed Data

In this section we utilize a variety of approaches to examine the correspondence between the model and Armenian data. First, to examine the aspects of the actual data that the model replicates, we compare the model's various structural shocks with the business cycle patterns described in Section II. The estimation of the structural shocks involves examining between the variables estimated by the model and the observed data. Second, given the parameterization of the model, including standard deviation of shocks, we compare the asymptotic distributional aspects of the Armenian data to those predicted by the model. Finally, we examine the model's sample forecasting properties by performing a series of historical forecasts with the model.

Analysis of historical shocks

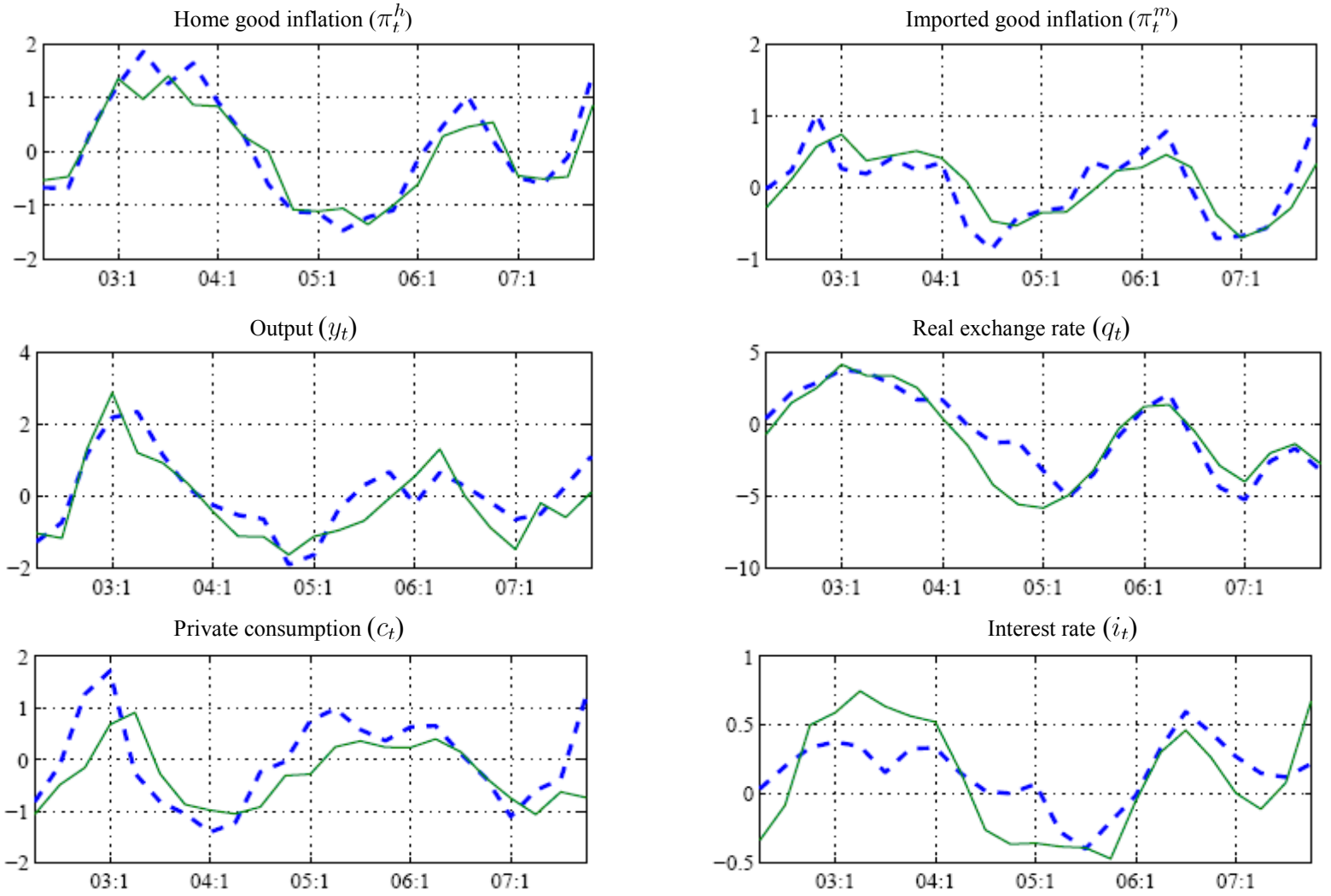
Figure 9 summarizes the comparisons of the observed data and estimated variables of the model, while Figure 10 presents the estimation results in terms of shocks. The results indicate that the business cycles patterns in the observed data are largely explained by the model.

The most significant deviation between the model and historical data is in the behavior of the real exchange rate over the period 2004Q3 to 2005Q2. The rapid increase in remittance inflows from 2005Q3 resulted in a sharp appreciation of the exchange rate. Prior to this period, the exchange rate had shown a strong trend depreciation. As a result, expectations of households were geared toward a further depreciation rather than appreciation of the currency. These expectations were the main reason for the exchange rate to not appreciate by as much as suggested by the observed data. In the model, the risk premium for future depreciation increased, which according the uncovered interest rate parity condition, is akin to an exchange rate shock. This is also confirmed by the observed data. At the same time, central bank interventions to smooth volatility in the exchange rate market during this period also represent an exchange rate shock. Figures 10-11 show that these kind of shocks hit the economy for almost a year.

The estimation results place the period of rapid dedollarisation (from 2006Q3 to 2007Q4) as a shock to the exchange rate. This kind of shock is also connected to the risk premium. The sustained appreciation created expectations of a continuing currency appreciation, and a resulting decline in the risk premium. This is also confirmed by actual data which show a rapid growth in demand for the domestic currency at the expense of the foreign currency. The other important shocks took place starting end-2006 are relevant for home and imported good inflation. Since end-2006 there was surge in global oil and food prices, which the model correctly shows as shocks to both home and imported good inflation.

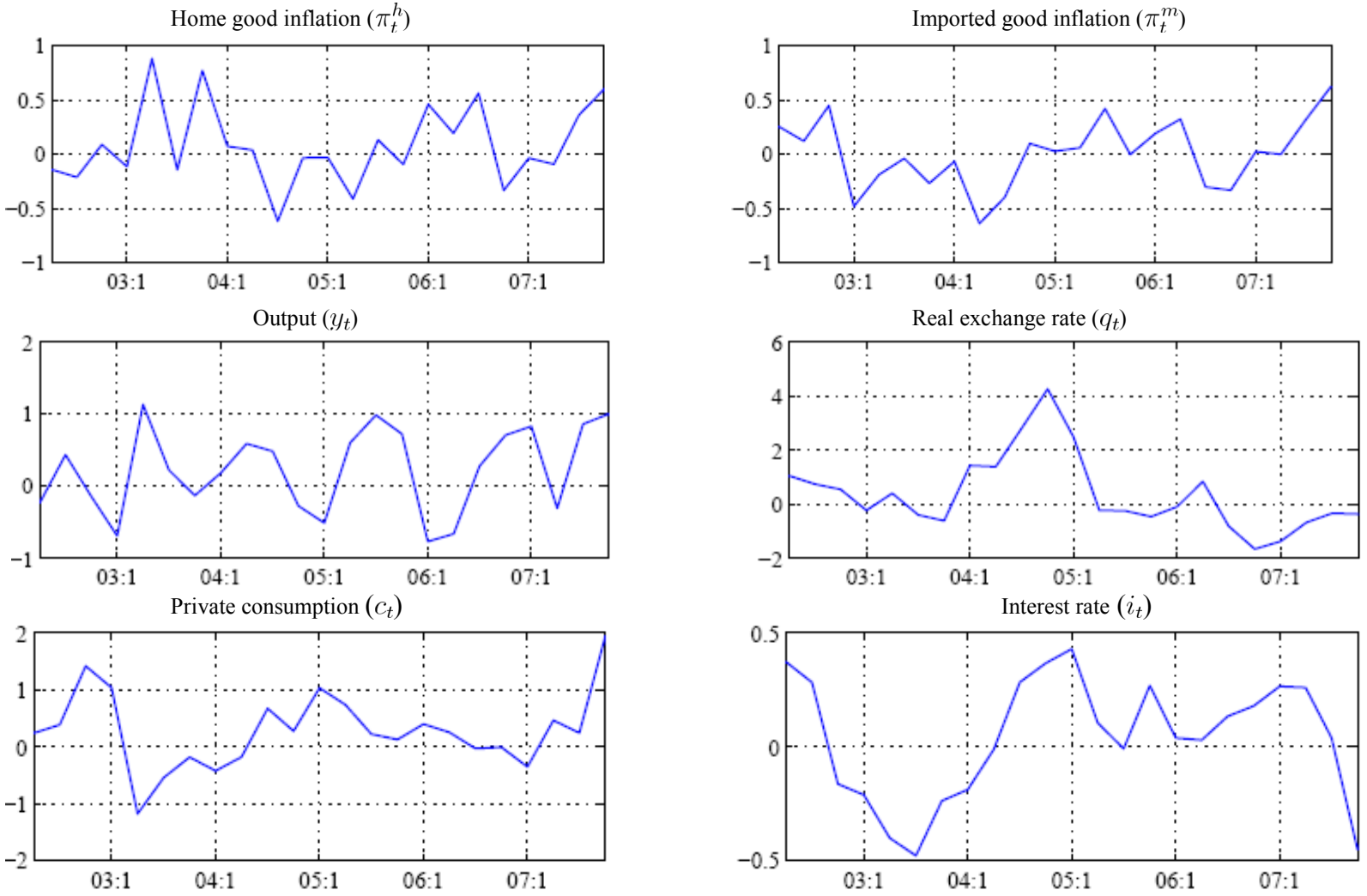
Interest rate estimations show a larger deviation from the actual data in the period prior to the adoption of inflation targeting. With the implementation of inflation targeting (in 2006), the estimated interest rate closely tracks the actual data, except for the last quarter of 2007. As mentioned above, in this period shocks to inflation were related to surging global commodity prices, with considerable uncertainty about the duration of these shocks. As a result, the central bank did not respond to commodity price shocks shock by the same magnitude as model estimations imply.

Figure 9. Estimated and Observed Variables*



* Solid line represents actual data.

Figure 10. Estimated Structural Shocks



Comparison of stylized facts.

In this section, we analyze some of the second-moment features of the model—standard deviations, autocorrelations and cross-correlations—against the background of observed data For the model, second moments are estimated using the model structure, estimated equation coefficients, and standard deviations of the estimated structural shocks. Business cycle patterns in the observed data are obtained by estimating the second (VAR implied) population moments of selected data series taking into account sampling uncertainty.[17] The variables chosen are those most relevant for characterizing the monetary policy transmission. We compare the model-implied properties with their observed counterparts for home and imported good inflation, output, real interest rate, real exchange rate and the real marginal cost of importer firms (coefficient of 0.74), and the LOP gap.

Visual inspection of a comparison of the standard deviations in Figure 11 shows that the model largely captures the relative variability of the observed data series (the figure reports standard deviations relative to the point estimate of the variables). In particular, the model matches very closely the standard deviations of home good inflation and the real interest rate. The results are less compelling for the real exchange rate, on account of the shocks to risk premium discussed earlier. However, the behavior of the real exchange rate estimated by the model reflects the influence of real marginal cost of importer firms, imported goods inflation, and output.

In capturing the estimated data persistence the model performs reasonably well (as measured by auto-correlations). As shown in Figure 12, the model captures well the persistence in home and foreign good inflation, the real exchange rate, and the real interest rate. However, it understates the persistence of output growth and the real marginal cost of importer firms.

The model also matches reasonably well the observed co-movements in the data (Figure 13). The model captures very well the negative cross-correlations between real interest rate and output and home good inflation. This observation is important as it confirms that economic activity may indeed be an important factor determining domestic good inflation in Armenia. The model also does well with the co-movements between the following: imported good inflation and the real marginal cost of importer firms, output and the real exchange rate, real interest rate and the real exchange rate, remittances and the real exchange rate. The correlation between home good inflation and the output gap, however, is low. This could, in part, follow from the assumption of perfect labor markets adopted in the model. In reality, frictions in labor markets could render the Philips curve different from what is assumed in the model.

[17] The observed characteristics are constructed using a bootstrap technique based on an estimated reduced-form VAR model on detrended and seasonally adjusted data. We resample 5000 times from the estimated VAR using the wild bootstrap technique, re-estimate the VAR parameters and re-construct the desired characteristics (see Benes and others (2007) for a more detailed description).

Figure 11. Population Standard Deviations

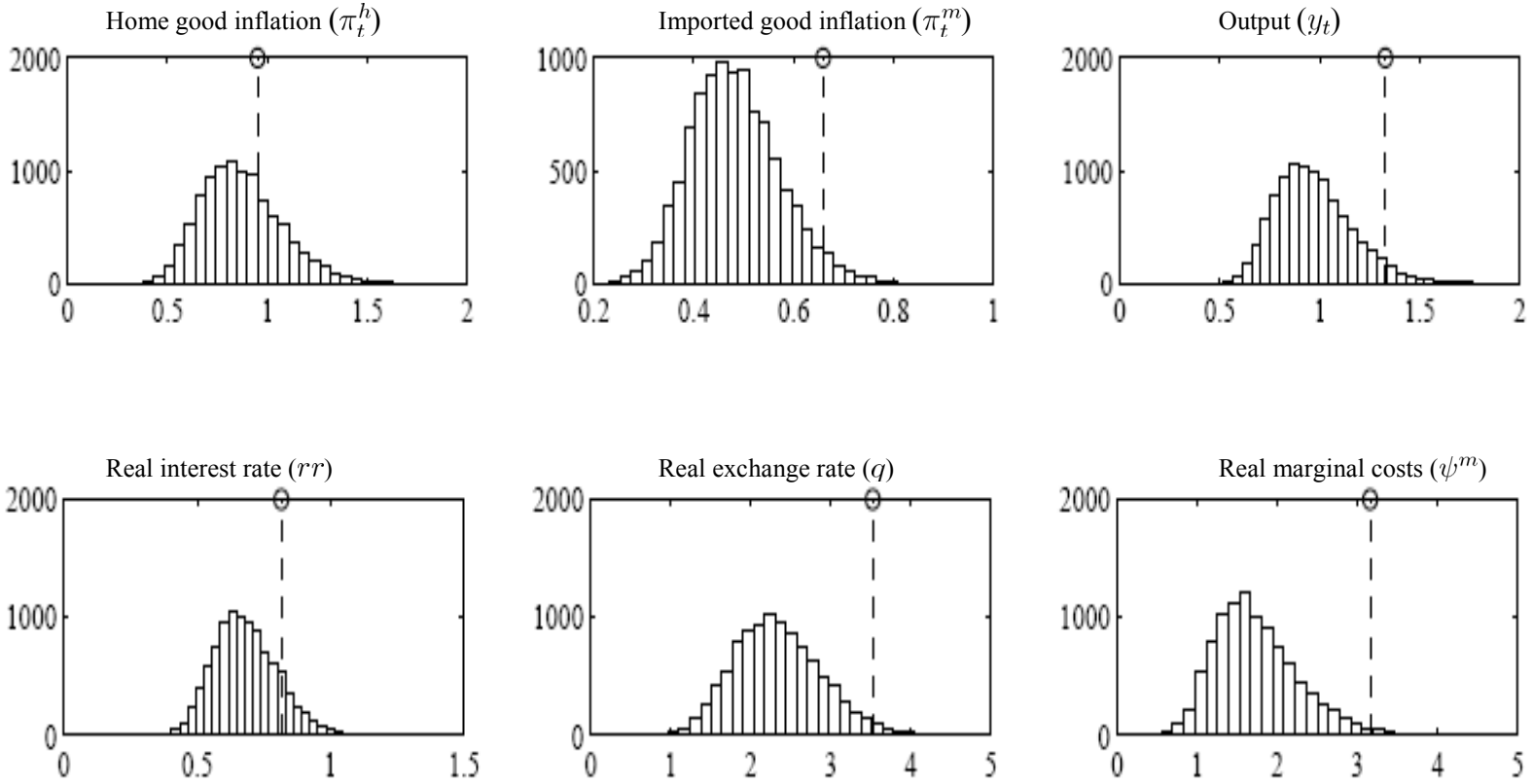


Figure 12. Population Autocorrelation Coefficients

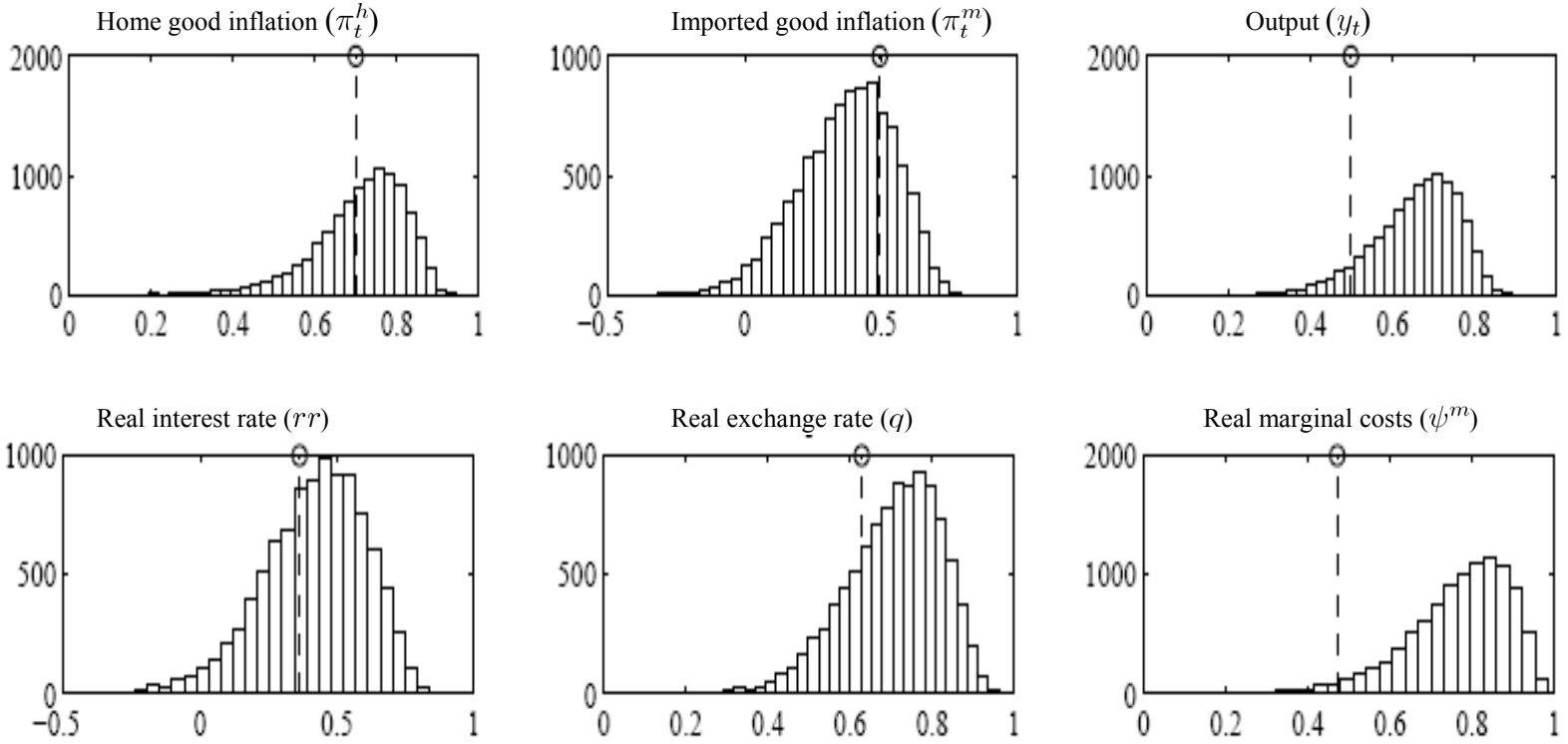
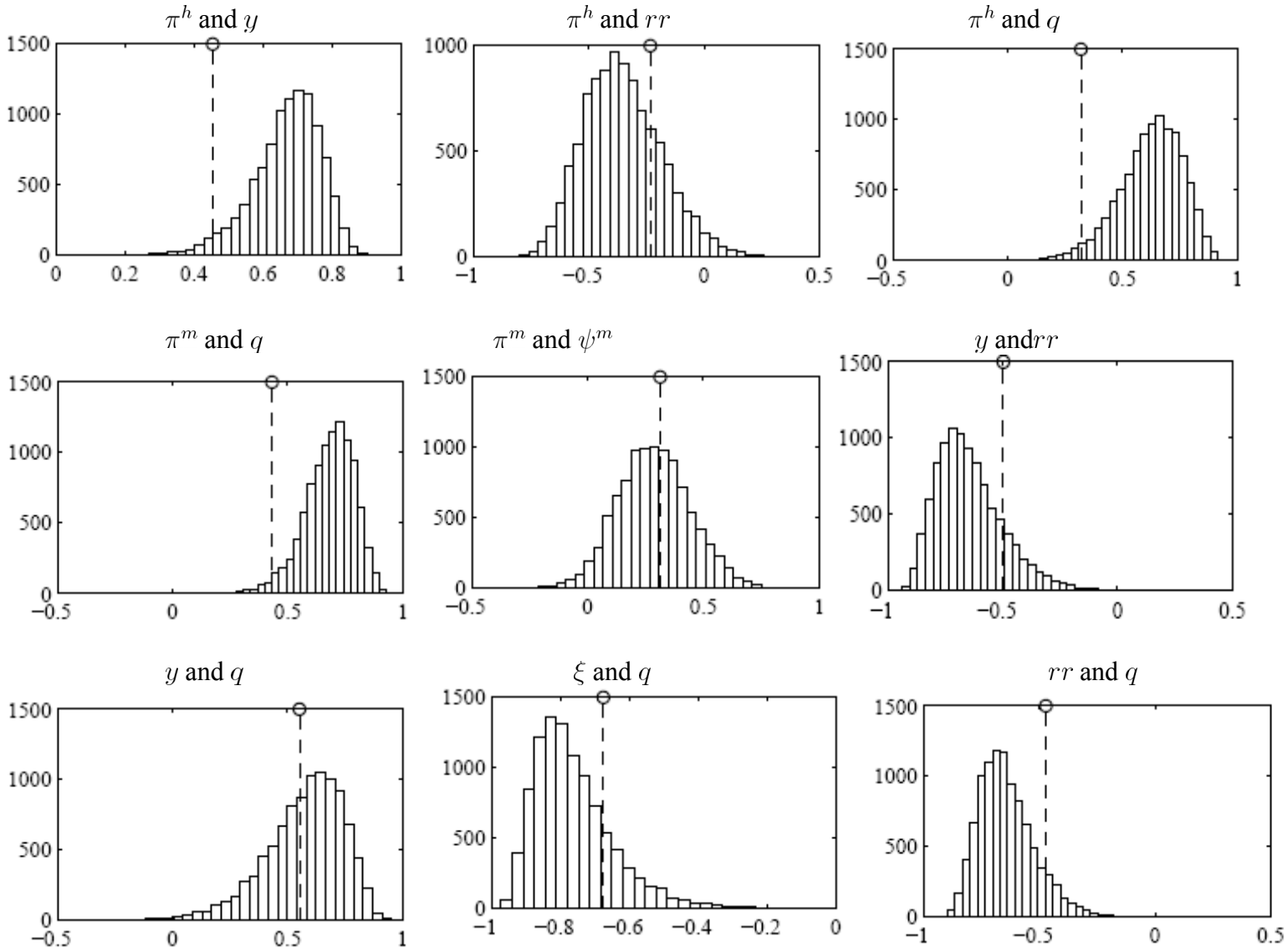


Figure 13. Population Cross-Correlation Coefficients



Historical simulations

We also examine the model's capacity to address observed phenomena by testing its forecasting properties on the historical sample. In this exercise, we perform a series of model simulations starting at various points in time to examine how useful the model would have been to capture business cycle movements observed in the Armenian economy.

The model simulations are presented in Figure 14. As can be seen from the figure, the model predicts well the overall movements in the output gap and home and imported inflation. Model predictions of real exchange rate movements are also in line with the business cycle patterns observed in the data. However, as discussed earlier, shocks to the risk premium that took place during periods of rapid remittance growth and dedollarisation lower forecasting accuracy somewhat. The model does not capture well the movements in the interest rate in the period prior to adoption of inflation targeting. However, with the adoption of inflation targeting in 2006, the correspondence between the model's prediction for interest rate behavior improves significantly.

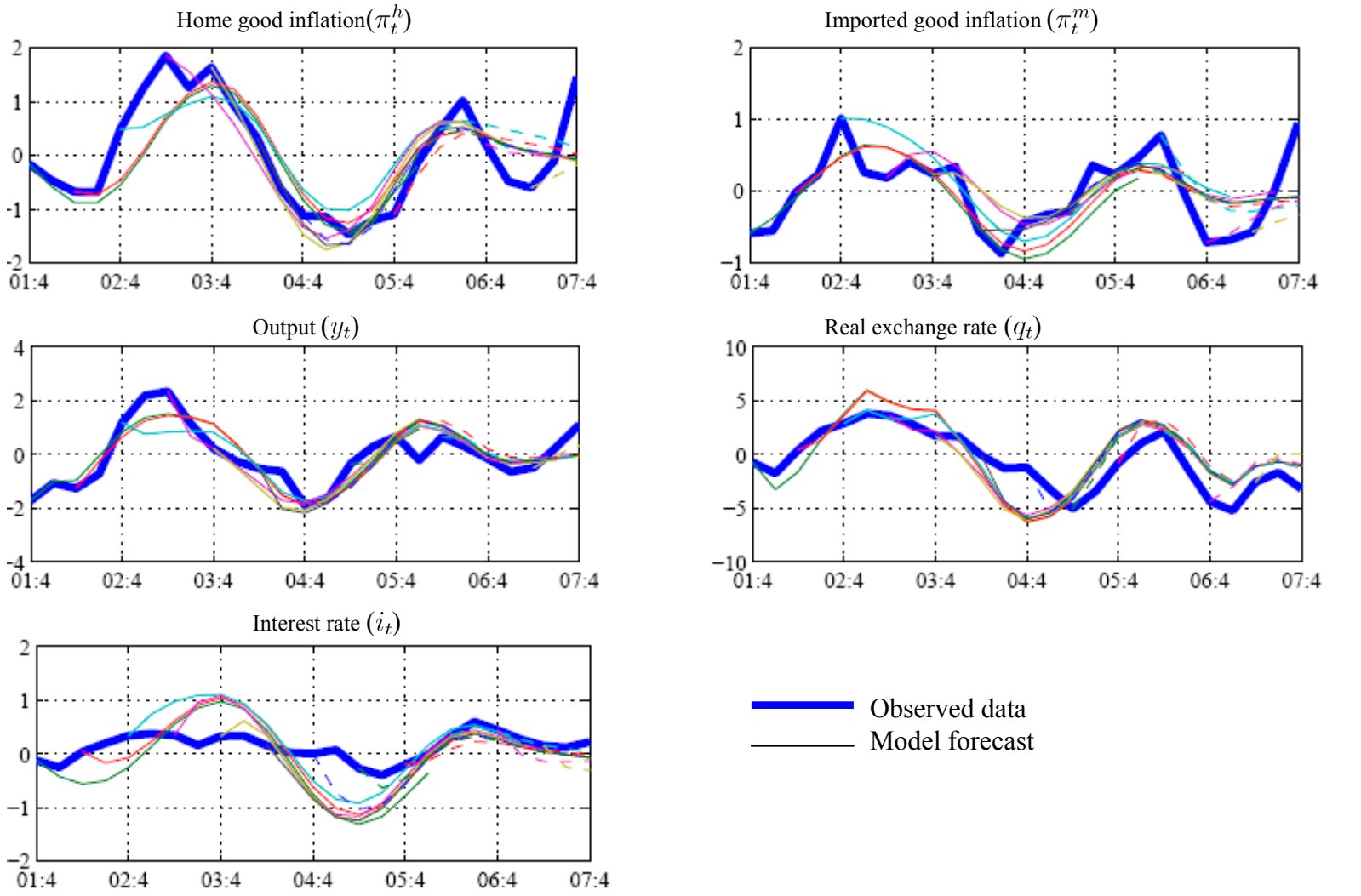
V. CONCLUSION

In this paper we develop a dynamic stochastic general equilibrium model of the Armenian economy. The model is based on a standard small open economy gap model and captures the pertinent features of the monetary policy transmission mechanism. The model and the set of estimated parameters can be used to guide future monetary policy questions in Armenia.

Our main contribution lies in capturing some key country-specific features in the model. First, we add an important source of nominal rigidity in the imported good sector in the Armenian economy by assuming the imported good sector uses labor services, suggesting the importance of domestic unit labor costs in firms pricing decisions. This implies that the aggregate price level and wages and, hence, real marginal costs are even less responsive to movements in the real exchange rate than in standard models with nominal rigidities. Second, we incorporate remittances in the model, given their importance in influencing output and the real exchange rate since 2004. Remittances are modeled as a negative preference shock for foreign households, who derive utility from a motive to remit income or to invest in the domestic economy at the expense of its own consumption. The model also captures the influence of remittances on the exchange rate (through the uncovered interest rate parity condition), which is important for understanding developments in the Armenian economy.

In calibrating the model to the Armenian economy, we demonstrate the model's capacity to capture many of the observed features of the data and policy responses. The analysis of the model's properties show that the main stylized features relevant for monetary policy transmission mechanisms in Armenia are well captured by the model. We also show that the model is of value in forecasting the economic adjustments and policy responses needed following the adoption of inflation targeting.

Figure 14. Historical Model Forecasts



Appendix A: Model Equations

Consumption equation[18]

$$c_t = hc_{t-1} - \frac{1-h}{\sigma} rr_t + y^*_{t+1} - hy^*_t + \frac{1-h}{\sigma} q_{t+1} + \frac{1-h}{\sigma} \xi_{t+1}$$

Good market clearing condition

$$y_t = d_1 q_t - d_2 \psi_t + (k_1 + k_2) c_t + (1 - k_1 - k_2) y^*_t$$

Uncovered interest parity

$$q_t = E_t q_{t+1} - rr_t + rr^*_t - (\xi_t - \xi_{t+1})$$

Nominal exchange rate and the LOP gap

$$\Delta\ s_t = \Delta q_t - \pi^*_t + \pi_t$$
$$\Delta \psi_t = \Delta s_t + \pi^*_t - \pi^m_t$$

Domestic inflation

$$\pi^h_t = \beta_h \pi^h_{t-1} + (1 - \beta_h)\beta E_t \pi^h_{t+1} + \lambda_{\pi^h} mc_t$$

Imported inflation

$$\pi^m_t = \beta_m \pi^m_{t-1} + (1 - \beta_m)\beta E_t \pi^m_{t+1} + \lambda_{\pi^m} \psi^m_t$$

Overall inflation

$$\pi_t = (1 - \gamma)\pi^h_t + \gamma \pi^m_t$$

Real marginal cost of the domestic firm

$$mc_t = \sigma c_t + \eta y_t + \frac{\gamma}{1-\gamma}(q_t - \psi_t) - (1 + \eta) z_t$$

Real marginal cost of importers

$$\psi^m_t = (1 - \gamma_\psi) mc_t - \frac{1 - \gamma_\psi}{1 - \gamma} q_t + \frac{1 - \gamma\gamma_\psi}{1 - \gamma} \psi_t$$

[18] The consumption equation is obtained by substituting equation (28) for consumption at time t+1 into the Euler equation (17).

Monetary policy rule

$$i_t = \mu_i i_{t-1} + (1-\mu_i)(\mu_{\pi_h}\pi_t^h + \mu_{\pi_m}\pi_t^m)$$

Exogenous processes:
Domestic productivity

$$z_t = \rho_z z_{t-1} + \epsilon_t^z$$

Foreign variables

$$y_t^* = \rho_z y_{t-1}^* + \epsilon_t^{y^*}$$

$$i_t^* = \rho_i^* i_{t-1}^* + \epsilon_t^{i^*}$$

$$\pi_t^* = \rho_\pi^* \pi_{t-1}^* + \epsilon_t^{\pi^*}$$

Foreign household preferences (Remittances)

$$\xi_t = \rho_\xi \xi_{t-1} + \epsilon_t^\xi$$

Appendix B: Data Description

Model estimations and simulations are based on quarterly data for the Armenian economy from 2002Q4 to 2007Q4. As the model is in gap form, all variables are in the form of detrended seasonally adjusted deviations from their dynamic trends.

- y_t- Log of real gross domestic product
- c_t- Log of private sector expenditures
- π_t^m - First difference of the log of imported consumer price index. The date is created by the Statistical Department of the Central Bank of Armenia
- π_t^h - First difference of the log of home good consumer price index. This is calculated as a residual taking into account the fact that the overall consumer price index is a geometric average of the home good and imported good price indices.
- q_t - Log of the real exchange rate
- i_t - Interbank repo action interest rate
- gov_t - Log of government expenditures
- tr_t - Log of private transfers
- y_t^* - Log of foreign real Gross Domestic Product. We take the weighted average of the data for the United States and the EU. The weights are calculated using trade weights for the USA and EU weights with Armenia.
- π_t^* - First difference of the log of Foreign Consumer Price Index. This is the weighted average of the data for the United States and the EU, using the above mentioned method.
- $\imath_t^*$ - Foreign interest rate. This is the weighted average of the discount rate of FED and Refinancing rate of ECB, using the above mentioned method.

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