Exploring the sources of Spanish Macroeconomic Fluctuations: An estimation of a small open economy DSGE model

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Abstract

This paper analyzes the role of a variety of shocks as determinants of Spanish macroeconomic fluctuations before the international financial and economic crisis (1970-2008). To do this we estimate a small open economy stochastic model using Kalman Filter techniques. The set of estimated parameters allows the replication with remarkable accuracy of the time path for the major macroeconomic aggregates. In particular, the model reproduces the so-called dual inflation phenomenon which burdens the competitiveness of the Spanish economy.

Keywords: DSGE model, Frequentist techniques, Filter Kalman estimation, small open economy.

JEL Classification: C13, C63, E32, F41, F44.

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1. Introduction

A combination of cyclical and structural factors has made prices evolve differently in the Spanish economy as compared to the rest of the Euro zone. This evolution of prices hampers Spanish competitiveness, hinders real convergence with Europe and burdens economic activity.

Countries that belong to a monetary union may experience temporary, though persistent, differences in inflation rates. These differences may be associated to real convergence processes. In this context, countries with higher productivity growth tend to have higher inflations rates. Additionally, these higher inflation rates could be caused by asymmetrical shocks. These asymmetrical shocks force an adjustment in relative prices among the countries of the monetary union. Finally, these inflation differentials can be generated by the structure of each country and the way common economic shocks spread over the economy.

In this sense, despite being part of the European Monetary Union (EMU), the Spanish economy has experienced positive inflation differentials with the Euro area over the last years along with a remarkable increase in the prices of non-tradable goods (relative to the prices of tradable goods) throughout three decades. This is the so-called dual inflation phenomenon which has had serious implications on Spain’s competitiveness. On the other hand, private consumption is remarkably more volatile in Spain than it is in any of its neighboring economies (Dolado et al. puzzle). Some researchers have mentioned several possible reasons behind Spanish distinct behavior: its different cyclical position, different economic structures in several markets and the different shocks hitting the economy.

In this paper, we use a Dynamic Stochastic General Equilibrium (DSGE) Model corresponding to a small open economy framework, in which the tradable or non-tradable nature of produced goods is taken into account. Using this paradigm, we estimate using the Kalman Filter approach a number of parameters, in order to explore the different sources driving the Spanish Business Cycle. In order to set aside the distortions produced by the financial crisis, we restrict the analysis to the period 1970-2008.

Some versions of the model have been previously used by Turnosvsky (1997), who presents several versions of the so-called ‘dependent economy’. Rebelo and Vehg (1995) also use these types of models to analyze the different exchange rate regimes, Fernandez de Cordoba and Kehoe (2000) use a deterministic model to explain the fluctuations of the real exchange rate since Spain entered the European Economic Community, Andrés et al. (2010) try to explain Spain's growth and inflation differentials with respect to the rest of the European Monetary Union and Martín-Moreno et al. (2014) use this type of model to try to reproduce the second moments of the Spanish business cycle.

As Martín-Moreno et al. (2014) pointed, one major contribution of the model we use here is to consider separately tradable and non-tradable goods. This is important in the Spanish case, characterized by a larger than average non-tradable sector share (around 70% out of total GDP). Furthermore, allows us to characterize the odd behavior observed in Spain for the prices of tradable goods relative to the prices of non-tradable goods, a stylized fact called dual inflation in the literature. Finally, disaggregation also allows us to analyze the Spanish economy at the sectorial level. Then we estimate the parameter values of the model to analyze the contributions of the several shocks considered to the fluctuations observed for the main economic variables. Additionally, we simulated the model to obtain: a) the model fit under the time paths observed for the five shocks considered (productivity, public spending, real interest rate and preferences), b) the variance decompositions of the main variables, and c) the impulse responses to the different types of shocks.

We show that the simulated paths for major aggregates replicate with a remarkable accuracy the corresponding observed time paths during the analyzed period, suggesting a good fit of the model. On the other hand, the variance decomposition analysis points to the preferences shock as the major source of private consumption volatility, while both the international interest rate and the tradable sector specific productivity shock are necessary to explain tradable output volatility, and finally, the non-tradable productivity shock is the main driving force to explain non-tradable output volatility. Moreover, a variety of cyclical properties of the data are also reproduced with a reasonable degree of accuracy.

The rest of the paper is organized as follows. Section 2 describes the theoretical model and derives the conditions of the equilibrium. Section 3 discusses the estimation of the model parameters. Section 4 presents the numerical simulation of the model and the results. Finally, Section 5 concludes.

2. The model

We start by describing the model. We will discuss each one of the four types of agents (households, tradable and non tradable goods sectors and government) and their decision-making behaviour. The model is a version of the one proposed by Martín-Moreno et al (2014). The basic structure includes a representative consumer that works, consumes and saves. Two representative firms, tradable and non-tradable sector and a government are modeled. The theoretical framework assumes rational expectations under a small open economy DSGE model[1].

2.1 The Household

The representative household maximizes the expected utility defined over the stochastic sequences of consumption (C_T, C_N) and labor (N_T, N_N) subject to the budget constraint:

$$\max_{\{C_{T_t}, C_{N_t}, N_{T_t}, N_{N_t}, K_{T_t}, K_{T_t}, D_t\}} E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\sigma} \left[\left[(C_{T_t})^{\phi} (C_{N_t})^{1-\phi} - \frac{1}{\Psi} \left(N_{T_t} + N_{N_t} \right)^{\Psi} \right]^{1-\sigma} - 1 \right] a_t \right\}$$

$$s.t: \qquad w_{T_t} N_{T_t} + w_{N_t} N_{N_t} + r_{T_t} K_{T_t} + r_{N_t} K_{N_t} + r_{t-1} D_{t-1} = \tag{1}$$

$$= \tau_t + P_{T_t} C_{T_t} + P_{N_t} C_{N_t} + P_{T_t} I_{T_t} + P_{N_t} I_{N_t} + D_t - D_{t-1}$$

E_0 denotes the expectation based upon the informational set available in the initial period, C_T is the consumption of tradable goods, C_N is the consumption of non-tradable goods, N_T and N_N are, respectively, the time devoted to work in the tradable sector and the non-tradable sector, a_t is a shock in preferences, $\beta > 0$ is the intertemporal subjective discount rate, $\sigma > 0$ is the risk aversion parameter, and $1/(\Psi - 1)$, with $\Psi > 1$, measures the elasticity of labor supply with respect to the real wage[2]. The household total income consists of three components: i) labor income from tradable and non-tradable sectors $(w_{T_t} N_{T_t} + w_{N_t} N_{N_t})$, with w_{T_t} and w_{N_t} being the nominal wage rate in each sector, ii) the return on the real capital stock allocated to each sector

[1]As aforementioned, following Chari, Kehoe and McGrattan (2008) and Aguiar and Gopinath (2007), we have chosen a model without any rigidities as a first approach to characterize the determinants of Spain's macroeconomic fluctuations.

[2] A well-known fact in the real business cycle literature for small open economies is that under Cobb-Douglas preferences in consumption and leisure, the consumption path is too smooth compared to the data. Correia, Neves and Rebelo (1995) show that under the preferences that we are using, this problem does not arise due to the absence of income effects on labor.

$(r_{T_t}K_{T_{t-1}} + r_{N_t}K_{N_{t-1}})$, with r_{T_t} and r_{N_t} being the nominal return on physical capital in each sector, and iii) the return on holdings of foreign debt $(r_{t-1}D_{t-1})$. On the other hand, after the payment of lump-sum taxes (τ_t), the current income and financial wealth can be used for: i) consumption $(P_{T_t}C_{T_t} + P_{N_t}C_{N_t})$, where P_{T_t} and P_{N_t} are the price of tradable and non-tradable consumption goods, ii) investment in physical capital $(P_{T_t}I_{T_t} + P_{N_t}I_{N_t})$, and iii) changes in his/her portfolio $(D_t - D_{t-1})$.

The household accumulates capital and rents it to firms. The accumulation technology in each sector is given by the following equations:

$$I_{T_t} = K_{T_t} - (1 - \delta_T)K_{T_{t-1}} + \frac{\Phi_T}{2}\left(\frac{K_{T_t} - K_{T_{t-1}}}{K_{T_t}}\right)^2 \quad (2)$$

$$I_{N_t} = K_{N_t} - (1 - \delta_N)K_{N_{t-1}} + \frac{\Phi_N}{2}\left(\frac{K_{N_t} - K_{N_{t-1}}}{K_{N_t}}\right)^2 \quad (3)$$

where a cost of adjustment that depends on the net investment has been included[3]. This adjustment cost reflects the fact that physical capital mobility is imperfect and, thus, the financial capital is more mobile than the physical capital. The parameter δ denotes the constant depreciation rate that we have assumed to be equal in both sectors for the sake of simplicity and Φ_T, Φ_N are the adjustment cost parameters.

Households can borrow and lend in the international capital market at the exogenous international real interest rate r_t. We assume that the domestic interest rate r_t is increasing in the aggregate stock of foreign debt D_t.[4] More precisely, we assume that r_t evolves according to:

$$r_t = R_t^* + \Lambda(D_t) \quad (4)$$

where $\Lambda(D_t)$ is a country-specific interest rate premium. The function $\Lambda(D_t)$ is assumed to be strictly increasing. Following Lim and McNelis (2008), we assume for the risk premium: $\Lambda(D_t) = sign(D_t)\varphi\left[e^{|D_t - D|} - 1\right]$, where φ is a parameter and D is the level of debt in the steady state.

[3] The adjustment cost function is assumed to be homogeneous of degree zero. In particular we take from Bruno and Portier (1995) the quadratic functional form.

[4] The computation of real business cycle models for small open economies has been troublesome because the dynamics is such that the unconditional variance of debt or consumption is infinite. The specifications we are adopting induce stationarity in such dynamics.

Then, at any level for the current account of the economy, an imbalance in the trade balance can be offset by purchasing or selling international bonds[5]:

$$D_t = TB_t + [1 + R^*_{t-1} + \Lambda(D_{t-1})]D_{t-1} \tag{5}$$

Finally, we assume that shocks in preferences and international interest rate follow an AR(1) process:

$$\ln a_{t+1} = \varphi_a \ln a_t + \varepsilon_{a_{t+1}}, \quad \varepsilon_{a_{t+1}} \sim iid\ N(0, \sigma_a^2) \tag{6}$$

$$\ln(1+R^*_{t+1}) = (1-\varphi_R)\ln(1+R^*) + \varphi_R \ln(1+R^*_t) + \varepsilon_{R^*_{t+1}}, \quad \text{where} \quad \varepsilon_{R^*_{t+1}} \underset{iid}{\sim} N\left(0, \sigma^2_{\varepsilon_R}\right) \tag{7}$$

Normalizing to 1 the price of tradable (that is, they act as a numeraire), the solution to the optimization program above (1) generates the following first order conditions for sectorial consumption, sectoral employment, sectorial capital stock and foreign debt:

$$P_{N_t} = \frac{1-\phi}{\phi}\frac{C_{T_t}}{C_{N_t}} \tag{8}$$

$$\frac{1}{\phi}\left(\frac{C_{T_t}}{C_{N_t}}\right)^{1-\phi}\left(N_{T_t} + N_{N_t}\right)^{\Psi-1} = w_{T_t} \tag{9}$$

$$\frac{1}{1-\phi}\left(\frac{C_{T_t}}{C_{N_t}}\right)^{-\phi}\left(N_{T_t} + N_{N_t}\right)^{\Psi-1} = w_{N_t} \tag{10}$$

$$U'_t\left(\frac{C_{T_t}}{C_{N_t}}\right)^{\phi-1} = \beta[(1 + R^*_t + \Lambda_t) + \Lambda'_t D_t]E_t\left[U'_{t+1}\left(\frac{C_{T_{t+1}}}{C_{N_{t+1}}}\right)^{\phi-1}\right] \tag{11}$$

$$U'_t\left(\frac{C_{T_t}}{C_{N_t}}\right)^{\phi-1}\left[1 + \Phi_T\frac{K_{T_t} - K_{T_{t-1}}}{K^2_{T_{t-1}}}\right] = $$

$$= \beta E_t\left[U'_{t+1}\left(\frac{C_{T_{t+1}}}{C_{N_{t+1}}}\right)^{\phi-1}\left(r_{T_{t+1}} + 1 - \delta_T + \Phi_T\frac{K_{T_{t+1}} - K_{T_t}}{K_{T_t}}\frac{K_{T_{t+1}}}{K^2_{T_t}}\right)\right] \tag{12}$$

$$U'_t\left(\frac{C_{T_t}}{C_{N_t}}\right)^{\phi}\left[1 + \Phi_N\frac{K_{N_t} - K_{N_{t-1}}}{K^2_{N_{t-1}}}\right] = $$

$$= \beta E_t\left[U'_{t+1}\left(\frac{C_{T_{t+1}}}{C_{N_{t+1}}}\right)^{\phi}\left(r_{N_{t+1}} + 1 - \delta_N + \Phi_N\frac{K_{N_{t+1}} - K_{N_t}}{K_{N_t}}\frac{K_{N_{t+1}}}{K^2_{N_t}}\right)\right] \tag{13}$$

[5] The international interest rate, in the end, is conditioned by the evolution of foreign demand as long as monetary policy is frequently used as a tool to expand or contract aggregate demand.

2.2. Firms that produce final goods

Both the traded good and the nontraded good are produced by competitive firms according to a Cobb-Douglas production functions, combining capital and labor as inputs. In addition, tradable goods can be imported from the rest of the world and can be exported, but non-tradable goods like factories, residences or infrastructures, must be produced in the domestic country.

$$Y_{j_t} = Z_{j_t} F\left(K_{j_{t-1}}, N_{j_t}\right) = B_j Z_{j_t} K_{j_{t-1}}^{1-i} N_{j_t}^{i} \quad (14)$$

where $j = T, N,$ represent tradable and non tradable sector, $i = \alpha, \eta,$ and Z_{j_t} is a shock on the total factor productivity in each sector.

The representative firm in each sector (tradable and non-tradable) solves the following problem:

$$\max_{\{N_{j_t}, K_{j_t}\}} E_0 \sum_{t=0}^{\infty} \mu_t \left[Y_{j_t} - w_{j_t} N_{j_t} - r_{j_t} K_{j_t}\right]$$

$$subject\ to\text{: } Y_{j_t}\ given\ by\ (14) \quad (15)$$

where $\mu_t = \beta^t U_{\widetilde{C_t}}$, with $\widetilde{C_t} = C_{T_t}^{\phi} C_{N_t}^{1-\phi}$ and $j = T, N$

The first-order conditions of this problem are:

$$w_{T_t} = \alpha B_T Z_{T_t} K_{T_{t-1}}^{1-\alpha} N_{T_t}^{\alpha-1}$$
$$r_{T_t} = (1-\alpha) B_T Z_{T_t} K_{T_{t-1}}^{-\alpha} N_{T_t}^{\alpha}$$
$$w_{N_t} = \eta B_N Z_{N_t} K_{N_{t-1}}^{1-\eta} N_{N_t}^{\eta-1}$$
$$r_{N_t} = (1-\eta) B_N Z_{N_t} K_{N_{t-1}}^{-\eta} N_{N_t}^{\eta}$$

We assume that technology shocks in both sectors are not independent, following a bivariate, first-order autoregressive process VAR(1)

$$\begin{bmatrix} \ln Z_{T_{t+1}} \\ \ln Z_{N_{t+1}} \end{bmatrix} = \begin{bmatrix} \rho_T & \upsilon^{Z_N} \\ \upsilon^{Z_T} & \rho_N \end{bmatrix} \begin{bmatrix} \ln Z_{T_t} \\ \ln Z_{N_t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{Z_{T_{t+1}}} \\ \varepsilon_{Z_{N_{t+1}}} \end{bmatrix}$$

$$\begin{bmatrix} \varepsilon_{Z_{T_t}} \\ \varepsilon_{Z_{N_t}} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_{Z_T}^2 & \sigma_{12} \\ \sigma_{12} & \sigma_{Z_N}^2 \end{bmatrix}\right) \quad (16)$$

where parameters ρ_T and ρ_N capture the persistence of the shocks, while υ^i reflects the spillover effects between both sources of fluctuations. Finally, the covariance is denoted by σ_{12} parameter.

2.3. Government

We assume a period by period balanced government budget. Hence, the level of government spending is always equal to the lump sum taxes revenues raised from households. We consider a non-tradable feature for government spending.[6] Then, the public budget constraint is given by:

$$G_{N_t} = \tau_t \tag{17}$$

Shocks in public spending also follow an AR(1) process:

$$\ln G_{t+1} = \left(1 - \varphi_G\right) \ln G_{ss} + \varphi_G \ln G_t + \varepsilon_{G_{t+1}}, \quad \varepsilon_{G_{t+1}} \sim iid\ N(0, \sigma_G^2) \tag{18}$$

2.4. The competitive equilibrium

A competitive equilibrium is a set of allocations $\{C_{T_t}, C_{N_t}, N_{T_t}, N_{N_t}, D_t, K_{T_t}, K_{N_t}, TB_t\}$ and a system of prices $\{P_{N_t}, w_{T_t}, w_{N_t}, r_{T_t}, r_{N_t}, r_t\}$ so that, given the sequence of lump sum taxes and the sequences for the technological, preferences and international interest rate shocks: i) $\{C_{T_t}, C_{N_t}, N_{T_t}, N_{N_t}, D_t, K_{T_t}, K_{N_t}\}$ solve the consumer problem; ii) $\{N_{T_t}, K_{T_t}\}$ solve the problem of the representative firm that produces the tradable good; iii) $\{N_{N_t}, K_{N_t}\}$ solve the problem of the representative firm that produces the non-tradable good; and iv) markets clear.

The available supply of tradable goods is consumed by the representative household and exported to the rest of the world. On the other hand, the supply of non-tradable goods is consumed by the representative household and by the government.

Therefore, the feasibility constraint for the non-tradable goods sector establishes that it is devoted to private and public consumption and investment:

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[6] We are aware that around 30% of public consumption can be considered as tradable in nature, but for the sake of simplicity of the model and considering that the major part of public spending is non-tradable, we have assumed that public consumption is entirely non-tradable. However, results do not change qualitatively if this assumption is modified.

$$Y_{N_t} = C_{N_t} + I_{N_t} + G_{N_t} \tag{19}$$

where G_{N_t} is public spending, equal to the amount of lump-sum taxes paid by the representative consumer.

The feasibility constraint for the tradable goods sector is similar. The difference comes from the possibilities of trading with the rest of the world:

$$Y_{T_t} = C_{T_t} + I_{T_t} + TB_t \tag{20}$$

Then, the aggregate resources constraint is:

$$C_{T_t} + P_{N_t}C_{N_t} + I_{T_t} + P_{N_t}I_{N_t} + P_{N_t}G_{N_t} + TB_t = Y_{T_t} + P_{N_t}Y_{N_t} \tag{21}$$

2.5. Steady state

The steady state is a vector $\{C_T, C_N, N_T, N_N, D, K_T, K_N, P_N, w_T, w_N, r_T, r_N\}$ that satisfies the optimality conditions of all the economic agents so that if the vector is reached in any period, in the absence of any perturbation, the system will stay at that point forever.

Given that our objective is to analyze the stochastic properties of our model economy, in a next step we describe the steady state, which will be used to characterize the long-run properties of the economy, and to estimate some of the structural parameters (as it is described in the next section).

The computation of the steady state can be carried out as follows:

Step 1: The following system of equations characterizes the steady state for this economy for the allocations $\{C_T, C_N, N_T, N_N, D, K_T, K_N, Y\}$, Y being a measure of the aggregate production of the model economy (see equation (29) bellow), and the trade balance to aggregate output ratio given exogenously $(TB/Y) = \xi$):

$$[1 + R^* + \varphi D]\beta = 1 \tag{22}$$

$$\frac{1-\phi}{\phi}\left(\frac{C_T}{C_N}\right) = \left(\frac{B_T}{B_N}\right)\left(\frac{\alpha}{\eta}\right)\left(\frac{K_T}{N_T}\right)^{1-\alpha}\left(\frac{K_N}{N_N}\right)^{\eta-1} \tag{23}$$

$$\left(\frac{K_T}{N_T}\right) = \left[\frac{(1-\alpha)B_T}{\frac{1}{\beta} - (1-\delta_T)}\right]^{\frac{1}{\alpha}} \tag{24}$$

$$\left(\frac{K_N}{N_N}\right) = \left[\frac{(1-\eta)B_N}{\frac{1}{\beta} - (1-\delta_N)}\right]^{\frac{1}{\eta}} \tag{25}$$

$$\left(\frac{C_T}{C_N}\right) C_N + \left[\delta_T \left(\frac{K_T}{N_T}\right) - B_T \left(\frac{K_T}{N_T}\right)^{1-\alpha}\right] N_T = -R^* D = \left(\frac{TB}{Y}\right) Y \tag{26}$$

$$C_N + \left[\delta_N \left(\frac{K_N}{N_N}\right) - B_N \left(\frac{K_N}{N_N}\right)^{1-\eta}\right] N_N = -G_{ss} \tag{27}$$

$$N_T + N_N = \left[\frac{1}{\phi} \frac{\left({C_T}/{C_N}\right)^{1-\phi}}{B_T \alpha \left({K_T}/{N_T}\right)^{1-\alpha}}\right]^{\frac{1}{1-\Psi}} \tag{28}$$

$$Y = B_T + \left(\frac{K_T}{N_T}\right)^{1-\alpha} N_T + \frac{1-\phi}{\phi}\left(\frac{C_T}{C_N}\right) B_N \left(\frac{K_N}{N_N}\right)^{1-\eta} N_N \tag{29}$$

$$P_N G_{ss} = \mu Y = \mu \frac{\phi}{1-\phi}\frac{C_N}{C_T} Y \tag{30}$$

Step 2: i) from (24)-(25) we obtain (K_T/N_T) and (K_N/N_N), ii) (C_T/C_N) is obtained from (23), iii) using (28) and taking $N_T + N_N = 0.31$ is obtained ψ, iv) from (26), (27) (29) and (30), $\{C_N, N_T, N_N, Y\}$ are calculated; v) with C_N and (C_T/C_N), C_T is obtained; vi) with N_T and (K_T/N_T), K_T is obtained; vii) with N_N and (K_N/N_N), K_N is obtained; viii) with Y and given $\{TB/Y, R^*\}$, D is calculated from (26), and, finally, ix) given φ from (22) we obtain β.

Step 3: By using the first order conditions for the problems faced by the firms that produce the tradable and non-tradable goods it is possible to find $\{w_T, w_N, r_T, r_N\}$, and from the first order conditions of the representative agent, we obtain $P_N = ((1-\phi)/\phi)(C_T/C_N)$.

3. Estimating the Model

3.1. Data

The sources of data for this paper are the Spanish National Accounts, the Ministry of Economy and BBVA Foundation. Data are annual and cover the period 1970 to 2008. All the empirical estimations referred to in the paper have been obtained from the cyclical component of the data, i.e., after trend extraction using the Hodrick-Prescott filter.

In order to achieve consistency between data and the variables of the model, we follow Kehoe and Fernández de Córdoba to disaggregate into tradable and non-tradable goods. To obtain tradable output we aggregate agriculture and industry[7] and for the non-tradable, we aggregate construction and services.[8,9] For sectorial price indices we use the sectorial value-added deflators which, according to Betts and Kehoe (1999), are close proxies for gross output deflators.

3.2. Estimation results

In this subsection we estimate the main parameters that drive the dynamics of the model as well as a wide variety of shocks that have hit the Spanish economy throughout the period under study (sectorial productivity shocks, public spending shocks, international interest rate shocks and preference shocks).

The parameterization strategy consists in fixing some parameters and estimating those related to the model dynamics using Kalman Filter techniques under frequentist approach. There are a total of 19 estimated parameters which include i) preferences, ii) Technology, iii) rigidities in adjustment dynamics of investment and iv) the stochastic processes. The parameters we choose to keep fixed at their calibrated values correspond to preferences (disutility of labor and the discount factor), and technology of production (capital depreciation).

The optimality conditions given by equations (2), (3), (5)-(13), (16) and (18)-(20) can be log-linearized around the steady state. By applying the method of Blanchard and Kahn (1980) we obtain a solution in the form of a state-space econometric model. The empirical model can be summarized by the following state-space system:

$$\zeta_{t+1} = F\zeta_t + J\vartheta_{t+1} \,,$$
$$X_t = H'\zeta_t \,,$$

where $\zeta_{t+1} = \left[\widehat{K}_{T_{t+1}}, \widehat{K}_{N_{t+1}}, \widehat{D}_{t+1}, \hat{Z}_{T_{t+1}}, \hat{Z}_{N_{t+1}}, \hat{a}_{t+1}, \widehat{G}_{t+1}, \widehat{R}^*_{t+1}\right]'$

$X_t \equiv \left[\widehat{Y}_{T_t}, \widehat{Y}_{N_t}, \widehat{P}_N, \hat{I}_{T_t}, \hat{I}_{N_t}\right]'$, $\quad \vartheta_{t+1} \equiv \left[\varepsilon_{Z_{T_{t+1}}}, \varepsilon_{Z_{N_{t+1}}}, \varepsilon_{a_{t+1}}, \varepsilon_{G_{t+1}}, \varepsilon_{R^*_{t+1}}\right]$

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[7] It would have been preferable to subtract electricity, gas and water out of the traded category and to add transportation services. Unfortunately these data are not available in the Spanish National Accounts.

[8] We exclude non-market services from the analyses because they are not traded on a market.

[9] This classification is used also by Salido and Pérez Quirós (2005).

with "^" denoting Hodrick-Prescott detrended levels for the observed variables (X_t) and log-deviatons with respect to the steady value for the non-observed variables (ζ_t).

When applied to this state-space system, the Kalman filter delivers forecasts for the eight unobserved states given by ζ_{t+1} vector, conditional on all observed values given by X_t.

These forecasts can be recursively obtained as follows:

$$\hat{\zeta}_{t+1/t} = F\hat{\zeta}_{t/t-1} + K\left(x_t - H'\hat{\zeta}_{t/t-1}\right),$$

$$P_{t+1/t} = FP_{t/t-1}F' - KH'P_{t/t-1}F' + \widetilde{Q'},$$

$$K = FP_{t/t-1}H\left(H'P_{t/t-1}H\right)^{-1}$$

$$\tilde{Q} = J\left(Cov(\vartheta_{t+1})\right)J',$$

$$E(\vartheta_{t+1}\vartheta'_{t+1}) = \begin{bmatrix} \sigma^2_{Z_T} & \sigma_{12} & 0 & 0 & 0 \\ \sigma_{12} & \sigma^2_{Z_N} & 0 & 0 & 0 \\ 0 & 0 & \sigma^2_a & 0 & 0 \\ 0 & 0 & 0 & \sigma^2_G & 0 \\ 0 & 0 & 0 & 0 & \sigma^2_{R^*} \end{bmatrix},$$

where $\hat{\zeta}_{t+1|t} \equiv \hat{E}\left(\zeta_{t+1}|\Omega_t\right), \quad \Omega_t \equiv (x'_t, x'_{t-1}, \ldots\ldots, x'_1)',$

$P_{t+1|t} \equiv \hat{E}\left[\left(\zeta_{t+1} - \hat{\zeta}_{t+1|t}\right)\left(\zeta_{t+1} - \hat{\zeta}_{t+1|t}\right)'\right],$

given $\hat{\zeta}_{1|0}$ and $P_{1|0}$ dados

Following Ireland (2004), the parameters of the empirical model can be estimated via maximum likelihood following the methods described by Hamilton (1994, Ch.13) and using Spanish data of annual frequency for tradable output, non-tradable output, non-tradable to tradable prices ratio, tradable investment and non-tradable investment as observed variables. The likelihood function for $\{x_t\}$ is

$$f_{x_{t|\Omega_{t-1}}} = (2\Pi)^{-n/2}\left|H'P_{t|t-1}H\right|^{-1/2} exp\left[-\frac{1}{2}\left(x_t - H'\zeta_{t|t-1}\right)'(H'HP_{t|t-1})(x_t - H'_t\zeta_{t|t-1})\right]$$

$for\ t = 1,2,\ldots,T, where\ n = 8\ .$

Thus, the sample log likelihood is

$$\sum_{t=1}^{T} \ln(f_{x_t|\Omega_{t-1}}) \,. \tag{31}$$

The expression (31) can then be maximized numerically for the structural parameters of the model (except calibrated parameters, i.e., β, δ_T and δ_N). Also, likelihood maximization is restricted to Ψ to be consistent with the fraction of hours worked in the steady state so that it is equal to the average fraction of the data (0.31). Thus, the estimation of the rest of the model parameters is conditioned by those calibrated values. The results obtained are listed in table 1 and 2.

[Insert Table 1 and 2]

4. Simulation results

After estimating the model with the parameter values and the equilibrium defined in Section 2, we infer the series of historical shocks that have generated the observed series. It is then possible to analyze the determinants of Spain's cyclical performance by assessing: a) the model fit under the time paths observed for the five shocks considered (productivity, public spending, real interest rate and preferences), b) the variance decompositions of the main variables, and c) the impulse responses to the different types of shocks.

4.1 Evaluating the model accuracy

In this subsection we compare the time paths of the series implied by the model estimates (in deviations with respect to their steady state levels) with the observed data (detrended by using the Hodrick-Prescott filter[10]). Two groups of variables are depicted: i) the set of variables included in the observation equation of the state space system, $X_t \equiv \left[\hat{Y}_{T_t}, \hat{Y}_{N_t}, \hat{P}_N, \hat{I}_{T_t}, \hat{I}_{N_t}\right]'$; and ii) a set of variables which have not been used for the estimation of structural parameters, $W_t = \left[\hat{N}_{T_t}, \hat{N}_{N_t}, \hat{N}_t, \hat{C}_t\right]'$, which will be used as a test of the model fit.

For the first group of variables, X_t, we represent the one-step ahead predictions $\hat{X}_{t+1|t}$

[10] The value used in the filter for the smoothing parameter λ is 10, in order to guarantee that the cyclical component is stationary.

obtained by applying the Kalman Filter (red dashed line), conditioned by the estimated set of structural parameters. For the second group of variables, W_t, we represent the former ($\hat{W}_{t+1|t}$) as well as the smoothed estimations of the Kalman Filter $\hat{W}_{t|T}$ (solid green line with diamonds).

Figure 1 depicts all the sectorial variables, both observed (blue line) and the one-step ahead predictions for $\left\{\hat{Y}_{T_{t+1|t}}, \hat{Y}_{N_{t+1|t}}, \hat{I}_{T_{t+1|t}}, \hat{I}_{N_{t+1|t}}, \hat{N}_{T_{t+1|t}}, \hat{N}_{N_{t+1|t}}, \hat{P}_{N_{t+1|t}}\right\}$: tradable and non-tradable added value, tradable and non-tradable private investment, tradable and non-tradable labor, and non-tradable to tradable price ratio. We can see that the model adequately replicates the observed data for these variables. Furthermore, we represent the smoothed estimations of the Kalman filter for tradable and non-tradable labor because they have not been used in the observed equation as input to estimate the structural parameters. We observe that the fit for this series is rather good and may indicate the goodness of fit for the model. The model correctly predicts high sectorial investment volatility. Similarly, the model succeeds in predicting volatility for sectorial outputs. It is also worth pointing out that the model captures the behavior of the relative non tradable prices very well. Thus, it captures the so-called dual inflation phenomenon.

Figure 2 represents the aggregate variables of consumption[11], added value, investment and labor. It depicts both the one-step ahead prediction and the smoothed estimations for consumption and labor $\left\{\hat{C}_{t+1|t}, \hat{C}_{t+1|T}, \hat{N}_{t+1|t}, \hat{N}_{t+1|T}\right\}$ because these variables have not been included in the observation equation of the state space system. The model predicts a higher volatility for consumption than the one observed in actual data, oversizing the Dolado et al. puzzle (1993). Contrarily, the model is able to replicate with remarkable accuracy the cyclical behavior of aggregate labor, even though it has not been used to estimate the structural parameters of the model. It also adequately predicts the cyclical behavior of the aggregate output and investment. [12]

[11] Aggregate consumption has been computed as: $C_t=(P_{Nt}/P_{Tt})^{\phi-1} C_{Tt}+(P_{Nt}/P_{Tt})^{\phi} C_{Nt}$, which implies that $P_tC_t=P_{Tt}C_{Tt}+P_{Nt}C_{Nt}$, where $P_t \equiv P_{Tt}^{\phi} P_{Nt}^{1-\phi}$ is the price index of our economy. The same computation has been carried out to obtain aggregate output.

[12] We have also tested the model using the standard business cycle approach consisting on computing the second order moments of the variables with the following results: in the data the volatility of aggregate production is 1.3 while in the model it is 1.04. In the case of sectorial investment we obtain the volatility for the tradable and non tradable investment of 4.33 and 3.56 while in the data these figures are 6.58 and 4.63 respectively. Finally the non tradable relative price presents a volatility of 1.54 in the data while the model reproduces 1.37 for this variable. For a detailed discussion see Martín Moreno et al. (2014).

4.2 Variance Decomposition

The orthogonalization of the variance-covariance matrix is required to develop the variance decomposition of the forecast error as well as the impulse response functions because the productivity shocks are correlated:

$$E(\vartheta_{t+1}\vartheta'_{t+1}) = \begin{bmatrix} \sigma_{Z_T}^2 & \sigma_{12} & 0 & 0 & 0 \\ \sigma_{12} & \sigma_{Z_N}^2 & 0 & 0 & 0 \\ 0 & 0 & \sigma_a^2 & 0 & 0 \\ 0 & 0 & 0 & \sigma_G^2 & 0 \\ 0 & 0 & 0 & 0 & \sigma_{R^*}^2 \end{bmatrix}$$

We use the Cholesky decomposition in the sub-matrix for the orthogonalization

$$V_1 = \begin{bmatrix} \sigma_{Z_T}^2 & \sigma_{12} \\ \sigma_{12} & \sigma_{Z_N}^2 \end{bmatrix} = \Gamma_1 \Gamma_1{}',$$

$$\text{where } \Gamma_1 = \begin{bmatrix} \sigma_{Z_T} & 0 \\ \sigma_{12} / \sigma_{Z_T} & \left(\sigma_{Z_T}^2 \sigma_{Z_N}^2 - \sigma_{12}^2\right) / \sigma_{Z_T}^2 \end{bmatrix},$$

implying that productivity shocks in the tradable sector have a contemporaneous impact on the non-tradable sector, but not vice-versa. That is to say, the productivity shock in the tradable sector may instantaneously cause a shock in non-tradable productivity but the shock in the non-tradable sector does not instantaneously cause a productivity shock on the tradable sector. In sum, the contemporary causality moves from the tradable towards the non-tradable sector.

Then, the state equation may be presented as follows:

$$\zeta_{t+1} = F\zeta_t + J\vartheta_{t+1} = F\zeta_t + J\,\Gamma\varepsilon_{t+1},$$

where $\vartheta_{t+1} = \Gamma\varepsilon_{t+1}$, $E(\varepsilon_{t+1}\varepsilon_{t+1}{}') = I_{5\times 5}$, and

$$\Gamma = \begin{bmatrix} \sigma_{Z_T} & 0 & 0 & 0 & 0 \\ \sigma_{12} / \sigma_{Z_T} & \left(\sigma_{Z_T}^2 \sigma_{Z_N}^2 - \sigma_{12}^2\right) / \sigma_{Z_T}^2 & 0 & 0 & 0 \\ 0 & 0 & \sigma_a & 0 & 0 \\ 0 & 0 & 0 & \sigma_G & 0 \\ 0 & 0 & 0 & 0 & \sigma_{R^*} \end{bmatrix}.$$

We now estimate the model of section 2 accounting for all the five shocks. This approach allows us to compute the contribution of each shock to aggregate fluctuations. Tradable and non-tradable productivity shocks are correlated and the remaining shocks (public spending, real interest rate and preferences) are assumed to be independent. The variance decomposition of the major sectorial variables of the Spanish economy at various terms is reported in Tables 3-11. Again the estimated contribution of each shock to the relevant variables appears to be very reasonable.

Sectorial productivity shocks explain most of the observed variance for the added values in the tradable and non tradable sectors. However, there is a difference between both sectors. In the non tradable sector the contribution of its own productivity shock exceeds 80% even 10 quarters after the shock has occurred. The contribution of the specific productivity shock in the tradable sector, subject to international competition, decreases with the time lag after the shock has occurred while the contribution of the international interest rates increases.

Furthermore, international interest rate shocks greatly account for the fluctuations of private investment in both sectors. However, they are much less relevant in the remaining variables.

Regarding the fluctuations in the relative price of non tradable to tradable goods, the contribution of the different shocks is more uniform. It is noteworthy to point out that the highest contribution corresponds to the international interest rate shock (exceeding 30%) in the early periods following the shock. This fact represents a remarkable difference with respect to previous works, such as Mendoza (1991) and Schmitt-Grohé (1998) among others, who conclude that this type of shock does not seem to be very important in explaining the cyclical behavior of economic variables. Furthermore, as expected, the preferences shock is very relevant and, as the time lag increases, the non tradable productivity shock becomes more relevant, in line with the Balassa-Samuelson effect.

Finally, as anticipated, domestic demand shock through preferences shock has proved to be the main factor in explaining the volatility of tradable and non tradable private consumption.

4.3 Impulse Response Analysis

In order to better understand the propagation mechanisms implied by the model, in this subsection we study the effects of different shocks in the aggregate and sectorial variables for the Spanish economy.

The response of the main aggregates to an impulse in the different shocks considered (tradable productivity, non tradable productivity, real interest rate and preferences) are depicted in Figures 4 to 7. Following the usual practice, the size of each shock is normalized to one standard deviation.

Figure 4 displays the responses to a productivity shock in the tradable sector. The improvement in productivity leads to a fall in the producer price of tradable goods. Spanish tradable goods become cheaper vis-à-vis home non-tradable goods, so the relative price P_{N_t} increases. The equilibrium level of tradable goods increases as a result of sectorial price behavior. The latter outweighs the drop in non-tradable production, so that the total added value in Spain increases. On the other hand, and as a consequence of this shock, tradable investment increases given the high productivity of this sector. Additionally, the resulting increase in domestic demand in Spain (tradable and non tradable consumption) is large enough to compensate for the fact that firms now need less labor to produce the same output. Thus, employment in tradable industry increases, and this positively affects total employment. As the theory suggests, the consequences of a positive technology shock in the non-tradable sector are opposite to the ones just described (see Figure 5).

The effects of an international real interest rate shock are shown in Figure 6. The increase in international interest rate harms private consumption and investment in Spain both at sectorial and aggregate levels. Since domestic demand in the EMU Area will also be negatively affected by the interest rate shock and it is Spain's main trading partner, total Spanish exports fall accordingly (not shown in the figure). As a result, production in the tradable sector drops more sharply than it does in the non-tradable sector. The fall in production produces a fall in Spanish employment at the aggregate level.

Finally, the response to a positive shock in preferences is an instantaneous increase in the consumption of tradable and also non-tradable goods (see Figure 7); however, non-tradable goods become more expensive relative to tradable goods because the price for the latter is fixed in international markets. The increase in the consumption of non-tradable goods leads to a parallel increase in the domestic production of this type of goods, and hence an increase in labor for this sector. Contrarily, the domestic production of tradable goods falls despite the rise in the consumption of this type of goods, suggesting a substitution in favor of imported goods. The labor in the tradable sector decreases accordingly. On the other hand, investment decreases in both sectors due to the increase in consumption and in the tradable sector also because of the decrease in output. It can also be observed that the convergence speed which governs the return to the steady state is lower in this case.

5. Conclusions

The study and analysis of the cyclical movements of the economy allows us to obtain valuable complementary information that enables us to analyze the adjustment mechanisms of prices and quantities, as well as the type of shocks underlying the cycle itself.

In particular, the characterization of the cyclical movements of the main Spanish economic variables have been analyzed by Puch and Licandro (1997), Martín-Moreno (1998), Martín-Moreno et al. (2012) and Martín-Moreno et al. (2014) among others. However, we believe that a deeper characterization of the business cycle for the Spanish economy is required.

In this sense, this paper includes five different types of shocks (tradable and non-tradable sectors productivities, public spending, international real interest rate and preferences) in a small open economy DSGE model which disaggregates the domestic output according to its tradable or non-tradable nature. The model structural parameters are then estimated using frequentist methods. This allow us to obtain the importance of these sources of fluctuations when characterizing the cyclical path of the Spanish Economy, the contribution of each shock to aggregate and sectorial economic fluctuations and the transmission channels of supply and demand shocks in the Spanish economy.

Our findings can be summarized as follows: First, our variance decomposition analysis suggests that private consumption volatility is mainly explained by the preferences shock, idiosyncratic productivity shock greatly accounts for non-tradable output volatility while shocks to both sectorial productivity and international interest rate account for tradable output. Second, model predictions may closely represent the Spanish economy data and, finally, the model captures the main cyclical qualitative features of the data reasonably well.

Table 1: Structural Parameters

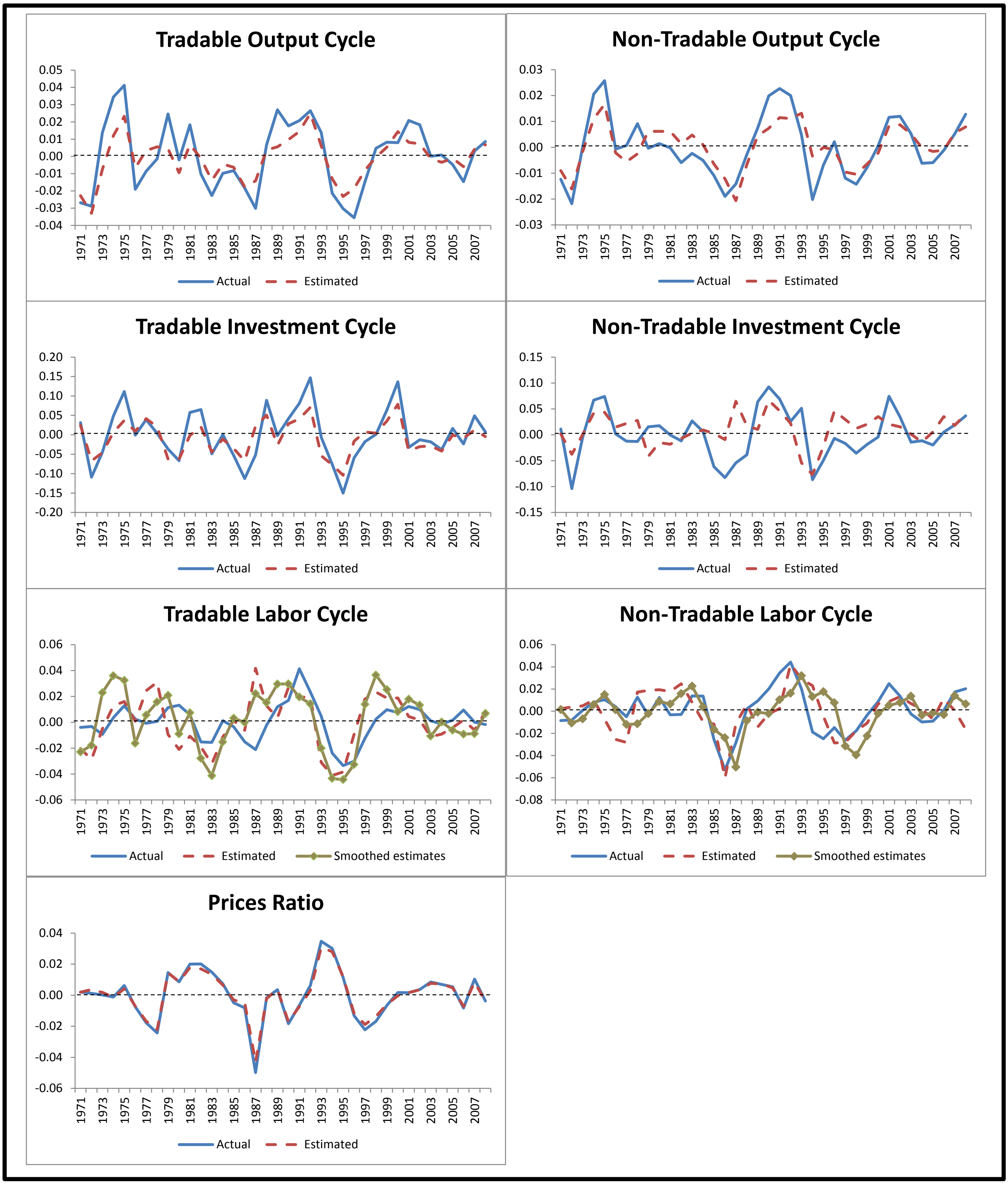
PREFERENCES		
	Estimated value	**Standard deviation**
β **(calibrated parameter)**	**0.9617**	
ϕ	**0.5910**	**0.0074**
Ψ**(*)**	**2.4313**	
σ	**1.0077**	**0.0298**
TECHNOLOGY		
α	**0.5841**	**0.0011**
η	**0.6112**	**0.0038**
B_T	**0.3600**	**0.0005**
B_N	**0.5473**	**0.0040**
RIGIDITIES		
Φ_T	**0.1519**	**0.0092**
Φ_N	$6.2*10^{-12}$	**0.0006**
DEPRECIATION RATES		
δ_T **(calibrated parameter)**	**0.06430**	
δ_N **(calibrated parameter)**	**0.04939**	

Note to the Table 1: (*) The estimation procedure is conducted to guarantee that the estimated value for Ψ is such that, conditional on the remaining parameters, the fraction of hours worked in the steady state is 0.31.

Table 2: Parameters of the shocks

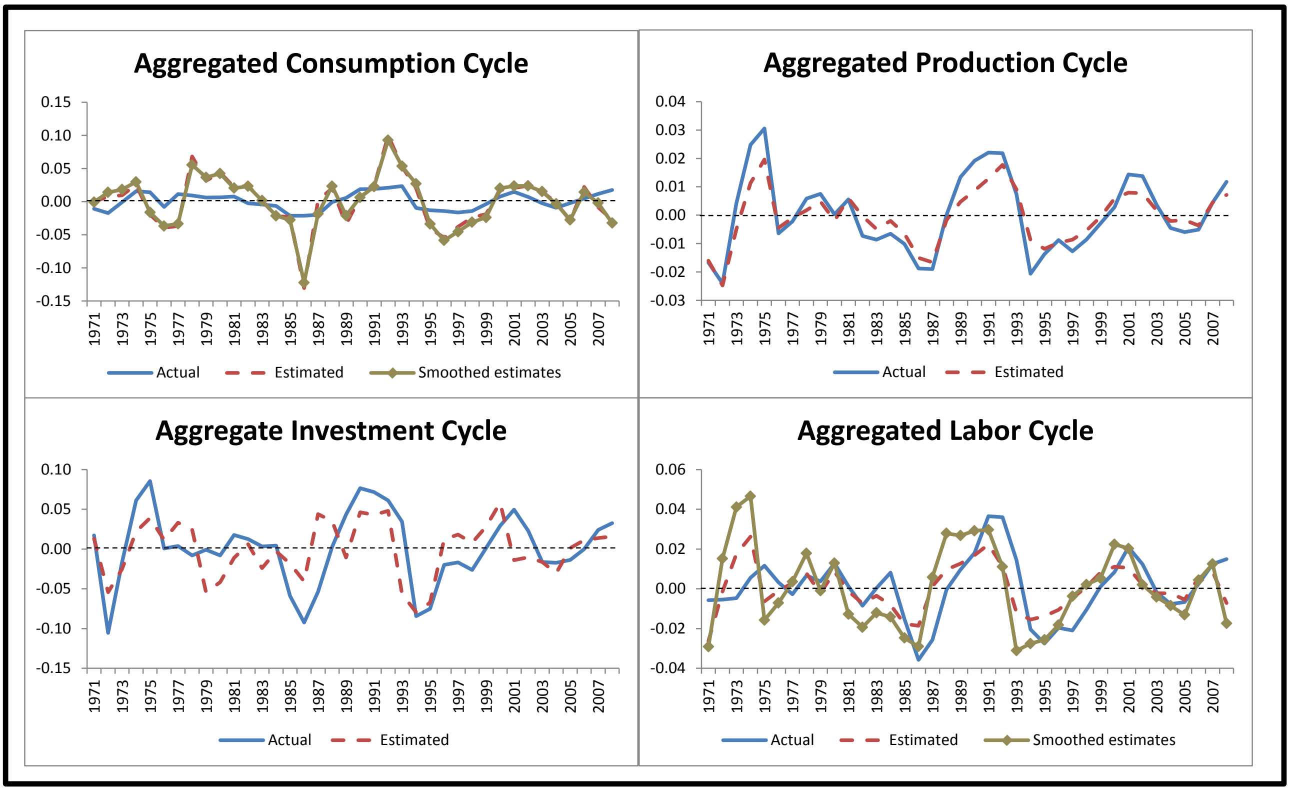
PRODUCTIVITY SHOCKS (estimated VAR(1) process)		
	Estimated value	**Standard deviation**
ρ_T	**0.4373**	**0.0752**
ρ_N	**0.4737**	**0.1176**
σ_{Z_T}	**0.0128**	**0.0013**
σ_{Z_N}	**0.0091**	**0.0040**
Corr (ε_T, ε_N)	**0.4199**	**0.0604**
PUBLIC SPENDING SHOCK (estimated AR(1) process)		
φ_g	**0.0089**	**0.0149**
σ_G	**0.0555**	**0.0040**
REAL INTEREST RATE SHOCK (estimated AR(1) process)		
φ_{R^*}	**0.7182**	**0.0117**
σ_{R^*}	**0.0025**	**0.0107**
PREFERENCES SHOCK (estimated AR(1) process)		
φ_a	**0.9304**	**0.0052**
σ_a	**0.0500**	**0.0017**

Figure 1: Sectorial Variables – Data and model fit



Blue lines: cyclical component for actual data; dashed red lines: one-step ahead predictions obtained by applying the Kalman Filter conditioned by the estimated set of structural parameters; and solid green lines with diamonds: smoothed estimations of the Kalman Filter.

Figure 2: Aggregate Variables - Data and model fit



Blue lines: cyclical component for actual data; dashed red lines: one-step ahead predictions obtained by applying the Kalman Filter conditioned by the estimated set of structural parameters; and solid green lines with diamonds: smoothed estimations of the Kalman Filter.

Table 3: The contribution (%) of shocks to tradable output (YT)

Periods	tradable productivity shock	non-tradable productivity shock	public spending shock	Real interest rate shock	preferences shock
1	94,85	1,49	0,56	1,98	1,11
2	85,93	1,12	0,64	9,89	2,43
3	74,26	1,04	0,78	20,03	3,88
4	63,70	1,19	0,93	28,98	5,20
5	55,56	1,47	1,05	35,63	6,29
6	49,68	1,78	1,17	40,19	7,18
7	45,52	2,09	1,26	43,20	7,92
8	42,60	2,40	1,35	45,14	8,51
9	40,56	2,68	1,43	46,35	8,98
10	39,14	2,93	1,50	47,07	9,35

Table 4: The contribution (%) of shocks to non-tradable output (YN)

Periods	tradable productivity shock	non-tradable productivity shock	public spending shock	Real interest rate shock	preferences shock
1	4,95	89,09	0,88	3,33	1,74
2	5,17	87,04	2,36	3,60	1,83
3	5,35	85,81	3,41	3,66	1,78
4	5,48	84,99	4,25	3,59	1,69
5	5,57	84,37	4,93	3,49	1,65
6	5,61	83,78	5,48	3,40	1,75
7	5,60	83,11	5,91	3,34	2,04
8	5,56	82,30	6,25	3,31	2,57
9	5,49	81,31	6,50	3,32	3,37
10	5,40	80,12	6,68	3,35	4,45

Table 5: The contribution (%) of shocks to tradable consumption (CT)

Periods	traceable productivity shock	non-traceable productivity shock	public spending shock	Real interest rate shock	preferences shock
1	5,68	1,65	0,01	6,48	86,18
2	4,64	1,17	0,03	6,12	88,03
3	4,09	0,94	0,06	5,80	89,11
4	3,78	0,82	0,08	5,54	89,78
5	3,62	0,75	0,11	5,34	90,19
6	3,53	0,71	0,13	5,18	90,44
7	3,51	0,69	0,16	5,07	90,58
8	3,52	0,68	0,19	4,98	90,63
9	3,55	0,68	0,23	4,93	90,62
10	3,60	0,69	0,26	4,89	90,57

Table 6: The contribution (%) of shocks to non traceable consumption (CN)

Periods	traceable productivity Shock	non-traceable productivity shock	public spending shock	Real interest rate shock	preferences shock
1	1,93	12,68	2,77	0,01	82,62
2	1,15	12,36	3,64	0,17	82,67
3	0,89	12,35	4,14	0,34	82,28
4	0,81	12,51	4,53	0,48	81,67
5	0,78	12,79	4,88	0,56	80,99
6	0,78	13,13	5,20	0,60	80,28
7	0,78	13,50	5,51	0,61	79,59
8	0,79	13,89	5,80	0,61	78,92
9	0,79	14,27	6,07	0,60	78,28
10	0,79	14,62	6,32	0,59	77,69

Table 7: The contribution (%) of shocks to traceable investment (IT)

Periods	traceable productivity shock	non-traceable productivity shock	public spending shock	Real interest rate shock	preferences shock
1	11,44	0,35	1,05	79,17	7,99
2	8,72	0,98	1,27	79,35	9,69
3	8,29	1,60	1,43	77,75	10,93
4	8,66	2,10	1,53	76,01	11,71
5	9,15	2,43	1,59	74,73	12,10
6	9,53	2,63	1,61	74,01	12,22
7	9,77	2,72	1,60	73,73	12,18
8	9,89	2,76	1,59	73,71	12,05
9	9,93	2,76	1,58	73,82	11,91
10	9,92	2,74	1,56	73,98	11,79

Table 8: The contribution (%) of shocks to non traceable investment (IN)

Periods	traceable productivity shock	non-traceable productivity shock	public spending shock	Real interest rate shock	preferences shock
1	11,44	0,35	1,05	79,17	7,99
2	8,72	0,98	1,27	79,35	9,69
3	8,29	1,60	1,43	77,75	10,93
4	8,66	2,10	1,53	76,01	11,71
5	9,15	2,43	1,59	74,73	12,10
6	9,53	2,63	1,61	74,01	12,22
7	9,77	2,72	1,60	73,73	12,18
8	9,89	2,76	1,59	73,71	12,05
9	9,93	2,76	1,58	73,82	11,91
10	9,92	2,74	1,56	73,98	11,79

Table 9: The contribution (%) of shocks to traceable labor (NT)

Periods	traceable productivity shock	non-traceable productivity shock	public spending shock	Real interest rate shock	preferences shock
1	78,62	9,32	3,53	1,55	6,97
2	74,61	7,83	3,70	2,12	11,73
3	67,26	7,15	4,03	5,77	15,80
4	59,49	7,11	4,21	10,68	18,50
5	53,03	7,36	4,29	15,23	20,09
6	48,18	7,71	4,32	18,79	20,99
7	44,72	8,08	4,34	21,38	21,49
8	42,31	8,42	4,35	23,16	21,75
9	40,66	8,75	4,38	24,35	21,87
10	39,56	9,04	4,40	25,12	21,88

Table 10: The contribution (%) of shocks to non traceable labor (NN)

Periods	traceable productivity shock	non-traceable productivity shock	public spending shock	Real interest rate shock	preferences shock
1	31,32	43,35	5,60	8,69	11,04
2	29,43	40,63	5,07	7,70	17,16
3	27,47	37,85	5,10	7,31	22,27
4	25,75	35,53	5,12	7,87	25,73
5	24,40	33,75	5,09	9,04	27,72
6	23,44	32,45	5,04	10,36	28,70
7	22,81	31,54	4,99	11,59	29,07
8	22,45	30,91	4,95	12,61	29,07
9	22,30	30,51	4,93	13,40	28,87
10	22,28	30,26	4,91	13,99	28,56

Table 11: The contribution (%) of shocks to relative prices (Pt)

Periods	traceable productivity shock	non-traceable productivity shock	public spending shock	Real interest rate shock	preferences shock
1	9,99	15,27	12,51	37,55	24,68
2	11,61	19,53	12,81	30,09	25,96
3	12,75	22,46	12,93	25,07	26,79
4	13,57	24,42	12,95	21,72	27,34
5	14,17	25,74	12,93	19,45	27,72
6	14,62	26,62	12,89	17,88	27,98
7	14,98	27,23	12,84	16,79	28,17
8	15,25	27,64	12,79	16,02	28,30
9	15,47	27,93	12,74	15,47	28,38
10	15,64	28,13	12,70	15,09	28,44

Figure 4: Impulse Response to a Tradable Productivity shock

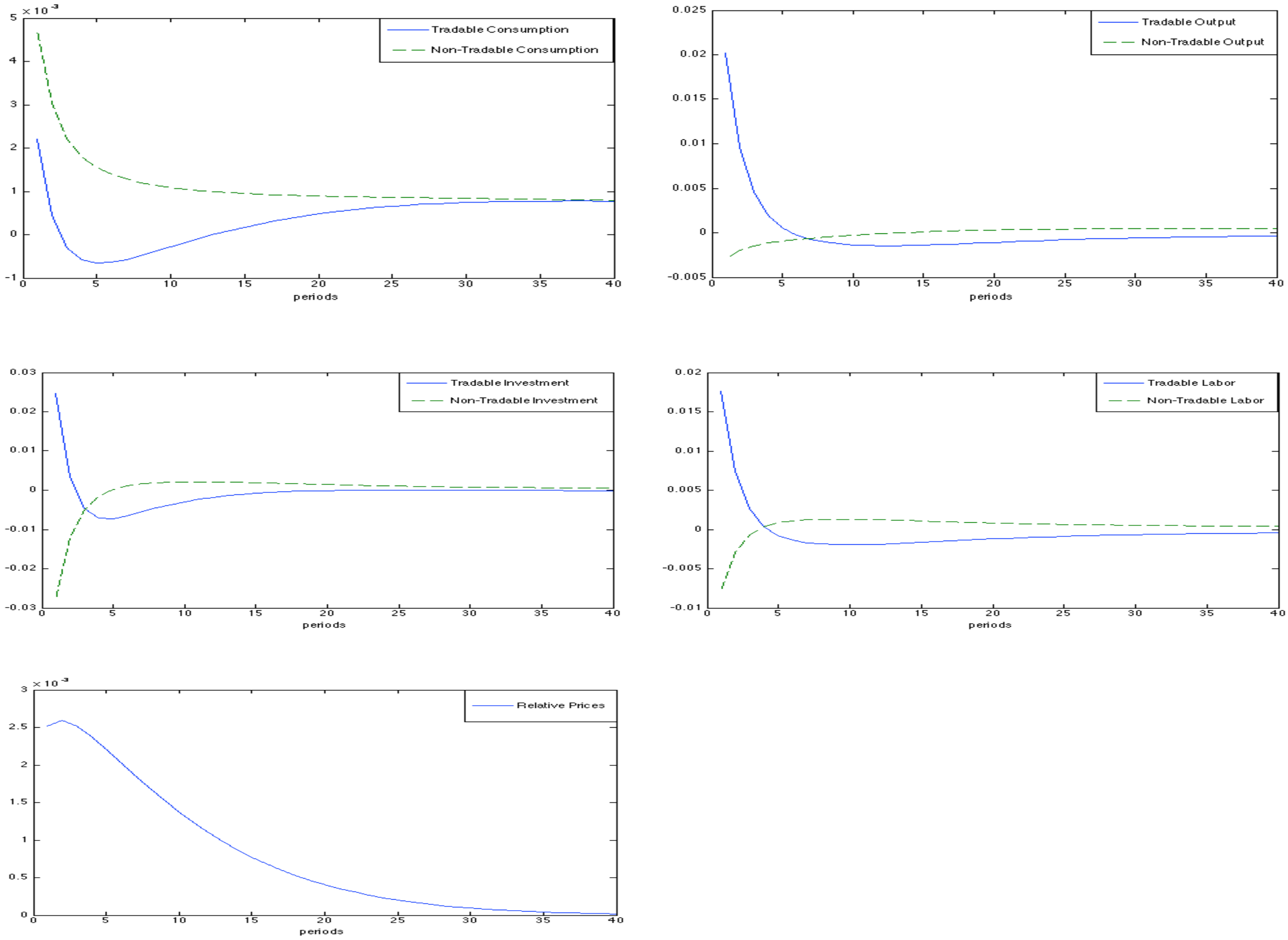


Figure 5: Impulse Response to a non-Tradable Productivity shock

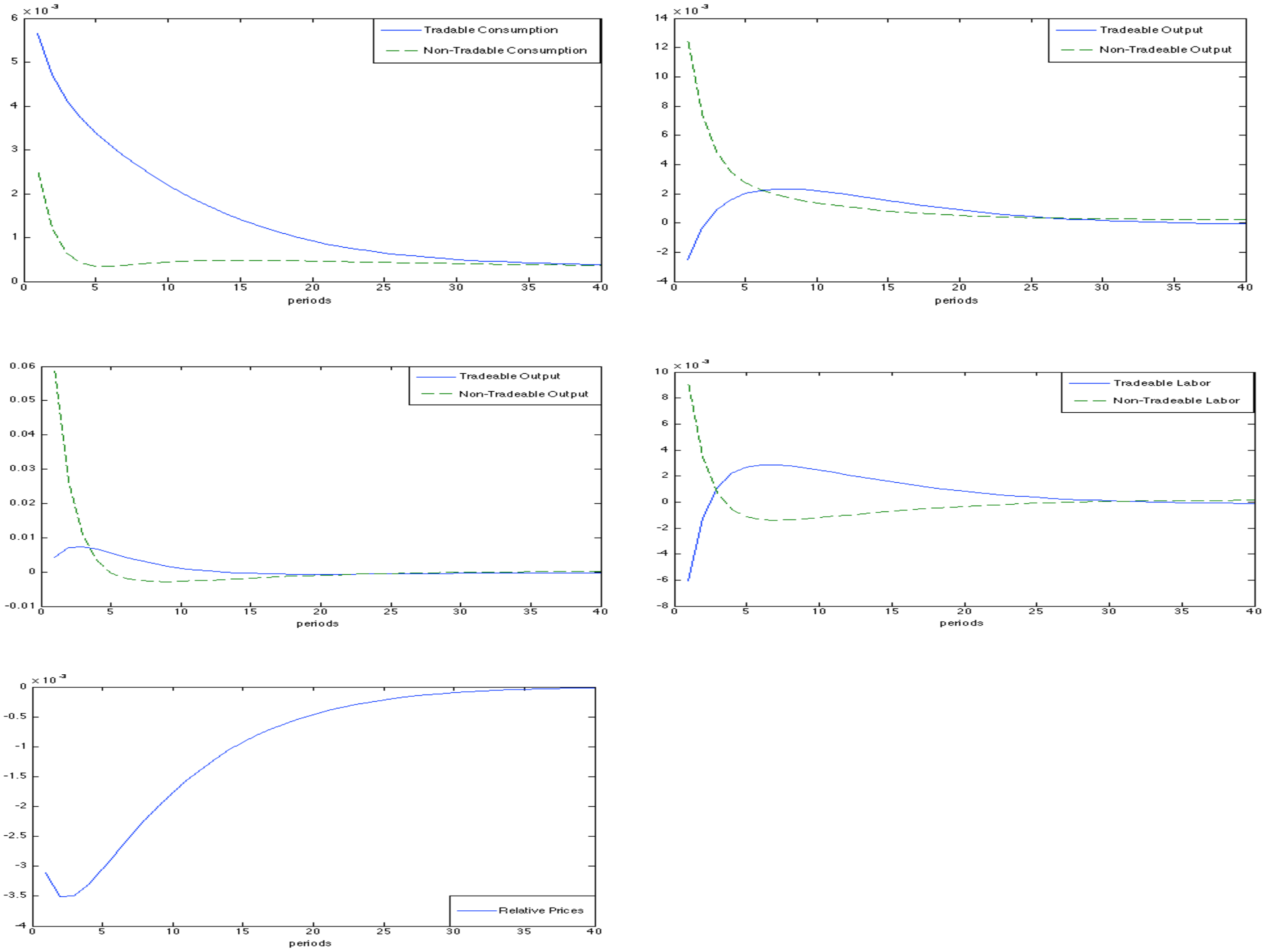


Figure 6: Impulse Response to a Real Interest Rate shock

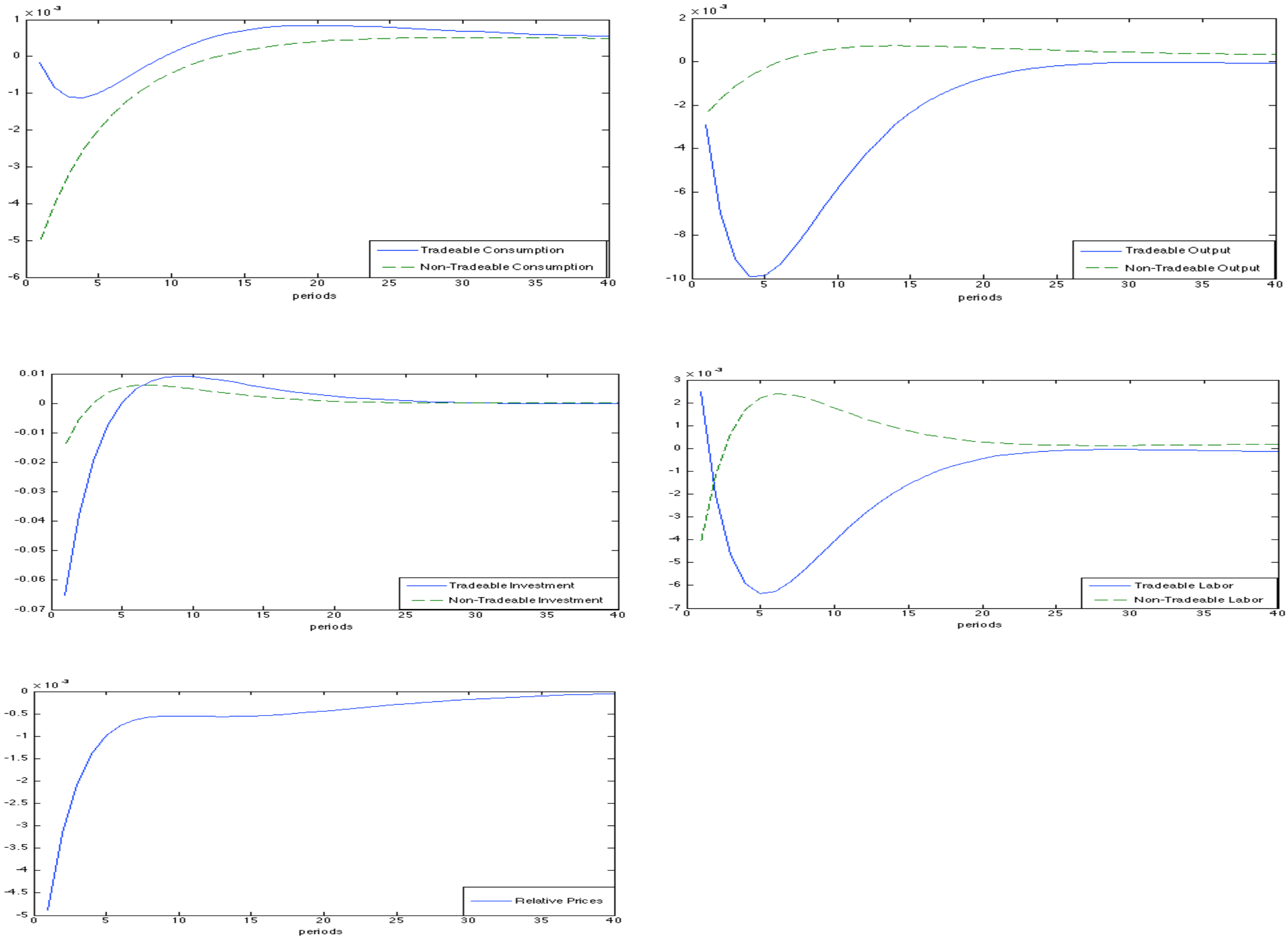
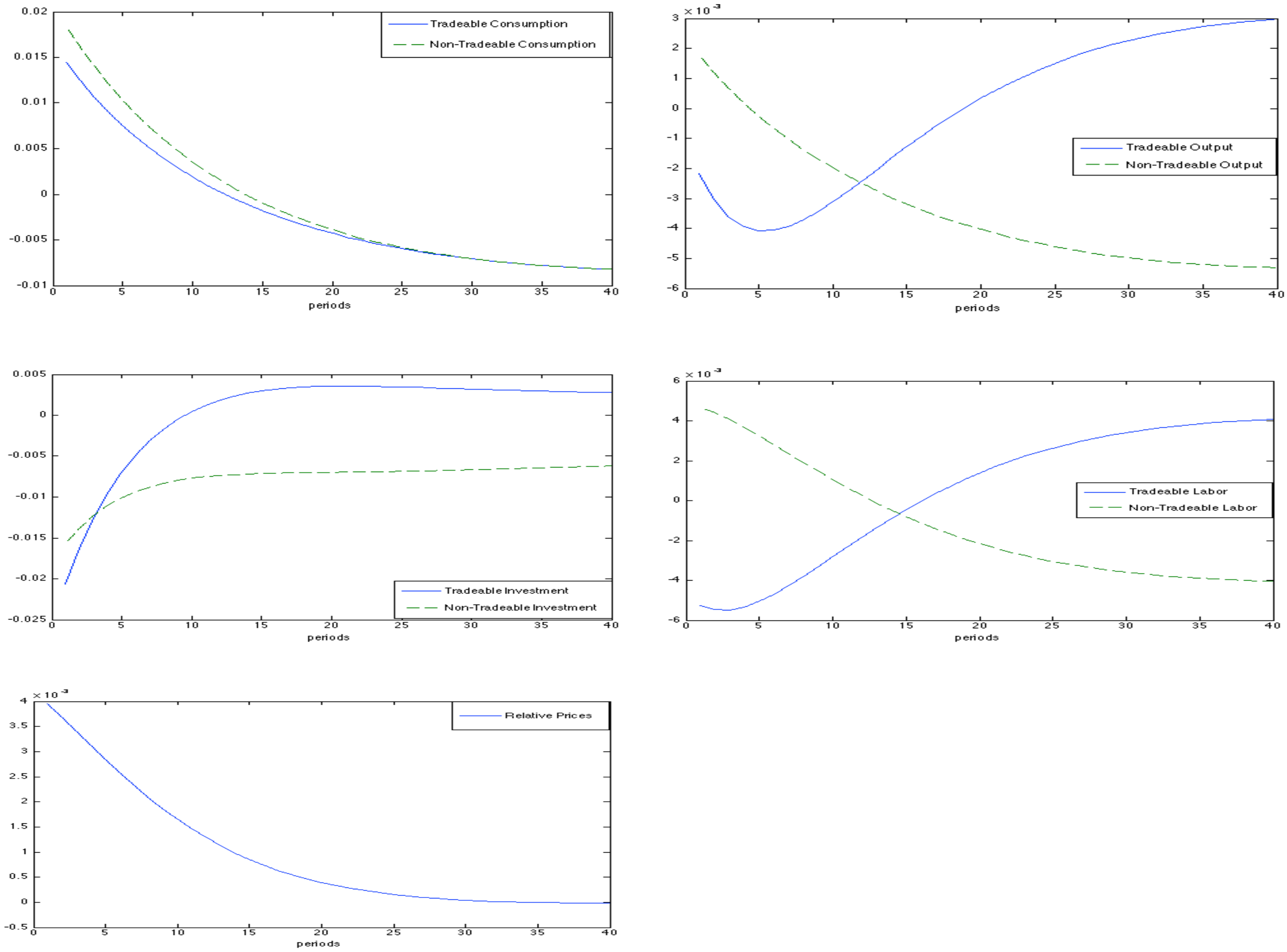


Figure 7: Impulse Response to a Preference shock



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