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Does the Central Bank of Peru Respond to Exchange Rate Movements?

TESIS PARA OPTAR EL TÍTULO PROFESIONAL DE LICENCIADA EN ECONOMÍA

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RESUMEN

El objetivo de esta investigación es investigar si los movimientos del tipo de cambio nominal afectan la fijación de la tasa de interés de política monetaria en Perú. Estimamos un modelo de equilibrio general dinámico estocástico (DSGE, siglas en inglés) neokeynesiano de una economía pequeña y abierta con hogares, dos sectores productivos de exportación (*commodities* y manufacturados) y un sector externo, basado en el modelo desarrollado por Schmitt-Grohé y Uribe (2017). El modelo considera mercados incompletos, rigidez de precios a la Calvo y una regla de política monetaria que responde a cambios en la inflación, el producto bruto interno y tipo de cambio nominal. Adicionalmente, se incluye una condición de paridad de la tasa de interés modificada que captura la intervención cambiaria, que ha sido utilizada activamente por el Banco Central del Perú desde principios de los años 90. Estimamos cuatro especificaciones del modelo por métodos bayesianos para los periodos 1T2002-4T2017 y 1T2010-4T2017, cuando el Banco Central del Perú sigue un régimen de metas de inflación. El principal resultado sugiere que la importancia del tipo de cambio nominal en la regla de política monetaria del Banco Central del Perú ha disminuido desde el 2010, lo que puede atribuirse al proceso de desdolarización de la economía peruana y la consolidación del régimen de metas de inflación. Durante el período 1T2020-4T2017, el Banco Central racionaliza su esquema de metas de inflación con instrumentos para limitar los riesgos vinculados a la dolarización e interviene en el mercado de divisas. Además, encontramos que la intervención en el mercado cambiario ha sido una característica relevante del mercado cambiario en Perú y de la determinación del tipo de cambio.

Clasificación JEL: C32, E52, F41.

Palabras Clave: Economía pequeña y abierta, regla de Taylor, regla de política monetaria, tipo de cambio, metodología bayesiana, economía peruana.

ABSTRACT

The aim of this paper is to investigate whether exchange rate movements affect the monetary policy interest rate setting in Peru. We estimate a New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model of a small open economy with households, two productive export sectors (commodities and manufacturing) and a foreign sector, based on the model developed by Schmitt-Grohé and Uribe (2017). The model considers incomplete markets, sticky prices a la Calvo and a monetary policy rule that responds to changes in inflation, output and in the nominal exchange rate. Additionaly, we include a modified interest rate parity condition that captures foreign exchange intervention, which has been actively used by the Central Bank of Peru since early 90s. We estimate four specifications of the model by Bayesian methods for the periods 2002Q1-2017Q4 and 2010Q1-2017Q4, when the Central Bank of Peru follows an inflation targeting regime. The main result suggests that the importance of the nominal exchange rate in the Central Bank of Peru's interest rate policy rule has decreased since 2010, which can be attributed to the de-dollarization process of the Peruvian economy and the consolidation of the inflation targeting regime. During 2010Q1-2017Q4, the Central Bank rationalizes its inflation targeting scheme with instruments to limit risks linked to dollarization and intervenes in the foreign exchange market. In addition, we find that foreign exchange market intervention has remained a relevant feature of the foreign exchange market in Peru and of the determination of the exchange rate.

JEL Classification: C32, E52, F41.

Key Words: Small Open Economy; Taylor Rule; Monetary Policy Rule; Exchange Rate; Bayesian Methodology; Peruvian Economy.

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1 INTRODUCTION

The monetary policy rule proposed by Taylor (1993) is a linear equation which describes how the central banks set the interest rate depending on the inflation rate and the output gap. Despite being simple, this equation encompasses the spirit of monetary policy behavior (see Orphanides, 2003). Many studies have focused on the response of monetary policy to inflation (see Svensson, 1996, 1997; Clarida, Galí and Gertler, 1998, 2000; Judd and Rudebusch, 1998; Nelson, 2000) and, later, to the output gap (see Favero and Rovelli, 1999, 2003; Rodríguez, 2008a, 2008b). But also, there have been some critiques about the simplicity of the Taylor rule, because the specifcation of the rule may be subject to great uncertainty and does not consider the discretionality of the responses to some specific circumstances (see Kozicki, 1999).

However, the discussion opens when we propose to add the exchange rate in the monetary policy rate decision. On one hand, some authors (see De Paoli, 2009) suggest that the optimal monetary policy rule in small open economies may include exchange rate smoothing, even in economies that are not financially vulnerable. On the other hand, other authors (see Calvo and Reinhart, 2002) consider this feature as fear of floating. Thus, the objective of this investigation is to identify the role of the nominal exchange rate in the monetary policy rule (see Taylor, 2001). This topic becomes relevant in a country like Peru, not only because it is a small open economy and mainly a raw materials producer and, thus, exposed to commodity prices fluctuations; but also because it is a partially dollarized country with an inflation targeting regime. In dollarized economies, the exchange rate volatility spills over finantial conditions, negatively affecting the real side of the economy. It could trigger balance sheet effects, having an impact on the aggregate supply-demand equilibrium and, therefore, on the inflation rate (see Humala and Rodríguez, 2010). Also, Rossini, Quispe and Serrano (2013) point out that dollarization turns the economy vulnerable to credit booms and busts associated with capital flows and the exchange rate fluctuations that determine the quality of the credit portfolio.

There is mixed evidence about the inclusion of exchange rate in the monetary policy rule. Specifically, there are two branches of literature on studying the role of the exchange rate in the monetary policy decision of the central banks. The first one studies the issue in an univariate setup. Clarida, Galí and Gertler (1998) estimate the monetary policy reaction function for some European countries and Japan. The authors suggest that inflation targeting may be superior to fixing the exchange rate because it may sacrifice monetary control. Leitemo and Söderström (2001) find that the inclusion of the exchange rate in the monetary policy rule reduces the volatility of import variables and performs better than the standard one. Furthermore, Calvo and Reinhart (2002) show that some emerging countries use the interest rate to smooth exchange rate fluctuations, because a floating exchange rate increases the exposure to exchange rate volatility and has a negative impact on the banking system and induces balance-sheet effects.

The second branch of literature studies the issue in a multivariate framework. Taylor (1999) finds that including the exchange rate in the monetary policy rule may improve its performance. Ball (1999) suggests that a Taylor-type rule improves its performance for an open economy model when adding exchange rate and long run inflation. The concern is about the effect of large movements in the exchange rate, because it may produce large fluctuations in output. The exchange rate has an impact on import prices and, therefore, on inflation. For this reason, inflation targeting may imply aggressive changes in the monetary policy rate. Finally, in a small open economy framework, Lubik and Schorfheide (2007) —based in Galí and Monacelli (2005) — demonstrate that the central banks of Australia and New Zealand do not respond to exchange rate movements while the central banks of Canada and the United Kingdom do.

In this paper, we develop a New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model of a small open economy. The model, based on Schmitt-Grohé and Uribe

(2017), considers households who decide how much to consume, invest, save and work. Also, it has two type of firms: commodity exporters and manufactured goods exporters. The model considers incomplete markets and sticky prices a la Calvo. The monetary policy rule responds to changes in the inflation rate and changes in the nominal exchange rate. Additionaly, we include a modified interest rate parity condition that captures foreign exchange intervention, which has been actively used by the Central Bank of Peru since early 90s. The nominal exchange rate is defined by the uncovered interest rate parity (UIP). The objective of this study is to evaluate the relevance of the parameter associated with the exchange rate in the monetary policy rule.

We estimate the model parameters by Bayesian methods using quarterly series of the Peruvian economy during the period 2002Q1-2017Q4, which is when Peru followed an inflation targeting regime. We estimate four specifications of the model. The main empirical results show that changes in the nominal exchange rate are relevant in the monetary policy decision. However, the estimation for a more recent subsample (2010Q1-2017Q4) shows that the exchange rate importance on the Central Bank's policy rule has declined since 2010. This result may reflect a lower level of dollarization of the Peruvian economy, particularly since 2014. Also, the estimation results show that foreign exchange intevention is a relevant feature of the dynamics of the exchange rate in Peru, as the model with foreign exchange intervention outperforms the model without foreign exchange intervention. The estimation results also show that the terms of trade shocks and productivity shocks are the most important determinants of the forecast error variance of output and that foreign exchange intervention reduces the impact of external shocks on the domestic inflation.

The paper is organized as follows. In section 2, we present the DSGE model; in section 3 we show the empirical results and section 4 concludes.

2 THE MODEL

The model is based on Schmitt-Grohé and Uribe (2017). It is a model of a small open economy composed by households, two productive export sectors (commodities and manufacturing), a monetary policy authority and a foreign sector. Additionally, the model includes nominal rigidities a la Calvo on the final consumption goods. The manufactured goods are converted to differentiated final goods.

2.1 Households

Households demand final goods produced by the manufacturing sector and supply their labor (h_t) to the manufacturing firms for a salary (w_t). Also, households decide how much to consume (c_t), save in local currency (d_t) and in foreign currency $\left(d_t^f\right)$. They maximize their utility function:

$$U_t\left(c_t, h_t\right) = \frac{\left[c_t - \left(\frac{h_t}{\omega}\right)^{\omega}\right]^{1-\sigma}}{1-\sigma}, \tag{1}$$

where ω is the inverse of the labor supply elasticity and σ is the inverse of the intertemporal substitution of consumption elasticity. The restriction of the household is

$$\begin{gathered} w_t h_t + \pi_t^x + \pi_t + s_t p_t^m d_{t-1}^f \left(1 + r_{t-1}^f\right) + d_{t-1}\left(1 + r_{t-1}\right) + u_t^x k_{t-1}^x + u_t k_{t-1}^x = \\ p_t c_t + p_t \left(k_t^x - (1-\delta)\, k_{t-1}^x\right) + p_t \Phi_{x,t}\left(k_t^x - k_{t-1}^x\right) \\ +p\left(k_t - (1-\delta)\, k_{t-1}\right) + p_t \Phi_t\left(k_t - k_{t-1}\right) - s_t p_t^m d_t^f - d_t. \end{gathered}$$

where s_t is the nominal exchange rate, p_t^m is the price of imported goods, r_{t-1} is the interest rate in $t-1$ in local currency, r_{t-1}^f is the interest rate faced by domestic agents in foreign currency, p_t is the price of the final goods, u_t^x is the cost of capital that commodities export firms pay to households and u_t is the cost of capital the manufacturing firms pay to households. The capital of the commodities export sector is k_t^x with the following law of movement

$$k_t^x = (1-\delta)\, k_{t-1}^x + i_t^x, \tag{2}$$

where δ is the depreciation rate and i_t^x is the investment in the commodities export sector. The law of movement of the capital of the manufacturing sector k_t is

$$k_t = (1-\delta)\, k_{t-1} + i_t^m, \tag{3}$$

where i_t^m is the investment in the manufacturing export sector.

Furthermore, $\Phi_x\left(k_t^x - k_{t-1}^x\right) = \frac{\varphi}{2}\left(k_t^x - k_{t-1}^x\right)^2$ is the capital adjustment cost of the commodities export sector and $\Phi\left(k_t - k_{t-1}\right) = \frac{\varphi}{2}\left(k_t - k_{t-1}\right)^2$ is the capital adjustment cost of the manufacturing sector.

Solving the the problem of households, the Lagrange multiplier is defined by

$$\lambda_t = \left[c_t - \left(\frac{h_t}{\omega}\right)^{\omega}\right]^{-\sigma}, \tag{4}$$

and the labor supply of households is given by

$$h_t^{\omega-1} = \frac{w_t}{p_t}. \tag{5}$$

The Euler equation in local currency and in foreign currency, respectively, are

$$\lambda_t = \beta E_t\left[\lambda_{t+1}\left(\frac{p_t}{p_{t+1}}\right)(1+r_t)\right], \tag{6}$$

$$\lambda_t s_t = \beta E_t\left[\lambda_{t+1} s_{t+1}\left(\frac{p_t}{p_{t+1}}\right)(1+r_t)\right], \tag{7}$$

where β is the discount factor.

2.2 Commodities Export Firms

The firms of this sector are price-takers (p_t^x). This sector only uses capital to produce such that

$$y_t^x = A_t^x \left(k_{t-1}^x\right)^{\alpha_x}, \tag{8}$$

where α_x is the parameter associated with capital in the production function and A_t^x is the productivity of the commodities exporters defined by an AR(1) equation

$$\ln \frac{A_t^x}{A^x} = \rho_{A^x} \ln \frac{A_t^x}{A^x} + \epsilon_t^{A^x}, \tag{9}$$

where ρ_{A^x} is the persistence of the productivity in the commodity export sector, A_t^x is the steady state of the productivity in the commodity export sector and $\epsilon_t^{A^x}$ is the productivity shock in the sector.

Commodity exporters firms maximize their profits

$$\pi_t^x = s_t p_t^x y_t^x - u_t^x k_{t-1}^x, \tag{10}$$

where p_t^x is the export price and the cost of capital is given by

$$u_t^x = \alpha_x \frac{s_t p_t^x}{p_t} \frac{y_t^x}{k_{t-1}^x}. \tag{11}$$

Finally, solving the problem of the firm, we have that the Tobin's Q of the commodities export firms is

$$\lambda_t \left(1 + \Phi'_{x,t}\right) = \beta E_t \left(\lambda_t X_{t+1} u_{t+1}^x + 1 - \delta + \Phi'_{x,t+1}\right), \tag{12}$$

where $X_{t+1} = \frac{S_t P_t^x}{P_t}$.

2.3 Manufacturing Firms

The firms of this sector use intermediate goods that are produced with a combination of imported goods and work. These firms follow a production function defined by

$$y_t = A_t \left(k_{t-1}\right)^{\alpha_k} m_t^{\alpha_m} \left(h_t\right)^{1-\alpha_k-\alpha_m}, \tag{13}$$

where k_{t-1} is the stock of capital of the manufactured goods producer, h_t is the number of hours used in this productive sector, α_m is the participation of the imported goods in the production function of the manufactured goods and α_k is the participation of the capital in the production function. The law of movement of the capital in this sector is

$$k_t = (1-\delta) k_{t-1} + i_t^m, \tag{14}$$

where i_t^m is the investment in the manufacturing export sector. Further, A_t is the productivity of the manufacturing firms and follows a dynamic of an AR(1) equation such that

$$\ln \frac{A_t}{A} = \rho_A \ln \frac{A_t}{A} + \epsilon_t^A + \lambda_{gg}\epsilon_t^{tot}, \tag{15}$$

where ρ_A is the persistence of the productivity in the manufacturing export sector firms, A is the steady state of the productivity, λ_{gg} is the correlation between the terms of trade shock and the productivity shock and ϵ_t^A is the productivity shock. See Castillo and Rojas (2014) for empirical evidence that shows a positive correlation between total factor productivity and terms of trade shocks in Peru.

The optimal demand of imported goods (m_t) used in the production of the intermediate goods is:

$$RER_t = \alpha_k \frac{y_t}{m_t}, \tag{16}$$

where α_k is the parameter associated with capital in the production function and RER_t is the real exchange rate defined by

$$RER_t = (RER_{t-1})^{\lambda_q} \frac{s_t}{(s_{t-1})^{(1-\lambda_q)}} \pi_t, \tag{17}$$

where λ_q is the rigidity of the real exchange rate and π_t is the inflation rate.

The manufacturing firms maximize their profits such that

$$\pi_t^m = p_t y_t - u_t k_{t-1} - s_t p_t^m m_t - w_t h_t, \tag{18}$$

where u_t is the cost of capital defined by

$$u_t = \alpha_k \frac{y_t}{k_{t-1}},$$

Solving the problem of the firm, we define the Tobin's Q of the manufacturing firms as:

$$\lambda_t (1 + \Phi_t) = \beta E_t \left[\lambda_{t+1} \left(\frac{u_{t+1}}{p_{t+1}} + 1 - \delta + \Phi'_{t+1} \right) \right]; \tag{19}$$

and the optimal demand for work in the intermediate goods producing sector is:

$$(1 - \alpha_m - \alpha_k) \frac{y_t}{h_t} = \frac{w_t}{p_t}. \tag{20}$$

The intermediate goods are transformed into final goods through a one to one technology. These final goods are used for consumption, investment and exports.

2.4 The Phillips Curve

The Phillips curve is given by

$$\phi\pi_t^{\varepsilon-1} = 1-(1-\phi)\left(\frac{V_t^N}{V_t^D}\pi_{t-1}^{\gamma}\right)^{1-\varepsilon}, \tag{21}$$

where ϕ is the capital adjustment cost function of the manufacturing export sector, ε is the Calvo probability of not changing prices, γ is the persistence of inflation. Also,

$$V_t^N = \Lambda_t Y_t \mu mc_t\left(z\right) + \beta\phi E_t\left(\pi_{t+1}^{\varepsilon}V_{t+1}^N\pi_t^{(1-\varepsilon)\gamma}\right), \tag{22}$$

$$V_t^D = \Lambda_t Y_t + \beta\phi E_t\left(\pi_{t+1}^{1-\varepsilon}V_{t+1}^D\pi_t^{-\varepsilon\gamma}\right), \tag{23}$$

where Λ_t is the firm's stochastic discount factor, μ is the firm's mark up, mc_t is the marginal cost of firms.

2.5 Foreign Sector

The equation that determines the balance of payments is obtained by aggregating the consumption demand, the investment and the exports of manufactured goods. This gives

$$\frac{xn_t}{p_t} = y_t + \frac{s_t p_t^x}{p_t}y_t^x - \frac{s_t p_t^m}{p_t}m_t - \left(c_t + i_t^x + \Phi_x\left(k_{t+1}^x - k_t^x\right) + i_t + \Phi\left(k_{t+1}-k_t\right)\right), \tag{24}$$

where xn_t represents the net exports.

The country risk premium is given by

$$r_t^f = r^* + \psi\exp\left(\frac{d_t}{d}-1\right) - \lambda_{x_i}\log\left(\frac{tot_t}{tot}\right) + \varepsilon_t^{rf}, \tag{25}$$

where r^* is the international interest rate, ψ is the risk premium and debt elasticity, λ_{x_i} is the persistence of the terms of trade and ϵ^{rf} is the shock of the country risk premium with a law of movement given by

$$\varepsilon_t^{rf} = \rho_{rf}\varepsilon_{t-1}^{rf} + \epsilon_{RR}, \tag{26}$$

where ρ_{rf} is the persistence of the risk premium shock.

The net assset position is:

$$\frac{s_t d_t}{p_t} = \frac{s_t}{p_t}\frac{p_{t-1}}{s_{t-1}}\frac{s_{t-1}d_{t-1}}{p_{t-1}}\left(1 + r_{t-1}\right) - \frac{xn_t}{p_t}. \tag{27}$$

The non-traditional exports are:

$$x_t^{NT} = \left(RER_t\right)^{\xi} C_t^*, \tag{28}$$

where ξ is the elasticity of the non-traditional exports C_t^* is the foreign demand of goods.

The price of the goods of the manufacturing sector is

$$y_t = \left(c_t + i_t^x + \Phi_x\left(k_{t+1}^x - k_t^x\right) + i_t + \Phi\left(k_{t+1} - k_t\right)\right) + x_t^{NT}. \tag{29}$$

The terms of trade are:

$$tot_t = \frac{p_t^x}{p_t^m}, \tag{30}$$

and the dynamics of the terms of trade are represented by an AR(1) equation

$$\ln\frac{tot_t}{tot} = \rho_{tot}\ln\frac{tot_{t-1}}{tot} + \epsilon_t^{tot}, \tag{31}$$

where ρ_{tot} is the persistence of the terms of trade, tot is the steady state of the terms of trade and ϵ_t^{tot} is a shock of terms of trade.

The relative price of exported goods are

$$\frac{s_t p_t^x}{p_t} = x_t = x_{t-1}^{\lambda_x} \left[\frac{s_t p_t^x}{s_{t-1} p_{t-1}^x \pi_t} \right]^{(1-\lambda_x)},$$

where λ_x is the rigidity of the relative price of exported goods.

2.6 Gross Domestic Product and Total Investment

We define the GDP as

$$y_t^{GDP} = p y_t + p^x y_t^x, \tag{32}$$

where p_t is the price of manufactured goods in steady state, p^x is the export price of commodities in steady state. The total investment is given by

$$i_t = i_t^x + i_t^m. \tag{33}$$

2.7 Monetary Policy

We assume that the Central Bank adjusts the interest rate in response to movements of the inflation rate, the nominal exchange rate and the output such that

$$(1 + r_t) = \left(\frac{1}{\beta} \right)^{1-\rho_R} (1 + r_{t-1})^{\rho_R} (\Pi_t)^{(1-\rho_R)\phi_\pi} \left(\frac{s_t}{s_{t-1}} \right)^{(1-\rho_R)\phi_e} y_t^{GDP^{(1-\rho_R)\phi_y}}. \tag{34}$$

The coefficient $\phi_\pi > 1$ is the size of the response of the monetary policy to changes in the inflation rate, $\phi_e > 0$ is the size of the response of the monetary policy to changes in the nominal exchange rate and $\phi_y > 0$ is the size of the response of the monetary policy to changes in the output. The persistence of the interest rate is $0 < \rho_R < 1$. We evaluate the bias of the monetary policy by $\phi_e > 0$ when there is fear of floating and $\phi_e = 0$ when there is no fear of floating.

Additionally, we consider that the Central Bank intervenes in the foreign exchange market. We include this in the model by modifying the UIP, such that

$$\left(\frac{s_t}{s_{t-1}}\right)^{\lambda_s} = E_t\left(\frac{s_{t+1}}{s_t}\right)\left(\frac{1+i_r^*}{1+r_t}\right)^{1-\lambda_s}, \tag{35}$$

where λ_s is a degree of exchange rate stickiness. The more the Central Bank intervenes, the higher this parameter.

3 EMPIRICAL RESULTS

3.1 Choice of Priors

The priors are selected to reflect the characteristics of the Peruvian economy (see Table 1 and Table 2). Peru is a small open economy with an important commodity producing sector. We use as a reference the Central Bank's quarterly projection model[1]. The distributions of priors are assumed to be independent and size restricted.

[1] For further information see Salas (2011) and Vega et al. (2009) of the Central Bank of Peru.

Table 1: Estimated Parameters, Priors Distributions

Parameters	Description	Distribution	Prior Mean	Prior Std. Dev.
ρ_{rf}	Persistence of the shock of the country risk premium	Inverse gamma	0.65	0.10
Φ_x	Capital adjustment cost function of the commodities export sector	Inverse gamma	0.80	0.20
Φ	Capital adjustment cost functionof the manufacturing export sector	Inverse gamma	1.50	0.15
ψ	Risk premium and debt elasticity	Beta	0.30	0.10
ω	Inverse of the labor supply elasticity	Inverse gamma	2.30	0.20
ξ	Elasticity of the non-traditional exports	Inverse gamma	0.50	0.01
ϕ_e	Response of the monetary policy rate to changes in the exchange rate	Inverse gamma	0.70	0.15
ϕ_y	Response of the monetary policy rate to changes in the gross domestic product	Inverse gamma	1.30	0.10
γ	Persistence of inflation	Beta	0.10	0.05
λ_q	Persistence of the real exchange rate	Beta	0.36	0.10
λ_s	Degree od exchange rate stickiness	Beta	0.60	0.20
λ_x	Rigidity of the relative price of exported goods	Beta	0.90	0.10
λ_{gg}	Correlation between terms of trade shocks and productivity of the manufacturing sector shocks	Beta	0.70	0.10
ρ_{tot}	Persistence of the terms of trade	Beta	0.95	0.01
ρ_{A_x}	Persistence of the productivity in the commodity export sector	Beta	0.83	0.01
ρ_A	Persistence of the productivity in the manufacturing export sector	Beta	0.80	0.10
ϕ_π	Response of the monetary policy rate to inflation	Inverse gamma	2.20	0.01

Table 2: Estimated Standard Deviations, Priors Distributions

Parameters	Description	Distribution	Prior Mean	Prior Std. Dev.
$\sigma^{\varepsilon_{RR}}$	Standard deviation of the premium risk shock	Inverse gamma	0.01	2.00
$\sigma^{\varepsilon_{tot}}$	Standard deviation of the terms of trade shock	Inverse gamma	0.30	2.00
$\sigma^{\varepsilon_{A^x}}$	Standard deviation of the productivity in the commodity export sector shock	Inverse gamma	0.01	2.00
$\sigma^{\varepsilon_{YY}}$	Standard deviation of the measurement error of the GDP	Inverse gamma	0.01	2.00
$\sigma^{\varepsilon_{AA}}$	Standard deviation of the productivity in the manufacturing export sector shock	Inverse gamma	0.10	2.00
$\sigma^{\varepsilon_{INV}}$	Standard deviation of the margin shock	Inverse gamma	0.01	2.00
$\sigma^{\varepsilon_{CC}}$	Standard deviation of the measurement error of consumption	Inverse gamma	0.01	2.00
$\sigma^{\varepsilon_{YY_x}}$	Standard deviation of the measurement error of the production in the commodity export sector	Inverse gamma	0.01	2.00

3.2 Data Description

The observable variables are gross domestic product (GDP), national output of raw materials, total investment, private consumption, terms of trade, consumer price index and the real exchange rate. These variables are seasonally adjusted and introduced in the model as the first log differences in deviations from its mean. The data is at quarterly frequency from 2002Q1 to 2017Q4 and are obtained from the statistics of the Central Bank of Peru. This is the period in which the Peruvian Central Bank has followed an inflation targeting regime.

3.3 Estimation Results

We estimate four specifications of the linear version of the model (see Table 3) by Bayesian methods for the periods 2002Q1-2017Q4 and 2010Q1-2017Q4. We do not estimate the model with a dataset before 2002, as in this period monetary aggregates were used as the monetary policy tool and the model developed in this paper is not suitable to reflect the mechanisms of that policy tool. Tables 4 and 5 show the comparison of the estimation of the four specifications by log marginal density, the Bayes ratio and the posterior probability during the period of inflation targeting for the two datasets.

We find that the importance of the exchange rate in the monetary policy rule has decreased. This is consistent with the use of the interest rate as a monetary policy instrument within an inflation targeting regime, adopted in 2002, where the interest rate does not respond anymore to money demand shocks and reacts to macroeconomic shocks that impact the inflation and the GDP. Also, in 2004, began the de-dollarization process of the Peruvian economy. As a consequence, the pass-through effect of the exchange rate to inflation decreased as Winkelried (2014) and Maertens, Castillo and Rodríguez (2012) point out.

Also, the results show that the model specifications with intervention of the Central Bank in the foreign exchange market (especification models 1 and 3) are superior to the ones with no intervention in the foreign exchange market. The Central Bank of Peru rationalized its inflation targeting scheme with additional instruments to limit the risks associated with financial dollarization, for example, with the foreign exchange market intervention.

Table 3: Model Specifications Description

Model	Description	
1	The Central Bank considers changes in the nominal exchange rate in the monetary policy rule and intervenes in the foreign exchange market	$\phi_e > 0$ $\lambda_s > 0$
2	The Central Bank considers changes in the nominal exchange rate in the monetary policy rule and does not intervene in the foreign exchange market	$\phi_e > 0$ $\lambda_s = 0$
3	The Central Bank does not consider changes in the nominal exchange rate in the monetary policy rule and intervenes in the foreign exchange market	$\phi_e = 0$ $\lambda_s > 0$
4	The Central Bank does not consider changes in the nominal exchange rate in the monetary policy rule and does not intervene in the foreign exchange market	$\phi_e = 0$ $\lambda_s = 0$

Table 4: Comparison of the Estimated Model Specifications, 2002Q1-2017Q4

Model	1	2	3	4
Log marginal density	871.79	855.53	870.07	863.61
Bayes ratio	1.0000	0.0000	0.1801	0.0003
Posterior model probability	0.8472	0.0000	0.1525	0.0002

Note: The prior density over the model is the same for the four model specifications.

Table 5: Comparison of the Estimated Model Specifications, 2010Q1-2017Q4

Model	1	2	3	4
Log marginal density	432.57	424.22	446.84	440.23
Bayes ratio	1.00	0.00	1578967.09	2112.69
Posterior model probability	0.000	0.000	0.999	0.001

Note: The prior density over the model is the same for the four model specifications.

3.4 Bayesian Impulse Response Functions

We present the Bayesian impulse response functions (IRF) of the best model specification using the dataset 2010Q1-2017Q4 (model 3) for a terms of trade shock and a risk premium shock. For this section, we use the linear version of the model.

Peru is a commodities export country so when a terms of trade shock occurs (see Figure 1), the investment in the commodity export sector increases (i_t^x) and, therefore, in the total investment (I_t). This, in turn, increases the stock of capital of the commodity sector (k_t^x) and the ouput of this sector (y_t^x). This means greater income for the households, so the consumption increases (c_t). The exchange rate appreciates (s_t), therefore, the imports turn cheaper so the inflation falls (π_t). As a result, the interest rate falls too (r_t).

A risk premium shock (see Figure 2) causes a decrease in the investment and private consumption and, therefore, the GDP falls. The exchange rate depreciates, the imported goods become more expensive and the inflation rises. The monetary authority responds rising the local interest rate.

Additionally, we compare the Bayesian IRF of the model described above when the monetary policy includes the changes in the nominal exchange rate in the monetary policy rule (fear of floating, model specification 1) with the model which does not (no fear of floating, model specification 3) for the period 2010Q1-2017Q4. In Figure 3 shows that when a terms of trade occurs, the investment, consumption and, therefore, the GDP reacts slightly less strong when there is fear of floating. Also, the interest rate falls less and the real exchange rate is less volatile than the model with no fear of floating. Upon a risk premium shock (see Figure 4), we show that the endogenous variables of the model have a stronger reaction and, in equilibrium, the interest rate ends up reacting less.

3.5 Forecast Error Variance Decomposition

We present the evolution of forecast error variance decomposition (FEVD) for the GDP for 60 periods in Figure 5. It shows that the productivity shock is the most important, which explains nearly 60 percent of the GDP variation in the long term. The terms of trade account for approximately 40 percent of the GDP variation. This result is consistent with the findings of Schmitt-Grohé and Uribe (2017), that shows that terms of trade shock are an important determinant of GDP in Peru.

4 CONCLUSIONS

We estimate a DSGE model for a small open economy. The model has households who decide how much to consume, save, invest and work, two productive export sectors: commodities and manufacturing and a foreign sector. The monetary policy rule responds to changes in the nominal exchange rate, GDP and in the inflation rate. Also, the Central Bank intervenes in the foreign exchange market. The model includes nominal rigidities and incomplete markets.

We estimate the model parameters by Bayesian methods using quarterly series for Peruavian economy for the period 2002Q1-2017Q4, in which the Central Bank of Peru has followed an inflation targeting regime. The model specification with the best fit is the one which includes the changes in the exchange rate in the monetary policy rule and the Central Bank intervenes in the foreign exchange market.

Nonetheless, we find that, in the last eight years (2010Q1-2017Q4), the relevance of the exchange rate in the monetary policy rate has decreased and the model specifications with best fit of the data are the ones that the Central Bank only intervenes in the foreign exchange market of the Central Bank. This is consistent with use of the interest rate as a policy tool and the de-dollarization of Peru which results in a reduction of the pass-through effect of the exchange rate to inflation. In addition, we find that the foreign exchange market intervention has remained a relevant feature of the foreign exchange market in Peru and of the determination of the exchange rate.

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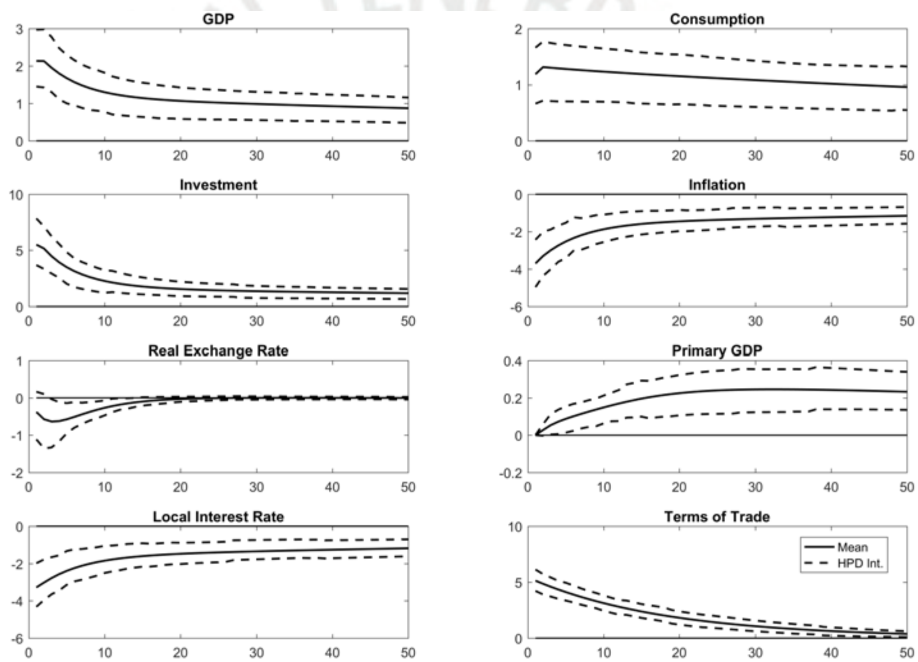

Figure 1: Impulse Response Functions, Terms of Trade Shock, 2010Q1-2017Q4

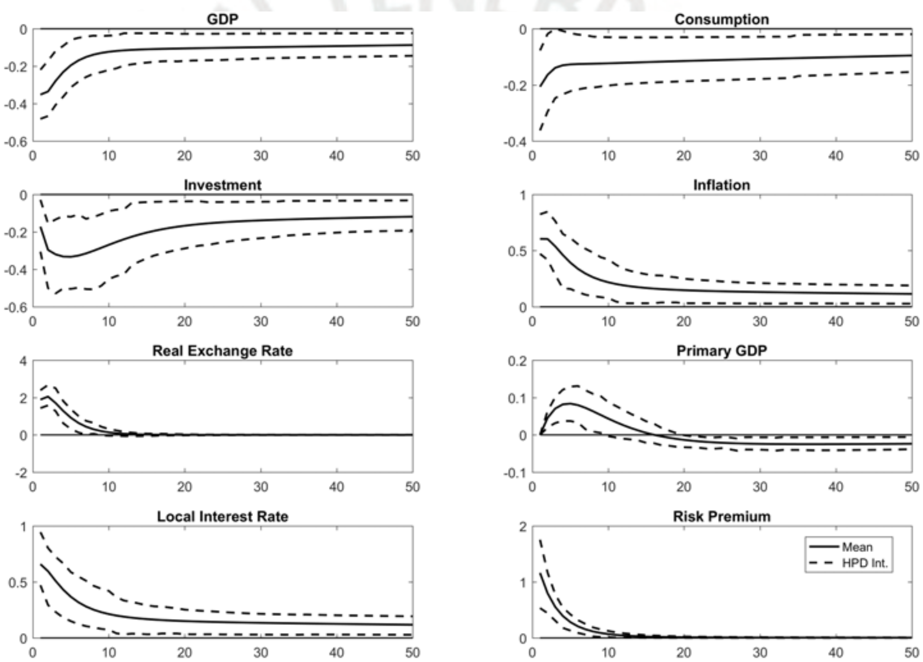

Figure 2: Impulse Response Functions, Risk Premium Shock, 2010Q1-2017Q4

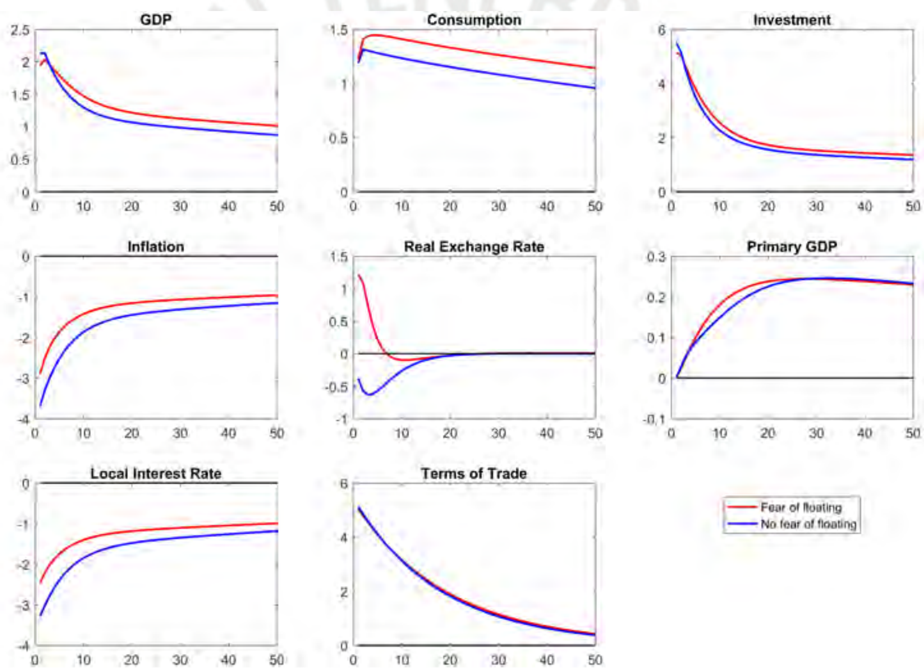

Figure 3: IRF Comparison, Terms of Trade Shock, 2010Q1-2017Q4

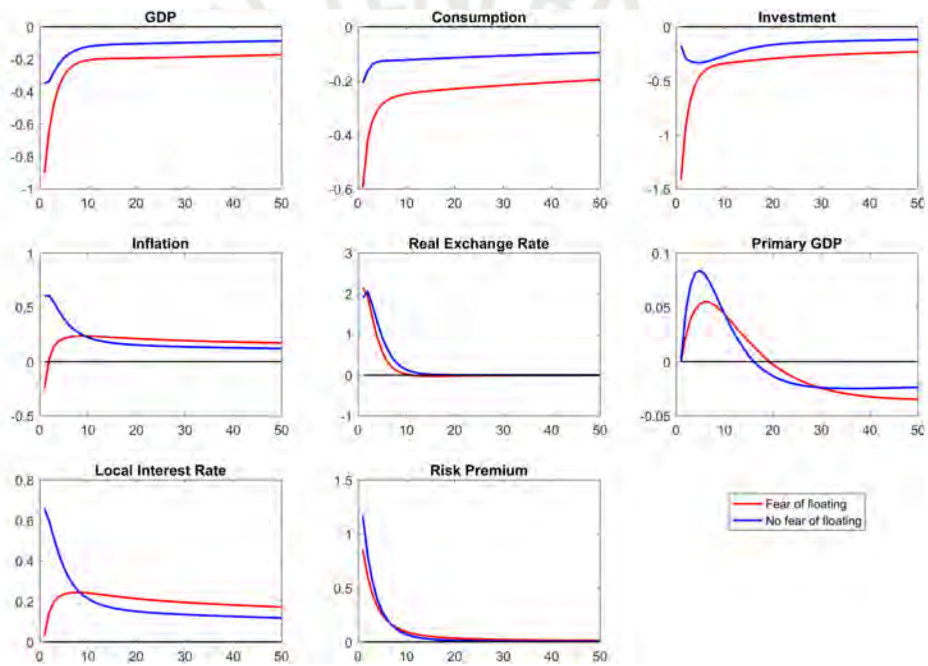

Figure 4: IRF Comparison, Risk Premium Shock, 2010Q1-2017Q4

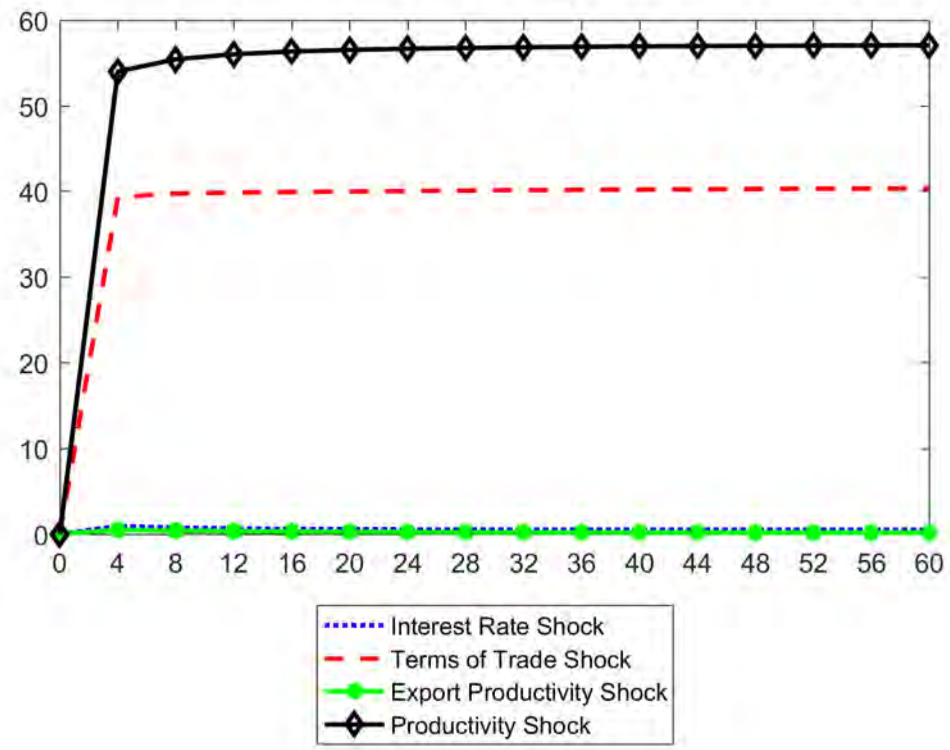

Figure 5: Foreign Error Variance Decomposition for GDP, External Shocks, 2010Q1-2017Q4

6 APPENDIX

6.1 Linear Model

Households

Lagrange multiplier

$$\lambda_t = -\sigma \left(\frac{c}{c - \left(\frac{h}{\omega}\right)^{\omega}} \right) c_t + \left(\frac{\sigma h \left(\frac{h}{\omega}\right)^{\omega}}{c - \left(\frac{h}{\omega}\right)^{\omega}} \right) h_t$$

Labbor supply

$$(\omega - 1)\, h_t = wp_t$$

Euler equation

$$\lambda_t = \lambda_{t+1} + i_t - \pi_{t+1}$$

Commodities Export Firms

Production function

$$y_t^x = a_t^x + \alpha_t^x k_{t-1}^x$$

Law of movement of capital

$$k_t^x = (1 - \delta)\, k_{t-1}^x + \delta i_t^x$$

Productivity law of movement

$$a_t^x = \rho_{A^x} a_{t-1}^x + \varepsilon_t^x$$

Cost of capital

$$x_t + y - k^x_{t-1} = \frac{u^x_t}{p_t}$$

Tobin's Q

$$\lambda_{p,t} + \Phi_x \left(k^x_t - k^x_{t-1}\right) = \lambda_{p,t+1} + \frac{\frac{u^x}{p}}{\left(\frac{u^x}{p} + 1 - \delta\right)} E_t \left(u^x_{p,t+1}\right) + \frac{\Phi_x}{\left(\frac{u^x}{p} + 1 - \delta\right)} E_t \left(k^x_{t+1} - k^x_t\right)$$

Manufacturing Firms

Production function

$$y_t = a_t + \alpha_k k_{t-1} + \alpha_m m_t + (1 - \alpha_m - \alpha_k) h_t$$

Law of movement of capital

$$k_t = (1 - \delta) k_{t-1} + \delta i^m_t$$

Productivity law of movement

$$a_t = \rho_a a_{t-1} + \xi^a_t + \lambda_{gg} \varepsilon^{tot}_t$$

Cost of capital

$$y_t - k_t + \alpha_k = \frac{u_t}{p_t}$$

Demand of labor

$$y_t - h_t + \alpha_k = w p_t$$

Tobin's Q

$$\lambda_{p,t} + \Phi\left(k_t - k_{t-1}\right) = \lambda_{p,t+1} + \frac{\frac{u}{p}}{\left(\frac{u^x}{p} + 1 - \delta\right)} E_t\left(u_{p,t+1}\right) + \frac{\Phi}{\left(\frac{u^x}{p} + 1 - \delta\right)} E_t\left(k_{t+1} - k_t\right)$$

Phillips Curve

$$\pi_t = \beta E_t \pi_{t+1} + \frac{(1-\beta\varepsilon)(1-\varepsilon)}{\varepsilon} mc_t + \gamma \frac{(1-\varepsilon)}{\varepsilon} \pi_{t-1} + \mu p_t$$

Foreign Sector

Net exports

$$\frac{xn_t}{p_t} = Exp_t + \frac{p_t^x}{p_t} y_t^x - \frac{p_t^m}{p_t} m_t$$

Definition of the exchange rate

$$RER_t = \lambda_q RER_{t-1} + \left(1 - \lambda_q\right)\left(s_t - \pi_t\right)$$

Demand for imported goods

$$y_t - m_t + mc_t = RER_t$$

Risk premium

$$i_t^f = r^* + \psi d_t - \lambda_{Xi} tot_t + \varepsilon_t^{rf}$$

Risk premium shock

$$\varepsilon_t^{rf} = \rho_{rF} \varepsilon_{t-1}^{rf} + \varepsilon_t^{RR}$$

Net asset position

$$\left(\frac{d_{ss}RER_{ss}}{d_{ss}RER_{ss}+xn_{ss}}\right)d_t+\left(\frac{xn_{ss}}{d_{ss}RER_{ss}+xn_{ss}}\right)xn_t=d_{t-1}+i^f_{t-1}+RER_t\left(1+r_{t-1}\right)$$

Price defintion of the manufactured goods

$$y_t=\left(\frac{c}{y}c_t+\frac{i^x}{y}i^x_t+\frac{i}{y}i_t\right)+\Phi\left(k_t-k_{t-1}\right)+\Phi^x_t\left(k^x_t-k^x_{t-1}\right)+\frac{Exp}{y}Exp_t,$$

where

$$Exp_t=-p_t+y^*_t$$

Relative price of exports

$$x_t=\lambda_x x_{t-1}+\left(1-\lambda_x\right)\left(ds_t+p^x_t-p^x_{t-1}-\pi_t\right)$$

Definition of the terms of trade

$$tot_t=p^x_t$$

Law of movement of the terms of trade

$$tot_t=\rho_{tot}tot_{t-1}+\varepsilon^{tot}_t$$

Gross Domestic Product and Total Investment

Total investment

$$i_t=\left(\frac{i^x_{sss}}{i^x_{sss}+i^m_{sss}}\right)i^x_t+\left(\frac{i^x_{sss}}{i^x_{sss}+i^m_{sss}}\right)i^m_t$$

Monetary Policy

Monetary policy rule

$$i_t = \rho_r i_{t-1} + (1 - \rho_r) \left(\phi_\pi \pi_{t+1} + \phi_y y_t + \phi_e ds_t\right)$$

Uncovered interest rate parity

$$\lambda_s ds_t = ds_{t+1} + (1 - \lambda_s) \left(i_t^f - i_t\right)$$

6.2 Estimation Results

Table A1: Posterior Estimation: Model Specification 1 ($\phi_e > 0$, $\lambda_s > 0$), 2002Q1-2017Q4

Parameters	Posterior mean	Lower credibility band	Upper credibility band	Posterior Std. Dev.
ρ_{rf}	0.69	0.55	0.81	0.08
Φ_x	0.91	0.46	1.24	0.29
Φ	1.36	1.23	1.53	0.09
ψ	0.01	0.01	0.02	0.00
ω	2.33	1.95	2.62	0.23
ξ	0.50	0.48	0.51	0.01
ϕ_e	0.44	0.33	0.56	0.08
ϕ_y	0.99	0.90	1.05	0.05
γ	0.06	0.02	0.09	0.02
λ_q	0.40	0.25	0.52	0.09
λ_s	0.68	0.51	0.78	0.08
λ_x	0.86	0.60	0.99	0.16
λ_{gg}	0.47	0.33	0.61	0.08
ρ_{tot}	0.95	0.93	0.97	0.01
ρ_{A_x}	0.83	0.82	0.85	0.01
ρ_A	0.83	0.80	0.84	0.01
ϕ_π	2.20	2.18	2.22	0.01
$\sigma^{\varepsilon_{RR}}$	0.01	0.00	0.01	0.00
$\sigma^{\varepsilon_{A^x}}$	0.05	0.05	0.07	0.01
$\sigma^{\varepsilon_{INV}}$	0.00	0.00	0.01	0.00
$\sigma^{\varepsilon_{YY}}$	0.01	0.01	0.02	0.00
$\sigma^{\varepsilon_{AA}}$	0.05	0.04	0.05	0.01
$\sigma^{\varepsilon_{INV}}$	0.09	0.07	0.11	0.01
$\sigma^{\varepsilon_{CC}}$	0.01	0.01	0.01	0.00
$\sigma^{\varepsilon_{YY_x}}$	0.04	0.03	0.05	0.00

Table A2: Posterior Estimation: Model Specification 2 ($\phi_e > 0$, $\lambda_s = 0$), 2002Q1-2017Q4

Parameters	Posterior mean	Lower credibility band	Upper credibility band	Posterior Std. Dev.
ρ_{rf}	0.71	0.59	0.85	0.08
Φ_x	0.80	0.52	1.07	0.19
Φ	1.31	1.14	1.51	0.11
ψ	0.03	0.01	0.04	0.01
ω	2.30	2.05	2.63	0.18
ξ	0.50	0.48	0.52	0.01
ϕ_e	0.30	0.24	0.37	0.04
ϕ_y	1.04	0.92	1.15	0.07
γ	0.05	0.02	0.07	0.02
λ_q	0.64	0.55	0.74	0.06
λ_s	-	-	-	-
λ_x	0.68	0.48	0.93	0.14
λ_{gg}	0.49	0.34	0.65	0.10
ρ_{tot}	0.94	0.92	0.96	0.01
ρ_{A_x}	0.83	0.82	0.85	0.01
ρ_A	0.81	0.80	0.84	0.01
ϕ_π	2.21	2.19	2.22	0.01
$\sigma^{\varepsilon_{RR}}$	0.01	0.00	0.01	0.00
$\sigma^{\varepsilon_{tot}}$	0.05	0.05	0.06	0.00
$\sigma^{\varepsilon_{A^x}}$	0.00	0.00	0.01	0.00
$\sigma^{\varepsilon_{YY}}$	0.01	0.01	0.02	0.00
$\sigma^{\varepsilon_{AA}}$	0.05	0.04	0.06	0.01
$\sigma^{\varepsilon_{INV}}$	0.09	0.08	0.11	0.01
$\sigma^{\varepsilon_{CC}}$	0.01	0.01	0.01	0.00
$\sigma^{\varepsilon_{YY_x}}$	0.04	0.03	0.05	0.00

Table A3: Posterior Estimation: Model Specification 3 ($\phi_e = 0,\ \lambda_s > 0$), 2002Q1-2017Q4

Parameters	Posterior mean	Lower credibility band	Upper credibility band	Posterior Std. Dev.
ρ_{rf}	0.69	0.54	0.83	0.09
Φ_x	0.75	0.51	1.03	0.17
Φ	1.32	1.16	1.55	0.12
ψ	0.02	0.01	0.04	0.01
ω	2.22	1.98	2.48	0.15
ξ	0.50	0.48	0.51	0.01
ϕ_e	-	-	-	-
ϕ_y	0.97	0.87	1.05	0.06
γ	0.04	0.02	0.07	0.01
λ_q	0.56	0.40	0.74	0.11
λ_s	0.62	0.43	0.83	0.13
λ_x	0.68	0.49	0.98	0.16
λ_{gg}	0.44	0.33	0.56	0.07
ρ_{tot}	0.94	0.93	0.96	0.01
ρ_{A_x}	0.83	0.82	0.85	0.01
ρ_A	0.82	0.80	0.84	0.01
ϕ_π	2.21	2.19	2.22	0.01
$\sigma^{\varepsilon_{RR}}$	0.01	0.00	0.02	0.00
$\sigma^{\varepsilon_{tot}}$	0.05	0.04	0.06	0.01
$\sigma^{\varepsilon_{A^x}}$	0.01	0.00	0.01	0.00
$\sigma^{\varepsilon_{YY}}$	0.01	0.01	0.02	0.00
$\sigma^{\varepsilon_{AA}}$	0.04	0.04	0.05	0.00
$\sigma^{\varepsilon_{INV}}$	0.09	0.07	0.10	0.01
$\sigma^{\varepsilon_{CC}}$	0.01	0.01	0.01	0.00
$\sigma^{\varepsilon_{YY_x}}$	0.04	0.03	0.05	0.00

Table A4: Posterior Estimation: Model Specification 4 ($\phi_e = 0$, $\lambda_s = 0$), 2002Q1-2017Q4

Parameters	Posterior mean	Lower credibility band	Upper credibility band	Posterior Std. Dev.
ρ_{rf}	0.75	0.57	0.92	0.11
Φ_x	0.69	0.46	0.89	0.14
Φ	1.30	1.11	1.43	0.10
ψ	0.08	0.02	0.17	0.05
ω	2.22	1.93	2.53	0.19
ξ	0.50	0.48	0.52	0.01
ϕ_e	-	-	-	-
ϕ_y	1.00	0.93	1.07	0.04
γ	0.03	0.01	0.04	0.01
λ_q	0.83	0.76	0.89	0.04
λ_s	-	-	-	-
λ_x	0.68	0.53	0.96	0.13
λ_{gg}	0.44	0.29	0.57	0.09
ρ_{tot}	0.94	0.92	0.96	0.01
ρ_{A_x}	0.83	0.81	0.85	0.01
ρ_A	0.82	0.81	0.84	0.01
ϕ_π	2.20	2.19	2.22	0.01
$\sigma^{\varepsilon_{RR}}$	0.01	0.00	0.01	0.00
$\sigma^{\varepsilon_{tot}}$	0.05	0.04	0.06	0.00
$\sigma^{\varepsilon_{A^x}}$	0.00	0.00	0.01	0.00
$\sigma^{\varepsilon_{YY}}$	0.01	0.01	0.02	0.00
$\sigma^{\varepsilon_{AA}}$	0.04	0.03	0.05	0.01
$\sigma^{\varepsilon_{INV}}$	0.08	0.07	0.10	0.01
$\sigma^{\varepsilon_{CC}}$	0.01	0.01	0.01	0.00
$\sigma^{\varepsilon_{YY_x}}$	0.04	0.03	0.05	0.00

Table A5: Posterior Estimation: Model Specification 1 ($\phi_e > 0$, $\lambda_s > 0$), 2010Q1-2017Q4

Parameters	Posterior mean	Lower credibility band	Upper credibility band	Posterior Std. Dev.
ρ_{rf}	0.71	0.56	0.88	0.10
Φ_x	0.74	0.54	0.98	0.14
Φ	1.35	1.13	1.56	0.13
ψ	0.04	0.01	0.07	0.02
ω	2.31	2.00	2.59	0.18
ξ	0.50	0.49	0.52	0.01
ϕ_e	0.51	0.41	0.61	0.06
ϕ_y	1.12	1.00	1.22	0.07
γ	0.06	0.03	0.10	0.02
λ_q	0.33	0.20	0.45	0.07
λ_s	0.70	0.56	0.85	0.09
λ_x	0.92	0.87	0.98	0.04
λ_{gg}	0.61	0.45	0.82	0.11
ρ_{tot}	0.95	0.93	0.96	0.01
ρ_{A_x}	0.83	0.82	0.85	0.01
ρ_A	0.82	0.79	0.85	0.02
ϕ_π	2.20	2.18	2.22	0.01
$\sigma^{\varepsilon_{RR}}$	0.01	0.00	0.01	0.00
$\sigma^{\varepsilon_{A^x}}$	0.05	0.04	0.06	0.01
$\sigma^{\varepsilon_{INV}}$	0.00	0.00	0.01	0.00
$\sigma^{\varepsilon_{YY}}$	0.01	0.01	0.01	0.00
$\sigma^{\varepsilon_{AA}}$	0.04	0.03	0.05	0.01
$\sigma^{\varepsilon_{INV}}$	0.08	0.06	0.09	0.01
$\sigma^{\varepsilon_{CC}}$	0.01	0.01	0.01	0.00
$\sigma^{\varepsilon_{YY_x}}$	0.04	0.03	0.05	0.01

Table A6: Posterior Estimation: Model Specification 2 ($\phi_e > 0$, $\lambda_s = 0$), 2010Q1-2017Q4

Parameters	Posterior mean	Lower credibility band	Upper credibility band	Posterior Std. Dev.
ρ_{rf}	0.68	0.55	0.85	0.09
Φ_x	0.74	0.51	0.99	0.15
Φ	1.27	1.12	1.39	0.09
ψ	0.07	0.02	0.13	0.04
ω	2.26	1.95	2.53	0.19
ξ	0.50	0.49	0.51	0.01
ϕ_e	0.47	0.40	0.56	0.05
ϕ_y	1.15	1.02	1.25	0.07
γ	0.06	0.02	0.10	0.02
λ_q	0.47	0.36	0.59	0.07
λ_s	0.65	0.44	0.89	0.14
λ_x	0.62	0.44	0.75	0.10
λ_{gg}	0.95	0.93	0.96	0.01
ρ_{tot}	0.83	0.82	0.85	0.01
ρ_{A_x}	0.82	0.79	0.84	0.02
ρ_A	2.20	2.19	2.22	0.01
ϕ_π	0.01	0.00	0.01	0.00
$\sigma^{\varepsilon_{RR}}$	0.05	0.04	0.06	0.01
$\sigma^{\varepsilon_{A^x}}$	0.01	0.00	0.01	0.00
$\sigma^{\varepsilon_{INV}}$	0.01	0.01	0.01	0.00
$\sigma^{\varepsilon_{YY}}$	0.04	0.03	0.05	0.01
$\sigma^{\varepsilon_{AA}}$	0.08	0.06	0.09	0.01
$\sigma^{\varepsilon_{INV}}$	0.01	0.01	0.01	0.00
$\sigma^{\varepsilon_{CC}}$	0.04	0.03	0.05	0.00
$\sigma^{\varepsilon_{YY_x}}$	0.04	0.03	0.05	0.00

Table A7: Posterior Estimation: Model Specification 3 ($\phi_e = 0,\ \lambda_s > 0$), 2010Q1-2017Q4

Parameters	Posterior mean	Lower credibility band	Upper credibility band	Posterior Std. Dev.
ρ_{rf}	0.67	0.51	0.82	0.10
Φ_x	0.69	0.52	0.89	0.11
Φ	1.37	1.20	1.55	0.10
ψ	0.16	0.03	0.27	0.08
ω	2.24	2.01	2.50	0.16
ξ	0.50	0.48	0.51	0.01
ϕ_e	-	-	-	-
ϕ_y	1.10	0.98	1.21	0.07
γ	0.04	0.01	0.07	0.02
λ_q	0.50	0.35	0.69	0.11
λ_s	0.67	0.53	0.84	0.09
λ_x	0.67	0.46	0.89	0.13
λ_{gg}	0.57	0.36	0.76	0.12
ρ_{tot}	0.95	0.93	0.97	0.01
ρ_{A_x}	0.83	0.81	0.85	0.01
ρ_A	0.81	0.78	0.84	0.02
ϕ_π	2.20	2.19	2.22	0.01
$\sigma^{\varepsilon_{RR}}$	0.01	0.01	0.02	0.00
$\sigma^{\varepsilon_{A^x}}$	0.05	0.04	0.06	0.01
$\sigma^{\varepsilon_{INV}}$	0.01	0.00	0.01	0.00
$\sigma^{\varepsilon_{YY}}$	0.01	0.01	0.02	0.00
$\sigma^{\varepsilon_{AA}}$	0.04	0.03	0.04	0.01
$\sigma^{\varepsilon_{INV}}$	0.07	0.05	0.08	0.01
$\sigma^{\varepsilon_{CC}}$	0.01	0.01	0.01	0.00
$\sigma^{\varepsilon_{YY_x}}$	0.04	0.03	0.05	0.04 0.03 0.05 0.00

Table A8: Posterior Estimation: Model Specification 4 ($\phi_e = 0$, $\lambda_s = 0$), 2010Q1-2017Q4

Parameters	Posterior mean	Lower credibility band	Upper credibility band	Posterior Std. Dev.
ρ_{rf}	0.72	0.54	0.89	0.11
Φ_x	0.73	0.50	0.95	0.14
Φ	1.36	1.18	1.52	0.11
ψ	0.20	0.05	0.35	0.10
ω	2.24	1.95	2.52	0.17
ξ	0.50	0.49	0.51	0.01
ϕ_e	-	-	-	-
ϕ_y	1.11	1.01	1.22	0.07
γ	0.03	0.01	0.06	0.02
λ_q	0.76	0.67	0.84	0.05
λ_s	-	-	-	-
λ_x	0.61	0.44	0.80	0.11
λ_{gg}	0.53	0.35	0.70	0.11
ρ_{tot}	0.95	0.93	0.96	0.01
ρ_{A_x}	0.83	0.81	0.84	0.01
ρ_A	0.80	0.77	0.83	0.02
ϕ_π	2.20	2.19	2.22	0.01
$\sigma^{\varepsilon_{RR}}$	0.01	0.01	0.02	0.00
$\sigma^{\varepsilon_{A^x}}$	0.05	0.04	0.06	0.01
$\sigma^{\varepsilon_{INV}}$	0.01	0.00	0.01	0.00
$\sigma^{\varepsilon_{YY}}$	0.01	0.01	0.01	0.00
$\sigma^{\varepsilon_{AA}}$	0.04	0.03	0.04	0.01
$\sigma^{\varepsilon_{INV}}$	0.07	0.05	0.08	0.01
$\sigma^{\varepsilon_{CC}}$	0.01	0.01	0.01	0.00
$\sigma^{\varepsilon_{YY_x}}$	0.04	0.03	0.04	0.00