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Determinants of Current Account Dynamics: Simulation and Estimation of DSGE Models with a Bayesian Approach

Nicolás Butrón*, Carmen Rojas*, Diego Winkelried**

* Banco Central de Reserva del Perú
** Universidad del Pacífico

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Determinants of Current Account Dynamics: Simulation and Estimation of DSGE Models with a Bayesian Approach*

Nicolás Butrón†, Carmen Rojas‡, & Diego Winkelried§

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Abstract

This research analyzes the dynamics of the current account and its main components —particularly the trade balance and primary income— by identifying the key determinants of their fluctuations and evaluating the relative importance of the associated shocks. The study combines theoretical and empirical approaches, using Peru as a case of study, to exploit macroeconomic data within a structural framework. On the theoretical side, a DSGE model for a small open economy is developed, featuring three productive sectors: exportables, importables, and nontradables. Production relies on domestic inputs, foreign capital, and imported intermediate goods, allowing external shocks to propagate to domestic activity. The baseline specification, inspired by Mendoza (1995), includes shocks to sectoral productivity and export prices, and is extended to incorporate shocks to imported input prices, international interest rates, and foreign investment returns. Empirically, the paper documents stylized facts such as the persistence of the terms of trade, the volatility of profit outflows, and the countercyclicality of the current account. Parameters are estimated using Bayesian methods, and alternative specifications are compared to assess the contribution of each mechanism to explaining current account dynamics.

Keywords: Current account, international interest rates, foreign investment, countercyclicality, Bayesian estimation.

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†Email: nicolas.butron@bcrp.gob.pe. Monetary Program Section at the Central Reserve Bank of Peru.

‡Email: carmen.rojas@bcrp.gob.pe. Current Economic Analysis Section at the Central Reserve Bank of Peru.

§Email: winkelried_dm@up.edu.pe. Universidad del Pacífico.

1 Introduction

In accounting terms, the current account balance is not only determined by international trade in goods, but also by trade in services and by the flow of payments to productive factors —mainly physical and financial capital— between countries. While the trade balance is an account of great importance, recent episodes of increases in international transportation costs and their impact on service imports have explained a large part of the current account evolution. For this reason, it is necessary to consider its full definition, which not only captures movements in the trade balance, but also in the services balance and primary income (factor income).

Nevertheless, the theoretical literature has studied the trade balance as if it were equivalent to the current account, a practice that is not representative of economies such as Peru, where primary income constitutes the most important component of the current account. Likewise, the main shock studied has been the terms of trade shock, constructing mechanisms that affect the current account only through their impacts on the trade balance. However, the remaining accounts may also be affected by the terms of trade and by other mechanisms specific to them. For its part, the empirical literature has been able to include more determining factors in the analysis; however, its statistical models still lack solid theoretical mechanisms to support them.

We document some empirical regularities of the peruvian economy such as relationships —relative volatility, persistence, and correlations— observed among the variables that will later be considered endogenous within the theoretical general equilibrium model.

First, according to Central Reserve Bank of Peru (2024), changes in the current account outcome can be decomposed into two main factors: (i) that attributed to domestic absorption[1] and (ii) the return paid for the use of external factors of production and on external liabilities (debt instruments). Other factors include remittance flows and returns earned on external assets.

As shown in Table (1), in 2023 the improvement of 4.3 percentage points (p.p.) in the current account balance was largely explained by domestic absorption, which accounted for 2.8 p.p. This effect was supported by lower returns paid on external liabilities (0.4 p.p.) and further reinforced by a favorable environment of elevated international interest rates and their impact on interest income (1.1 p.p.). While in the majority of the years presented domestic absorption explains the largest share of changes in the current account balance, returns paid on external liabilities play a particularly important role in specific periods, such as 2004–2006, 2009, 2013 and 2020-2022.

[1]Domestic absorption is defined as the sum of consumption and investment spending, both public and private, carried out within a country's borders. This is equivalent to the balance of goods and services, which in turn can be explained by a price effect and a volume effect.

Table 1: *Peru: Decomposition of the Current Account; 1995–2023*

Variables	1995	1996	1999	2004-2006	2008	2009	2013	2016-2017	2020	2021-2022	2023
a: Domestic absorption	-2.2	0.8	3.3	9.4	-6.7	3.6	-2.7	4.7	0.2	-0.8	2.8
b: Returns paid on external liabilities	-0.1	1.7	0.7	-6.7	1.5	2.1	3.0	-1.3	2.3	-4.3	0.4
c: Other	-0.4	-0.4	-0.7	2.2	-0.6	-1.9	-2.2	0.4	-1.1	0.3	1.1
Current account (a + b + c)	**-2.7**	**2.2**	**3.3**	**4.9**	**-5.8**	**3.8**	**-1.9**	**3.7**	**1.5**	**-4.8**	**4.3**

Data for calculations from BCRP.

To characterize selected stylized facts of the Peruvian economy and ensure that the statistical analysis is consistent with the implications of the model, it is necessary to apply appropriate data transformations. We primarily follow the methodology proposed by Mendoza (1995), which uses nominal series expressed in U.S. dollars as the starting point. These series are converted into per capita terms, with the exception of price variables. They are then deflated using the import consumption price index, reflecting the role of these goods as the numeraire in the model economy. Finally, logarithmic variables are detrended in order to achieve stationarity.

Using these expressions, we compute the main external aggregates, which correspond to the trade balance and the current account. The trade balance is simply calculated as the difference between exports and total imports. In the case of the current account, it is constructed based on the trade balance and subtracting the two main components of primary income: interest outflows and profit outflows[2].

Tables (2), (3) and (4) present estimates of standard deviations, autocorrelations, relative volatilities, and contemporaneous correlations of the main variables that should be included to analyze international business cycles and their impacts on the evolution of the current account. First, we use the results in Table (2) to describe the volatility and persistence of national accounts. We note that private investment is approximately twice as volatile as output and the terms of trade, making it the most volatile component of GDP. Consumption is less volatile than GDP and also less volatile than the terms of trade. Consumption, as is usually the case, exhibits the highest degree of persistence —positive and moderately sized autocorrelation coefficient— among real variables.

Second, we analyze the empirical regularities of external variables. Foreign Direct Investment (FDI), the current account, freight prices, and profits are the most volatile variables, far exceeding all national accounts variables. The current account is six times more volatile than the trade balance, which is supported by the high volatility, mainly of profits and, to a lesser extent, interest. Moreover, it is between nine and ten times

[2]Although the services and secondary income balances were excluded from the explicit account definitions, the model indirectly captured the effects of increased transportation costs on imports, ensuring the consistency of the external sector analysis.

more volatile than GDP. With the exception of FDI, all other external accounts exhibit persistence, especially the components of the trade balance.

Table 2: *Volatility and persistence of the main variables in the model*

Variables	**Standard deviation**	**First-order autocorrelation**	**Volatility relative to TOT**	**Volatility relative to GDP**
GDP	0.06	0.34	0.87	1.00
Consumption	0.05	0.55	0.69	0.79
Private Investment	0.11	0.36	1.64	1.89
Terms of Trade	0.07	0.83	1.00	1.15
Trade Balance	0.09	0.55	1.39	1.59
Exports	0.12	0.53	1.79	2.05
Imports	0.10	0.65	1.44	1.65
Consumption goods imports	0.10	0.30	1.41	1.62
Intermediate goods imports	0.12	0.68	1.82	2.09
Capital goods imports	0.10	0.62	1.55	1.78
Current Account	0.54	0.27	8.06	9.25
Freight price	0.37	0.59	5.51	6.32
Profits	0.54	0.47	7.93	9.10
Interest	0.17	0.45	2.50	2.87
Foreign direct investment	0.69	0.02	10.19	11.69

Data for calculations from BCRP.

On the other hand, Table (3) allows us to analyze the relationship between these variables and the terms of trade and GDP. The trade balance is slightly procyclical, in contrast to the negative correlation of -0.365 found in Mendoza (1995) for Peru during the period 1961–1990 and the -0.1 found by Galindo, Montecinos, and Ortiz (2024) for a panel of countries (including Peru) during the period 1980–2020. The results obtained arise despite the fact that exports exhibit a lower positive correlation with output than the positive correlation recorded by imports. The slight procyclicality of the trade balance suggests that, in the period analyzed, the impulse generated by higher economic activity on export volumes has outweighed the increase in domestic demand, due to a greater preponderance of export sectors in the composition of economic growth.

As expected, the current account is countercyclical, in response to the procyclicality of profits of firms with foreign participation (FDI) operating in the country. Additionally, greater economic dynamism that increases the profitability of FDI would generate higher inflows thereof, which could lead to higher profits in subsequent periods.

Table 3: *Relative volatility and main correlations*

Variables	Relative volatility with respect to freight price	Correlation with Terms of Trade	Correlation with GDP
GDP	0.16	0.31	1.00
Consumption	0.12	-0.08	0.70
Private Investment	0.30	0.19	0.56
Terms of Trade	0.18	1.00	0.31
Trade Balance	0.25	0.47	0.02
Exports	0.32	0.57	0.47
Imports	0.26	0.25	0.56
Consumption goods imports	0.26	0.07	0.48
Intermediate goods imports	0.33	0.29	0.53
Capital goods imports	0.28	0.21	0.46
Current Account	1.46	-0.23	-0.48
Freight price	1.00	0.29	0.19
Profits	1.44	0.33	0.49
Interest	0.45	-0.05	0.00
Foreign direct investment	1.85	0.22	0.19

Data for calculations from BCRP.

It is also interesting to verify the presence of the HML effect[3], which is explained later in this section, but basically refers to a positive and moderate correlation between the terms of trade and the trade balance. Indeed, in the sample analyzed, we find a correlation of 0.47 between both variables. However, the terms of trade also have a positive impact on the profits of firms with foreign participation, negatively affecting the outcome of the primary income account and, consequently, that of the current account (-0.23).

In Table (4), it is observed that freight prices exhibit interesting correlations with the variables under analysis. In particular, they are positively correlated with exports and imports, especially intermediate goods. This suggests that fluctuations in freight prices operate through an increase in transportation costs and, in turn, in the effective price of traded goods, with a greater impact on commodities. The direction of the impact depends on the relative change between Peru's freight prices and those of its competitors; the positive correlation suggests that global freight rates have affected other international transport routes more than those used by Peru. Therefore, a properly specified model should include a mechanism that allows analyzing the impact of these prices on the

[3]The HML effect (Harberger-Laursen-Metzler) refers to the positive correlation between a country's terms of trade and its trade balance. Originally proposed by Harberger (1950) and Laursen and Metzler (1950), the mechanism suggests that an improvement in the terms of trade increases real income, leading to a rise in savings (as the marginal propensity to consume is less than one). Given that investment is assumed to be unaffected in the original Keynesian framework, this increase in savings translates into a direct improvement in the trade balance.

economy through transportation costs and, in turn, on the final price of traded goods.

Table 4: *Other correlations of interest*

Variables	**Correlation with Freight price**	**Correlation with Profits**	**Correlation with Interest**
GDP	0.19	0.49	0.00
Consumption	0.00	0.37	-0.01
Private Investment	0.30	0.53	0.12
Terms of Trade	0.29	0.33	-0.05
Trade Balance	0.20	0.35	-0.10
Exports	0.44	0.65	0.05
Imports	0.35	0.46	0.16
Consumption goods imports	0.10	0.26	0.16
Intermediate goods imports	0.44	0.49	0.11
Capital goods imports	0.22	0.30	0.15
Current Account	-0.30	-0.93	-0.35
Freight price	1.00	0.36	-0.08
Profits	0.36	1.00	0.02
Interest	-0.08	0.02	1.00
Foreign direct investment	0.17	0.33	0.04

Data for calculations from BCRP.

Thus, several of the empirical regularities documented by previous studies are supported, while others are contrasted. Moreover, interesting stylized facts are identified that allow for the recognition of mechanisms through which variables other than the terms of trade —such as freight prices, interest rates, and the return on foreign investment— affect the outcome of the current account.

Historically, the terms of trade have been considered one of the main determinants of a country's external accounts. The earliest studies that identified a transmission mechanism from the terms of trade to the current account[4] were those of Harberger (1950) and Laursen and Metzler (1950). Both studies aimed to analyze how exchange rate fluctuations affect countries' economic dynamics, with an emphasis on the trade balance in the former case and on employment in the latter.

As part of the results of these studies, it was found that the terms of trade play a crucial role in determining real income. Exchange rate fluctuations could generate movements in the terms of trade that, in turn, affect the purchasing power of the domestic economy. Thus, for example, a deterioration in the terms of trade results in a reduction

[4]Strictly speaking, the impact is analyzed on the trade balance; however, since it is the main component of the current account, the authors used both interchangeably.

in the purchasing power of exports and, therefore, in a decline in real income. Given that in the theoretical models underpinning these studies the marginal propensity to consume was less than one, national consumption also fell, but to a lesser extent. Investment was not affected by any mechanism; therefore, the current account balance deteriorated. This direct effect of the terms of trade on the current account is known as the HML effect.

The validity of the HML effect was later discussed in the literature in order to assess whether it holds in more complex models that incorporate other features of fluctuations not previously considered. Among these studies are those of Obstfeld (1982) and Svensson and Razin (1983). In the former, the model is extended to include two goods: one imported from abroad and one produced domestically. In this framework, households maximize discounted intertemporal utility by optimally allocating their income between consumption and the accumulation of international bonds, taking the terms of trade as given. The author finds a setting in which a deterioration in the terms of trade, instead of leading to a reduction in the current account balance, results in an increase in it, thereby invalidating the HML effect. This context arises when the decline in the terms of trade is permanent and unanticipated; under these conditions, households purchase foreign bonds to restore steady-state utility to its original level, which generates a decline in the value of expenditure on the domestic good and an improvement in the current account balance.

The study by Svensson and Razin (1983) follows the same line as Obstfeld (1982), in the sense that the proposed model also assumes intertemporal optimization and perfect capital mobility. However, Svensson and Razin (1983) provide a different perspective by emphasizing the distinction between the effects of temporary and permanent changes in the terms of trade on the trade balance. When a temporary deterioration in the terms of trade occurs, agents anticipate a future recovery and, due to consumption smoothing, the reduction in consumption is smaller than the reduction in income, thus leading to a deterioration in the trade balance. On the other hand, when the deterioration in the terms of trade is permanent, agents do not expect a future improvement to offset the current situation. In this case, the response of the trade balance can be ambiguous and depends on several factors, with the rate of time preference being one of the most important. If this rate is high, consumers may choose to reduce current consumption and increase savings in order to keep future utility unchanged, which could lead to an improvement in the trade balance in the long run. However, if the rate of time preference is low, current consumption may not decline significantly, resulting in a less favorable trade balance.

While the studies by Obstfeld (1982) and Svensson and Razin (1983) provide a more comprehensive analytical framework than those of Harberger (1950) and Laursen and Metzler (1950), none of them includes non-tradable goods, through which the terms of trade can have additional effects via the real exchange rate. This aspect is considered by Edwards (1987), who studies a small open economy with optimizing consumers who

can choose among three goods: importables, exportables, and non-tradables. As in Svensson and Razin (1983), Edwards (1987) finds that permanent and anticipated shocks to the terms of trade have different effects from temporary shocks on the real exchange rate and the current account. However, the inclusion of an additional sector allows for more complex and differentiated impacts. In the presence of temporary shocks to the terms of trade, these differentiated effects on tradable and non-tradable goods may dampen or amplify the impact on the current account, depending on the elasticity of substitution between these goods. Under permanent shocks, the impact described by Svensson and Razin (1983) may also be modified due to the reallocation of consumption between tradable and non-tradable goods.

The study by Edwards (1989) continues this discussion, particularly focusing on temporary shocks. To this end, it builds on the model of Edwards (1987) and extends the intertemporal framework of Svensson and Razin (1983) in several directions. Edwards (1989) finds that, in the presence of adverse temporary shocks, consumers tend to smooth consumption, resulting in a temporary deterioration of the current account. In addition, it is observed that temporary shocks affect saving and investment rates differently, with savings being more strongly affected. Finally, the study highlights that policies such as the imposition of temporary tariffs may worsen the current account in the first period of analysis, although they may have different effects depending on whether the terms-of-trade shocks are permanent or temporary.

The studies reviewed up to this point developed models that were analyzed in deterministic settings. Although most of them employed intertemporal optimization and studied dynamically the effects of temporary and permanent terms-of-trade shocks, none incorporated uncertainty or stochastic shocks. Thus, Mendoza (1991) constituted the first work to extend the real business cycle (RBC) framework to the study of a small open economy and its external dynamics. Although it does not explicitly introduce the terms of trade as a variable subject to exogenous and stochastic shocks, it interprets productivity shocks as proxies for terms-of-trade shocks, given that output is a tradable good. In this way, it shows how these shocks can generate real business cycles and negatively affect the trade balance, thereby replicating the countercyclicality of external trade.

Other studies that continued exploring technological shocks within the RBC and international business cycle frameworks, as well as their relationship with the current account and the terms of trade, include Backus, Kehoe, and Kydland (1992), Backus, Kehoe, and Kydland (1993), and Backus, Kehoe, and Kydland (1994). Taken together, these studies offer a comprehensive view of how international shocks (mainly productivity increases in trading partners) affect the current account, while emphasizing the importance of constructing theoretical models grounded in empirical evidence.

In the first study, the authors observe several properties of business cycles in the United States, including the countercyclicality of net exports, and attempt to replicate most of these using a two-country RBC model with productivity spillovers —that is, productivity increases are transmitted from one country to another. Their model generates volatility in output, consumption, and hours worked similar to the data, but produces investment and net exports volatility that is much higher than observed. Moreover, while consumption, investment, and hours worked are procyclical as in the data, net exports are acyclical, contradicting the empirical evidence.

The second study uses a model similar to the first, but now each country specializes in the production of a particular intermediate good. These intermediate goods are used to produce final goods destined for consumption, investment, and government spending. This model structure allows the terms of trade to be defined as the relative price between the two intermediate goods, with the price of the foreign-produced good in the numerator. The model predicts that, for a given volatility of the export-to-import ratio, the volatility of the terms of trade can be increased if intermediate inputs behave as complementary goods. However, by reducing the elasticity of substitution between these goods, the volatility of the aforementioned ratio also decreases, leading to the conclusion that attempting to explain terms-of-trade volatility generates predictions contrary to those observed empirically.

In the third article, the focus is on the dynamics of the trade balance and the current account. Specifically, the authors seek to explain, using a general equilibrium model, the countercyclicality of net exports and the tendency of the trade balance to be negatively correlated with current and future movements in the terms of trade[5], but positively correlated with past movements. The authors refer to this latter result as the S-curve, since the correlation function between the terms of trade and net exports has the shape of a horizontal S. To explain these regularities, they use, as in their previous studies, a two-country RBC model in which each country produces an intermediate good that is used to produce a final good in both countries. They find that a favorable productivity shock leads to a deterioration in the terms of trade due to a decline in the relative price between intermediate goods. In response to the persistent nature of the shock, the joint increase in investment[6] and consumption is larger than the gains in output, generating a trade deficit during periods of high production. This response can explain the asymmetric correlation function between net exports and the terms of trade.

As a result of all the studies reviewed, it became clear that the terms of trade play a fundamental role in generating business cycles and in determining a country's external dynamics. However, it was necessary to formalize this transmission mechanism, which

[5]In Backus, Kehoe, and Kydland (1994), the terms of trade are defined as the relative price of imports to exports, and the trade balance as the ratio of net exports to output.

[6]An investment boom occurs, as capital is allocated to the more productive country.

had been constructed based on model interpretations. In this sense, Mendoza (1995) was the first to explicitly include terms-of-trade shocks[7] in an RBC model for a small open economy.

Based on the observation of abrupt terms-of-trade fluctuations recorded during the 1980s and 1990s —which had a significant impact on economic activity in both industrialized and developing countries— Mendoza (1995) proposes a stochastic dynamic general equilibrium (DSGE) model with three sectors: exportables, importables, and non-tradables. In this model, imports are the numeraire good, and all prices in the economy are expressed in terms of imports. Therefore, the price of exportable goods can be interpreted as the country's terms of trade, which are modeled as a first-order autoregressive process. When analyzing the model's responses to shocks, it is found that the macroeconomic dynamics generated by terms-of-trade shocks differ markedly from those induced by productivity shocks. In particular, the former induce real appreciations and positive differentials in real interest rates, whereas the latter have opposite effects.

The importance of this study lies in the fact that it is highly consistent with observations that had already been widely documented up to that point[8]. Among these, and particularly relevant for our purposes, are the following: (i) terms-of-trade shocks are large and persistent, and (ii) the HML effect is present but weak; developing economies exhibit greater volatility in their macroeconomic aggregates than industrialized economies. In addition, the sensitivity analysis —consisting of changing the values of some deep structural parameters of the model— shows that the persistence, magnitude, and contemporaneous correlation of terms-of-trade and productivity shocks, as well as the elasticity of substitution between tradable and non-tradable consumption, play a key role in the model's dynamics.

Subsequently, turning to studies with an empirical focus, Medina, Munro, and Soto (2008) estimate a DSGE model to analyze the determinants of the current account in Chile and New Zealand, two small open economies that share key structural characteristics, including a strong dependence on natural resources and trade-oriented economic policies. The authors assess the effects of several types of shocks, such as productivity, external, fiscal, and monetary shocks. Their results indicate that external shocks —particularly commodity price shocks and external interest rate shocks— play a significant role in improving the current account by inducing a real exchange rate appreciation and strengthening the trade balance. Productivity shocks primarily affect consumption and investment, leading to a short-run deterioration of the current account due to higher domestic absorption. In contrast, fiscal and monetary policy shocks are found to have a relatively limited impact on current account dynamics. Overall, the study underscores

[7]Earlier models considered productivity shocks as a proxy for terms-of-trade shocks. Mendoza (1995) also includes sectoral productivity shocks.

[8]Despite contradicting several theoretical predictions derived from deterministic models.

the relevance of a structural modeling approach to adequately capture the transmission of shocks and their effects on the interaction between consumption, investment, and the real exchange rate in small open economies with a high degree of natural resource dependence.

The discussion on the terms of trade and other determinants that may affect current account dynamics has also been addressed from a purely empirical perspective, using panel data for a group of countries. First, there is the work of Cashin and McDermott (2002), in which the authors examine how large terms-of-trade shocks affect the current account and the economy as a whole, comparing two commodity-exporting countries with a relatively small non-tradable sector (Australia and New Zealand) with three large industrial countries (the United States, the United Kingdom, and Canada).

Regarding persistence, the authors find that terms-of-trade shocks are persistent in all countries (extremely persistent in New Zealand and the United Kingdom), except in the United States. Concerning the relative importance of permanent and transitory components in these shocks, countries with a larger tradable goods sector exhibit a higher share of permanent shocks relative to transitory ones. They use a structural vector autoregression (SVAR) model to study the impact of various shocks on the current account and output. The results suggest that terms-of-trade shocks have no impact on the current account balance of Canada, the United Kingdom, and the United States; in contrast, they explain a significant proportion of the variation in the current account balances of Australia and New Zealand.

Additionally, Cashin, Céspedes, and Sahay (2004) examine the impact of terms-of-trade fluctuations on the real exchange rate in developing economies that are heavily dependent on commodity exports. The study considers a sample of 58 countries over the period from January 1980 to March 2002 and constructs country-specific export price indices. Employing time-series methodologies, the authors find evidence of a long-run relationship between the real exchange rate and real commodity prices in approximately one-third of the countries analyzed. For this subset of economies, commodity prices constitute a key determinant of long-run deviations of the real exchange rate from purchasing power parity. Moreover, the results indicate that, in these cases, the real exchange rate adjusts toward equilibrium with commodity prices within an average of 10 months, a substantially faster pace than that suggested by traditional estimates. This finding is relevant insofar as fluctuations in the real exchange rate ultimately affect external competitiveness and, by extension, the current account, thereby reinforcing previously documented evidence.

Moreover, studies such as Brissimis et al. (2012), Yang (2011), and Morsy (2015) extend the analysis beyond the role of the terms of trade by employing cointegration techniques and other econometric methods to examine the full set of determinants of

the current account in both the short and long run across different countries and time periods. Brissimis et al. (2012) focus on Greece, where the current account exhibited a seemingly unsustainable expansion of its deficit, primarily driven by a sharp decline in private saving rates associated with rapid credit growth. Yang (2011) analyze data for the eight largest emerging Asian economies over the period 1980–2009 and show that, despite substantial cross-country heterogeneity in current account dynamics, the initial net foreign asset position and trade openness emerge as the main long-run determinants for all countries except China. Finally, Morsy (2015) use annual panel data for 74 advanced and developing economies, including 28 oil-exporting countries, from 1970 to 2009. Their results indicate that, for oil-exporting economies, the current account is influenced by factors such as the fiscal balance, the oil balance, oil wealth, age dependency, economic growth, and the degree of oil-related imports. In addition, country-specific characteristics, including underground wealth and the maturity of oil production, play an important role in shaping the current account equilibrium.

Finally, Schmitt-Grohé and Uribe (2018) attempt to bridge the results obtained from theoretical and empirical models regarding the role of terms-of-trade shocks in generating business cycles. The empirical methodology consists of estimating two SVAR models[9], specific to each country, using annual data for 38 emerging economies over the period 1980–2011. The theoretical analysis is conducted using a three-sector model, similar to that of Mendoza (1995), which is calibrated in a way that, in the authors' view, increases the likelihood of matching the data. The most notable result of this study is the finding of a median contribution of the terms of trade to total output variance of less than 10%, which contrasts with theoretical models that claim terms-of-trade shocks explain at least 30% of fluctuations in aggregate activity. Another relevant empirical result is that a 10% increase in the terms of trade leads to an improvement in the trade balance of half a percentage point of GDP, thus supporting the HML effect.

Much of the research on this topic highlights the importance of linking theoretical approaches with empirical evidence when studying terms-of-trade shocks in open economies. This approach underscores the need to integrate robust theories with solid empirical validation to adequately capture economic dynamics, especially in emerging economy contexts, and reinforces the relevance of continuing to develop country-specific models that reflect both economic reality and the complexity of external shocks.

[9]The first includes the terms of trade, the trade balance, output, consumption, investment, and the real exchange rate. The second adds the interest rate differential as a measure of the international cost of funds.

2 The Model

2.1 Households

2.1.1 Preferences

Households derive utility from consumption (c) and leisure (l), according to the following function:

$$u(c_t, l_t) = \frac{(c_t l_t^w)^{(1-\gamma)}}{(1-\gamma)};\ \omega > 0, \gamma > 1$$

Where ω is the elasticity of labor supply and γ is the inverse of the intertemporal elasticity of substitution of consumption.

Consumption, in turn, is a basket composed of importable goods (c^m) and non-tradable goods (c^n), defined by the CES aggregator (constant elasticity of substitution):

$$c_t = \left[(c_t^m)^{-\mu} + (c_t^n)^{-\mu}\right]^{-1/\mu}$$

Where the elasticity of substitution between importables and non-tradables is equal to $1/(1+\mu)$.

It is necessary to clarify that consumption of importables is composed of goods produced both by the domestic economy and by the foreign economy; meanwhile, consumption of non-tradables is composed exclusively of goods produced domestically.

2.1.2 Supply of production factors

On the one hand, households supply labor to the three productive sectors that make up this economy: exportable (L_t^x), importable (L_t^m), and non-tradable (L_t^n). In the exportable and importable sectors, labor is supplied inelastically[10], such that:

$$L_t^x = L^x; L_t^m = L^m$$

On the other hand, households accumulate physical assets in the form of capital, which is supplied only to the importable (k_t^m) and non-tradable (k_t^n) sectors. As in Mendoza (1995), we assume that capital is homogeneous; that is, it can be used interchangeably in both sectors and that its supply to the non-tradable sector is inelastic.

Accordingly, total capital supplied by households is the sum of capital supplied to the

[10]The same simplifying assumption of Mendoza (1995) is used here and whenever inelastic factor supply is mentioned.

importable and non-tradable sectors:

$$k_t = k_t^m + k_t^n$$

Where: $k_t^n = k^n$

Total domestic capital evolves according to the following law of motion:

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

Capital adjustment costs are imposed in the model, governed by the parameter ϕ:

$$\phi(k_t, k_{t+1}) = \frac{\phi}{2}\left(k_{t+1} - k_t\right)^2$$

2.1.3 Structure of financial markets

As is usual in this literature, incomplete financial markets are assumed. Households invest in one-period non-contingent bonds that pay a fixed interest rate in units of importable goods. As argued by Schmitt-Grohé and Uribe (2003), it is precisely this feature that makes the dynamic equilibrium of standard small open economy (SOE) models have a random walk (non-stationary) component.

For this reason, many researchers have introduced various modifications to this model, among which stand out the inclusion of: an endogenous discount factor, a debt-elastic interest rate, and convex portfolio adjustment costs. In this paper, we choose to incorporate an endogenous risk premium, which causes the interest rate on bonds to increase as the country's external assets decline relative to their steady-state level ($\bar{B}$). This mechanism is captured by the following equation:

$$r_t^f = r^* + rp_t$$

Where:

$$rp_t = \chi_B \left(e^{(\bar{B} - B_t)} - 1\right)$$

2.1.4 Constraints

To construct the household budget constraint, we consider their income and expenditures. Regarding income, households receive wages for labor supplied, which differ by sector (w_t^x, w_t^m and w_t^n), and an interest rate on rented capital that is also differentiated

(r_t^k and $r_t^k n$). According to their net foreign asset position[11], they pay or receive interest at the rate r_t^f. In addition, households own the firms and receive the profits resulting from their productive activities, which are assumed to be zero.

$$\pi_t^x = \pi_t^m = \pi_t^n = 0$$

Regarding expenditures, households purchase a consumption basket, which is an aggregate of two types of goods, at price p_t^c. Finally, they invest in capital and pay adjustment costs when their investment increases the stock of this asset.

The budget constraint is as follows:

$$p_t^c c_t + k_{t+1} - (1-\delta)k_t + \phi(k_{t+1} - k_t) + B_{t+1} = w_t^x L_t^x + w_t^m L_t^m + w_t^n L_t^n + r_t^k k_t^m + r_t^k n k_t^n + (1 - r_{t-1}^f)B_t$$

Likewise, we have the following time constraint:

$$l_t + L_t^x + L_t^m + L_t^n = T$$

2.1.5 Optimization processes

Households face the following optimization problem:

$$Max_{c_t, l_t, k_{t+1}, B_{t+1}} \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \frac{(c_t l_t^\omega)^{1-\gamma}}{1-\gamma} \right]$$

Subject to:

$$\begin{aligned} p_t^c c_t + k_{t+1} - (1-\delta)k_t + \phi(k_{t+1} - k_t) + B_{t+1} \\ = w_t^x L^x + w_t^m L^m + w_t^n (T - l_t - L^x - L^n) \\ + r_t^k k_t^m + r_t^{kn} k_t^n + (1 + r_{t-1}^f) B_t. \end{aligned}$$

The first-order conditions of this problem are the following:

- c_t:

$$(c_t l_t^\omega)^{-\gamma} l_t^\omega = \lambda_t p_t^c \tag{1}$$

- l_t:

$$(c_t l_t^\omega)^{-\gamma} c_t \omega l_t^{\omega - 1} = \lambda_t \omega_t^n \tag{2}$$

[11] If $B_t > 0$, households in this economy are net creditors vis-à-vis the rest of the world; if $B_t < 0$, they are net debtors.

- k_{t+1}:

$$\lambda_t[1+\phi(k_{t+1}-k_t)] = \beta \mathbb{E}_t \lambda_{t+1}[(1-\delta)+\phi(k_{t+2}-k_{t+1})+r^k_{t+1}] \tag{3}$$

- B_{t+1}:

$$\lambda_t = \beta \mathbb{E}_t[\lambda_{t+1}(1+r^f_t)] \tag{4}$$

By combining (1) and (2), we obtain the labor supply:

$$\omega \frac{c_t}{l_t} = \frac{w^n_t}{p^c_t} \tag{5}$$

Combining (1) and (3) yields the Euler equation for capital:

$$\frac{U_{c,t}}{p^c_t}\left[1+\phi(k_{t+1}-k_t)\right] = \beta\, E_t\left\{\frac{U_{c,t+1}}{p^c_{t+1}}\left[r^k_{t+1}+(1-\delta)+\phi(k_{t+2}-k_{t+1})\right]\right\} \tag{6}$$

Finally, we obtain the Euler equation for bonds using (1) and (4):

$$\frac{U_{c,t}}{p^c_t} = \beta E_t\left[\frac{U_{c,t+1}}{p^c_{t+1}}(1+r^f_t)\right] \tag{7}$$

In equations (6) and (7):

$$\frac{U_{c,t}}{p^c_t} = \frac{(c_t\, l^\omega_t)^{-\gamma}}{p^c_t}\, l^w_t$$

With the previous equations, the optimal level of household consumption has been determined. However, as already mentioned, consumption is a basket composed of two other goods. To this end, we consider the following expenditure minimization problem:

$$\min_{c^m_t,\, c^n_t} \; c^m_t + p^n_t c^n_t$$

Subject to:

$$c_t = \left[(c^m_t)^{-\mu} + (c^n_t)^{-\mu}\right]^{-\frac{1}{\mu}}$$

From this problem, the demands for importable and non-tradable goods are obtained:

- c^m_t:

$$\frac{c_t}{c^m_t} = \left(\frac{1}{p^c_t}\right)^{\frac{1}{1+\mu}} \tag{8}$$

- c^n_t:

$$\frac{c_t}{c^n_t} = \left(\frac{p^n_t}{p^c_t}\right)^{\frac{1}{1+\mu}} \tag{9}$$

2.2 Firms

The productive structure presented below is constructed to reflect, in a simple way, how the Peruvian economy operates. It is divided into three sectors: commodities (sector devoted exclusively to exports), importables, and non-tradables.

2.2.1 Exportable-goods-producing firms

As in Medina, Munro, and Soto (2008), it is assumed that there are firms producing a fully exportable commodity. This commodity represents Peruvian mining production, which is mostly destined for export. To produce this good, domestic labor (L_t^x), foreign capital (k_t^x), and an imported input (f_t^x) are used. The profits of firms operating in this sector are:

$$\pi_t^x = p_t^x Q A_t^x (L_t^x)^{\alpha_x} \left((k_t^x)^{1-\psi_x}(f_t^x)^{\psi_x}\right)^{1-\alpha_x} - r_t^x k_t^x - w_t^x L_t^x - p_t^f f_t^x$$

Where Q is a scale factor of total productivity. Assuming that any level of labor is supplied to meet demand, the first-order conditions of the profit maximization problem are:

- L^x:
$$\alpha_x p_t^x Q A_t^x (L_t^x)^{\alpha_x - 1} \left((k_t^x)^{1-\psi_x}(f_t^x)^{\psi_x}\right)^{1-\alpha_x} = w_t^x$$
- k_t^x:
$$(1-\alpha_x)(1-\psi_x) p_t^x Q A_t^x (L_t^x)^{\alpha_x} \frac{\left((k_t^x)^{1-\psi_x}(f_t^x)^{\psi_x}\right)^{1-\alpha_x}}{k_t^x} = r_t^x$$
- f_t^x:
$$(1-\alpha_x)\psi_x \, p_t^x Q A_t^x (L_t^x)^{\alpha_x} \frac{\left((k_t^x)^{1-\psi_x}(f_t^x)^{\psi_x}\right)^{1-\alpha_x}}{f_t^x} = p_t^f$$

If we define exportable production as follows:

$$y_t^x = Q A_t^x (L_t^x)^{\alpha_x} \left((k_t^x)^{1-\psi_x}(f_t^x)^{\psi_x}\right)^{1-\alpha_x}$$

We obtain the demands for domestic labor, foreign capital, and imported input by the exportable sector:

$$\alpha_x p_t^x \frac{y_t^x}{L_t^x} = w_t^x \tag{10}$$

$$(1-\alpha_x)(1-\psi_x)\, p_t^x \frac{y_t^x}{k_t^x} = r_t^x \tag{11}$$

$$(1-\alpha_x)\psi_x\, p_t^x \frac{y_t^x}{f_t^x} = p_t^f \tag{12}$$

2.2.2 Firms producing importable goods

These firms produce only consumption goods, which are demanded by households. To do so, they use domestic capital (k_t^m), domestic labor (L^m), and an imported input (f_t^m). The profits of firms operating in this sector are given by:

$$\pi_t^m = QA_t^m (L_t^m)^{\alpha_{m1}} (f_t^m)^{\alpha_{m2}} (k_t^m)^{1-\alpha_{m1}-\alpha_{m2}} - r_t^k k_t^m - w_t^m L_t^m - p_t^f f_t^m$$

Where Q is a scale factor of total productivity. Considering that any level of labor is supplied to satisfy labor demand, the first-order conditions of the profit maximization problem are the following:

- L^m:
$$\alpha_{m1} Q A_t^m (L_t^m)^{\alpha_{m1}-1} (f_t^m)^{\alpha_{m2}} (k_t^m)^{1-\alpha_{m1}-\alpha_{m2}} = w_t^m$$
- k_t^m:
$$(1-\alpha_{m1}-\alpha_{m2}) Q A_t^m (L_t^m)^{\alpha_{m1}} (f_t^m)^{\alpha_{m2}} (k_t^m)^{-\alpha_{m1}-\alpha_{m2}} = r_t^k$$
- f_t^m:
$$\alpha_{m2} Q A_t^m (L_t^m)^{\alpha_{m1}} (f_t^m)^{\alpha_{m2}-1} (k_t^m)^{1-\alpha_{m1}-\alpha_{m2}} = p_t^f$$

If we define importable output as follows:

$$y_t^m = QA_t^m (L_t^m)^{\alpha_{m1}} (f_t^m)^{\alpha_{m2}} (k_t^m)^{1-\alpha_{m1}-\alpha_{m2}}$$

We obtain the demands for domestic labor, domestic capital, and the imported input by the importable sector:

$$\alpha_{m1} \frac{y_t^m}{L^m} = w_t^m \tag{13}$$

$$(1-\alpha_{m1}-\alpha_{m2}) \frac{y_t^m}{k_t^m} = r_t^k \tag{14}$$

$$\alpha_{m2}\, \frac{y_t^m}{f_t^m} = p_t^f \tag{15}$$

2.2.3 Firms producing non-tradable goods

This sector represents the production of services, for which capital (both domestic and foreign), domestic labor, and an imported input are used. The profits of firms operating in this sector are given by:

$$\begin{aligned}\pi_t^n = {} & p_t^n Q A_t^n (L_t^n)^{\alpha_{n1}} (f_t^n)^{\alpha_{n2}} \left((k_t^n)^{\psi_n} (k_t^{n*})^{1-\psi_n}\right)^{1-\alpha_{n1}-\alpha_{n2}} \\ & - r_t^{kn} k_t^n - r_t^{k*} k_t^{n*} - w_t^n L_t^n - p_t^f f_t^n\end{aligned}$$

Where Q is a scale factor of total productivity. Considering that any level of domestic capital is supplied to satisfy its demand, the first-order conditions of the profit maximization problem are the following:

- L_t^n:

$$\alpha_{n1} p_t^n Q A_t^n (L_t^n)^{\alpha_{n1}-1} (f_t^n)^{\alpha_{n2}} \left((k_t^n)^{\psi_n} (k_t^{n*})^{1-\psi_n}\right)^{1-\alpha_{n1}-\alpha_{n2}} = w_t^n$$

- k^n:

$$\psi_n (1-\alpha_{n1}-\alpha_{n2})\, p_t^n Q A_t^n (L_t^n)^{\alpha_{n1}} (f_t^n)^{\alpha_{n2}} \left((k_t^n)^{\psi_n} (k_t^{n*})^{1-\psi_n}\right)^{1-\alpha_{n1}-\alpha_{n2}} \frac{1}{k_t^n} = r_t^{kn}$$

- k_t^{n*}:

$$(1-\psi_n)(1-\alpha_{n1}-\alpha_{n2})\, p_t^n Q A_t^n (L_t^n)^{\alpha_{n1}} (f_t^n)^{\alpha_{n2}} \left((k_t^n)^{\psi_n} (k_t^{n*})^{1-\psi_n}\right)^{1-\alpha_{n1}-\alpha_{n2}} \frac{1}{k_t^{n*}} = r_t^{k*}$$

- f_t^n:

$$\alpha_{n2} p_t^n Q A_t^n (L_t^n)^{\alpha_{n1}} (f_t^n)^{\alpha_{n2}-1} \left((k_t^n)^{\psi_n} (k_t^{n*})^{1-\psi_n}\right)^{1-\alpha_{n1}-\alpha_{n2}} = p_t^f$$

If we define non-tradable output as follows:

$$y_t^n = Q A_t^n (L_t^n)^{\alpha_{n1}} (f_t^n)^{\alpha_{n2}} \left((k_t^n)^{\psi_n} (k_t^{n*})^{1-\psi_n}\right)^{1-\alpha_{n1}-\alpha_{n2}}$$

We obtain the demands for domestic labor, capital, and the imported input by the non-tradable sector:

$$\alpha_{n1} p_t^n \frac{y_t^n}{L_t^n} = w_t^n \tag{16}$$

$$\psi_n (1-\alpha_{n1}-\alpha_{n2})\, p_t^n \frac{y_t^n}{k_t^n} = r_t^{kn} \tag{17}$$

$$(1-\psi_n)(1-\alpha_{n1}-\alpha_{n2})\, p_t^n \frac{y_t^n}{k_t^{n*}} = r_t^{k*} \tag{18}$$

$$\alpha_{n2}\, p_t^n \frac{y_t^n}{f_t^n} = p_t^f \tag{19}$$

2.3 External sector

Given that we are modeling a small open economy, prices —both of foreign capital and of the imported input— are determined in international markets and are therefore exogenous.

Consider the following equation for the price of the imported input:

$$p_t^f = p^{f*}$$

The equilibrium quantity of the imported input is determined by equations (12), (15), and (19), derived from the optimization problems of domestic firms.

However, for the case of the external interest rate on capital, a dynamic similar to that of the interest rate on debt (r_t^f) is assumed. Although this price is partially exogenous, it also exhibits an endogenous component that depends on the amount of capital supplied, as shown below:

$$r_t^{k*} = r^{k*} + \chi_K \left(e^{(\bar{k}^* - k_t)} - 1 \right)$$

As can be observed in the equation above, the higher the level of invested capital, the lower the return on that investment. This elasticity of the interest rate with respect to capital acts as a signal to attract or discourage capital flows depending on the context. The exponential form of the equation allows the adjustment to be gradual but significant.

The exogenous interest rate on foreign capital (r_k^*) is related to the international bond interest rate (r^*) as follows:

$$r_k^* = r^* + \delta$$

This approach assumes that foreign capital must yield a return that compensates both the opportunity cost of investing in international bonds and the depreciation cost of physical capital. Since foreign investors can choose between investing in bonds or in physical capital, the adjusted rate of return must be equal in equilibrium, by the arbitrage condition.

On the other hand, to capture the fact that investment undertaken in the current period takes a certain amount of time to be transformed into capital that is effectively

used in the production of goods in the exportable sector[12] and in the non-tradable sector, the concepts of effective investment (i_t^{e*}) and current investment (i_t^*) are introduced.

In this context, a dynamic relationship between effective investment and current investment is established; that is, a distributed lag model of the former on the latter, captured by the following equation:

$$i_t^{e*} = \lambda i_{t-1}^{e*} + (1-\lambda) i_t^*$$

Current investment is the flow of goods entering the country, but it becomes effective investment —the one that actually forms capital— with some delay. Therefore, the law of motion for foreign capital must be defined in terms of effective investment:

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

As in the case of domestic capital, foreign capital is assumed to be subject to capital adjustment costs, governed by the parameter ϕ':

$$\Phi'(k_t^*, k_{t+1}^*) = \frac{\phi'}{2} \left(k_{t+1}^* - k_t^*\right)^2$$

At this point, we are in a position to define the variables that represent the main external accounts, whose dynamics are the focus of this research.

Since the only sector that produces goods that can be exported is the commodity sector (the mining sector in Peru) and, moreover, since it is assumed that all of its production is consumed abroad, exports (x_t) are equivalent to:

$$x_t = y_t^x$$

On the other hand, as mentioned previously, the consumption of importable goods can be satisfied with goods produced both abroad and domestically. Therefore, any portion not covered by domestic production must be covered externally. For this reason, consumption imports (m_t^c) are defined as follows:

$$m_t^c = c_t^m - y_t^m$$

Likewise, the inputs (intermediate goods such as food, oil and fuels, paper, wood, and other industrial inputs) used by firms in the different sectors of this economy are entirely imported (at the same price), thus constituting total intermediate input imports (m_t^f).

[12] With this formulation, the intention is to characterize the way in which mining investment operates in Peru.

$$m_t^f = f_t^x + f_t^m + f_t^n$$

The only element missing from the theoretical analysis to reflect the structure of Peruvian imports —explained in greater detail in the first section— is capital imports. To define them, it is necessary to assume that foreign capital is also homogeneous and can be used interchangeably in the two sectors that demand it.

$$k_t^* = k_t^x + k_t^{n*}$$

Capital imports are therefore defined as the following flow:

$$m_t^k = i_t^*$$

Hence, total imports in this economy are given by:

$$m_t = m_t^c + p_t^f m_t^f + m_t^k$$

In this definition, it is assumed that the price of capital imports is equal to that of consumption imports.

Recall that in the model proposed by Mendoza (1995) and developed in detail in Galindo, Montecinos, and Ortiz (2024), the terms of trade are assumed to be equivalent to the export price (p_t^x). This assumption is reasonable, since only consumption imports exist and these are the numeraire good.

In contrast, in the model proposed in this research, the inclusion of an imported input and foreign physical capital expands the definition of imports and, therefore, their price. We now have:

$$p_t^m = \gamma_1 + \gamma_2 + \gamma_3\, p_t^f$$

Where γ_i represents the share of imports of a specific type in total imports, for $i =$ consumption, capital, and inputs.

Thus, our definition of the terms of trade is the following:

$$\text{TOT}_t = \frac{p_t^x}{p_t^m}$$

This allows us to define the first aggregate of the current account, the trade balance, as follows:

$$tb_t = p_t^x x_t - m_t^f$$

The second aggregate, primary income (or factor income), is mainly composed of interest paid on net foreign assets —which in countries like Peru usually consists of interest paid on debt— and the return on foreign investment, which represents the profits of firms with foreign investment in the country:

$$int_t = r_{t-1}^f B_t$$

$$util_t = -r_t^{k^*} k_t^{k^*}$$

Finally, the current account is defined as:

$$ca_t = tb_t + int_t + util_t$$

2.4 Market clearing and shock definitions

We construct the aggregate resource constraints for the different sectors. For the tradable sector, we have:

$$c_t^m + i_t^m + \frac{\phi}{2}(k_{t+1}^m - k_t^m)^2 + B_{t+1} + r_t^{k^*} k_t^* = p_t^x y_t^x + y_t^m + i_t^x + (1 + r_{t-1}^f)B_t$$

The non-tradable sector faces the following constraint:

$$c_t^n + k_t^n - (1-\delta)k_t^n + r_t^{k^*} k_t^{n^*} = y_t^n + i_t^{n^*}$$

Total current foreign investment is given by:

$$i_t^* = i_t^x + i_t^{n^*}$$

Likewise, it is necessary to define aggregate production in the tradable sector and in the economy as a whole as follows:

$$y_t^T = (y_t^x)^\alpha \, (y_t^m)^{1-\alpha}$$

$$y_t = \left(y_t^T\right)^\kappa \, (y_t^n)^{1-\kappa}$$

In the baseline model, we have two types of shocks: price shocks (which affect the terms of trade, TOT_t, through the export price p_t^x) and sectoral productivity shocks. These shocks evolve as follows:

$$\ln(p_t^x) = \rho^p \ln(p_{t-1}^x) + \epsilon_t^p, \qquad \epsilon_t^p \sim N(0, \sigma^2_{\epsilon_t^p})$$

$$\ln(A_t^x) = \rho^x \ln(A_{t-1}^x) + \epsilon_t^x, \qquad \epsilon_t^x \sim N(0, \sigma^2_{\epsilon_t^x})$$

$$\ln(A_t^m) = \rho^m \ln(A_{t-1}^m) + \epsilon_t^m, \qquad \epsilon_t^m \sim N(0, \sigma^2_{\epsilon_t^m})$$

$$\ln(A_t^n) = \rho^n \ln(A_{t-1}^n) + \epsilon_t^n, \qquad \epsilon_t^n \sim N(0, \sigma^2_{\epsilon_t^n})$$

2.5 Relative prices

In this section, we derive the relative prices of consumption p_t^c and output p_t^y in terms of importable consumption goods.

2.5.1 For p_t^y

First, we find a relative price of tradable output in terms of importable consumption and capital goods:

$$\min_{y_t^x, y_t^m} \; p_t^x y_t^x + y_t^m \quad \text{s.t.} \quad y_t^T = (y_t^x)^\alpha (y_t^m)^{1-\alpha}$$

The first-order conditions of the problem are:

- y_t^x:
$$p_t^x = \lambda_t \left(\alpha (y_t^x)^{\alpha-1} (y_t^m)^{1-\alpha}\right) \tag{20}$$
- y_t^m:
$$1 = \lambda_t \left(\alpha (y_t^x)^{\alpha} (y_t^m)^{-\alpha}\right) \tag{21}$$

From the minimization problem, it is straightforward to see that $\lambda_t = p_t^T$. Substituting and solving (20) and (21), we obtain, respectively:

$$y_t^x = \alpha \, y_t^T \frac{p_t^T}{p_t^x} \tag{22}$$

$$y_t^m = (1-\alpha)\, y_t^T\, p_t^T \tag{23}$$

Substituting (22) and (23) into the definition of y_t^T:

$$y_t^T = \left(\alpha\, y_t^T\, \frac{p_t^T}{p_t^x}\right)^{\alpha} \left((1-\alpha)\, y_t^T\, p_t^T\right)^{1-\alpha}$$

$$p_t^{y^T} = \alpha^{-\alpha}\, (p_t^x)^{\alpha}\, (1-\alpha)^{-(1-\alpha)} \tag{24}$$

Next, we pose the same minimization problem between the tradable and non-tradable sectors:

$$\min_{y_t^T,\, y_t^n} \; p_t^{y^T}\, y_t^T + p_t^n\, y_t^n \qquad \text{s.t.} \qquad y_t = (y_t^T)^{\kappa} (y_t^n)^{1-\kappa}$$

Repeating the procedure used for the tradable sector, we obtain:

- y_t^T:

$$y_t^T = \kappa\, y_t \frac{p_t^y}{p_t^{y^T}} \tag{25}$$

- y_t^n:

$$y_t^n = (1-\kappa)\, y_t \frac{p_t^y}{p_t^n} \tag{26}$$

Substituting (25) and (26) into the definition of y_t:

$$y_t = \left(\kappa y_t \frac{p_t^y}{p_t^{y^T}}\right)^{\kappa} \left((1-\kappa) y_t \frac{p_t^y}{p_t^n}\right)^{1-\kappa}$$

$$p_t^y = \left(\frac{p_t^{y^T}}{\kappa}\right)^{\kappa} \left(\frac{p_t^n}{1-\kappa}\right)^{1-\kappa}$$

Finally, substituting (24) into the equation above, we obtain the composite output price in terms of importable goods:

$$p_t^y = \left[\left(\frac{p_t^x}{\kappa\alpha}\right)^{\alpha} \left(\frac{1}{\kappa(1-\alpha)}\right)^{1-\alpha}\right]^{\kappa} \left[\left(\frac{p_t^n}{1-\kappa}\right)^{1-\kappa}\right]$$

2.5.2 For p_t^c

To compute the price of the consumption basket, we use the demands in (8) and (9):

$$c_t = \left[(c_t^m)^{-\mu} + (c_t^n)^{-\mu}\right]^{-\frac{1}{\mu}}$$

$$c_t = \left[\left(c_t\,(p_t^c)^{\frac{1}{1+\mu}}\right)^{-\mu} + \left(c_t\left(\frac{p_t^c}{p_t^n}\right)^{\frac{1}{1+\mu}}\right)^{-\mu}\right]^{-\frac{1}{\mu}}$$

Simplifying the expression above, we obtain the model's consumer price index:

$$p_t^c = \left[1 + (p_t^n)^{\frac{\mu}{1+\mu}}\right]^{\frac{1+\mu}{\mu}}$$

With the prices derived above, it is possible to express the two main aggregates in terms of consumption imports:

$$y_t^{\text{imp}} = p_t^y\, y_t$$

$$c_t^{\text{imp}} = p_t^c\, c_t$$

2.6 Additional mechanisms

2.6.1 Specification 2. Addition of a shock to the price of the imported input

In the baseline model, it is assumed that the price of the imported input is exogenous and internationally determined, that is, $p_t^f = p^{f*}$. As with the international interest rate, this price can be set as a parameter in order to estimate it later using information relevant for the dynamics of the economy.

On the other hand, although freight prices do not appear directly in the equations that determine the trade balance and, therefore, the current account, as described in the first section, this variable shows a significant correlation with these accounts. Additionally, it exhibits a high and positive correlation with the profits of firms with foreign investment.

Consequently, it is necessary to introduce a mechanism through which it is possible to analyze the impacts of random variations in this price on the dynamics of external accounts. Thus, supported by empirical evidence, it is assumed that global freight prices affect the transportation costs of inputs and, consequently, their prices. Since, in this model, firms in all sectors use the imported input as a production factor, their profits will be affected by shocks to this price. If we focus on firms in the exportable sector, this mechanism could explain the correlation found with profits.

To this end, the modeling of p_t^f is modified as follows:

$$p_t^f = p_t^{f*} s_t^f$$

Where:

$$\ln(s_t^f) = \rho^f \ln(s_{t-1}^f) + \epsilon_t^f, \qquad \epsilon_t^f \sim \mathcal{N}(0, \sigma_{\epsilon_f}^2)$$

With this definition, an additional mechanism is introduced through which the terms of trade can be affected (p_t^m is affected by p_t^f).

2.6.2 Specification 3. Addition of shocks to the interest rate on debt

According to Neumeyer and Perri (2005), B_t constitutes risky assets, given the possibility that Peru, as an emerging market economy, may default.

For this reason, in an alternative specification, the equation defining the dynamics of the bond interest rate is modified to incorporate the impact of default risk.

$$r_t^f = r^* + r_t^* + rp_t$$

The interest rate paid on external debt is composed of two parts. The first reflects foreign investors' perception of the country's risk of failing to meet its obligations.

$$rp_t = \chi \left(e^{\bar{B} - B_t} - 1 \right) + \epsilon_t^{rp}, \qquad \epsilon_t^{rp} \sim N(0, \sigma_{\epsilon_t^{rp}}^2)$$

Additionally, this perception may be altered by stochastic events capable of increasing the aforementioned risk (ϵ_t^{rp}), which may include political factors that threaten the country's institutional framework.

The second component of the interest rate reflects the fact that investors' preferences for risky assets are persistent, but also subject to unforeseen and purely random changes.

$$r_t^* = \rho^{r^*} r_{t-1}^* + \epsilon_t^{r^*}, \qquad \epsilon_t^{r^*} \sim N(0, \sigma_{\epsilon_t^{r^*}}^2)$$

2.6.3 Specification 4. Addition of a shock to foreign investment

As argued in Justiniano, Primiceri, and Tambalotti (2010), an investment shock captures an exogenous variation in the efficiency with which invested goods are transformed into new capital. One possible interpretation of such variation is provided by Greenwood, Hercowitz, and Krusell (2000), in whose model the process accompanying investment represents the current state of technology for producing capital goods. Thus, variations in this process represent technological changes specific to the production of capital goods.

Additionally, Justiniano, Primiceri, and Tambalotti (2010) show that the presence of such shocks may also reflect disturbances in the process through which investment is converted into productive capital.

These shocks have been termed investment-specific technology shocks (IST) in the RBC literature, and their transmission mechanism —in an open economy context— has been thoroughly documented by Raffo (2010). In Raffo (2010), a positive shock to domestic investment leads to an investment boom and an expansion of consumption that exceeds the increase in domestic production, driven by higher utilization rates of capital services and a strong positive response of employment, consistent with an increase in the marginal productivity of labor. The expansion of investment is financed both by domestic resources and by resources attracted from abroad in response to higher productive efficiency. These dynamics lead to an increase in domestic absorption associated with a trade deficit and an appreciation of the terms of trade, consistent with higher prices of domestically produced goods.

In the present study, we adopt the interpretation of Justiniano, Primiceri, and Tambalotti (2011) and include IST shocks in the process of foreign investment formation. The objective of this modification is to reflect the fact that this type of investment —essentially interpreted as mining investment— requires long investment periods to complete projects and often faces additional difficulties that further hinder its conversion into productive capital. Therefore, the following law of motion for foreign capital is proposed:

$$k^*_{t+1} = (1-\delta)k^*_t + \mu_t \, i^{e^*}_t$$

Where:

$$\ln(\mu_t) = \rho^{\mu} \ln(\mu_{t-1}) + \varepsilon_{\mu,t}, \qquad \varepsilon_{\mu,t} \sim N(0, \sigma^2_{\varepsilon_\mu})$$

Given the empirical motivation of this research, there is an additional justification for the inclusion of this shock in the context of international business cycles, as discussed by Raffo (2010). The author argues that, in order to replicate the stylized facts of open economies, a model must generate large changes in domestic absorption over the business cycle. In this sense, IST shocks introduce an important source of variation in absorption, as they do not directly affect aggregate efficiency. Although our model differs substantially from that of Raffo (2010), in subsection 4.2.7 we explain the transmission mechanism generated by the introduction of this shock in our model and how it differs from the baseline framework.

3 Methodology and Estimation

This section describes the data for the Peruvian economy used in the estimation of the most relevant parameters of our model and the Bayesian methodology employed to carry out such estimation, including the description of the prior distributions.

3.1 Data

In the estimation of the model parameters, the following variables are considered as observables and, therefore, are those that provide valuable information to the model in order to reflect the characteristics of the Peruvian economy:

- Output
- Private consumption
- Private investment
- Exports
- Intermediate goods imports
- Capital goods imports
- Consumption goods imports
- Export price index
- Import price index
- Interest payments
- Profit payments
- Net foreign assets
- Consumer price index
- Non-tradable goods price index

It is necessary to specify that these variables are expressed in per capita units, deflated by the consumption import price index, in logarithmic terms, and as deviations from their trend. The main characteristics of these variables have already been presented in the Introduction.

The data were obtained from the statistics section of the website of the Central Reserve Bank of Peru. The sample covers the period starting in the first quarter of 1994 and ending in the fourth quarter of 2023.

The choice of these indicators for the estimation of the model parameters is based on the explanatory power they provide and on the ease with which they can be linked to the theoretical variables of the model without incurring large measurement errors. From the real sector, variables that allow us to assess the performance of national economic activity in terms of production and employment are considered. For our purposes, this set consists of GDP, Private Consumption, and Private Investment. Given that the interest of this research is to characterize the functioning of the external sector and its components, additional groups of indicators are added to the real variables in order to complement their contribution to the model fit. Among them are variables that describe the dynamics of international trade in goods, both in volume and price. Their inclusion within the group of observable variables responds to the importance of the trade balance in understanding the external sector of the economy and the outcome of the current account.

Likewise, variables that characterize the evolution of external prices faced by our small open economy are included, which are highly volatile and depend on exogenous factors. These are considered due to the importance of the trade balance, particularly through shocks to the terms of trade —both on the export and import sides— for understanding the current account balance. Finally, variables related to total payments made for the use of foreign financial capital (interest payments) and foreign physical capital (profit payments) are included.

3.2 Bayesian model selection

To define the Bayes Factor (BF), we start from the assumption that a set of observables denoted by the vector Y has been generated by one of two available models (and/or specifications) (M_1 and M_2) according to the following probability distribution: $\gamma_1 = p(M_1 \mid Y)$ and $\gamma_2 = 1 - p(M_1 \mid Y)$. Given a prior distribution $(\gamma_{1,0}, \gamma_{2,0})$, the data produce a posterior distribution $(\gamma_{1,T}, \gamma_{2,T})$.

From Bayes' theorem, we obtain:

$$\gamma_{j,T} = \frac{p(Y \mid M_j)\, p(M_j)}{p(Y \mid M_1)\, p(M_1) + p(Y \mid M_2)\, p(M_2)}, \qquad j = 1, 2$$

Dividing for each value of j, that is, constructing the odds ratios, we have:

$$\frac{\gamma_{1,T}}{\gamma_{2,T}} = \frac{p(Y \mid M_1)\, p(M_1)}{p(Y \mid M_2)\, p(M_2)}$$

$$\frac{\gamma_{1,T}}{\gamma_{2,T}} = \frac{p(Y \mid M_1)\,\gamma_{1,0}}{p(Y \mid M_2)\,\gamma_{2,0}}$$

From the previous equation, we can observe that the transformation performed by the data consists of multiplying the prior odds ratio by a factor that we define as the Bayes Factor, in order to obtain the posterior odds ratio. Thus:

$$posterior\ odds = Bayes\ factor\ x\ prior\ odds$$

Where:

$$BF_{12} = \frac{p(Y \mid M_1)}{p(Y \mid M_2)} \tag{27}$$

represents the Bayes Factor for model 1 against model 2, terminology that will be used in the discussion in the results section.

However, in practice, an estimator of the data likelihood is often available instead of $p(Y \mid M_j)$, in logarithmic terms. In that case, equation (27) would be estimated, as suggested by Chib (1995), as follows:

$$\widehat{BF}_{12} = \exp\{\ln \hat{p}(Y \mid M_1) - \ln \hat{p}(Y \mid M_2)\} \tag{28}$$

The interpretation suggested by Kass and Raftery (1995) is presented in Table (5) and used to discuss the results in the corresponding section.

Table 5: *Interpretation of the Bayes Factor*

B_{ij}	**Interpretation**
[1, 3.2]	The evidence against model j is *weak*.
(3.2, 10]	The evidence against model j is *substantial*.
(10, 100]	The evidence against model j is *strong*.
(100, $+\infty$)	The evidence against model j is *decisive*.

Source: Kass and Raftery (1995).

3.3 Definition of priors

This section presents and justifies the formulation of the priors used for the parameters (θ) that have been subject to Bayesian estimation. Following Del Negro and Schorfheide (2008), the parameters are grouped into three categories: parameters that determine the steady state (θ_{ss}), parameters that intervene in the endogenous propagation of shocks

(θ_{endo}), and those that characterize the law of motion of exogenous processes (θ_{exo}). In this sense, Table (6) shows this strategic grouping of parameters, their domain, and the characterization of their respective prior distributions.

Table 6: *Prior distributions of the model parameters*

Parameter	**Symbol**	**Domain**	**Distribution**	**Mean**	**Standard deviation**
Steady-state parameters θ_{ss}					
Risk-free international interest rate	r^*	$\mathbb{R}^+$	Gamma	0.0195	0.001
Ratio of expenditure on importable consumption relative to non-tradables	$\frac{c^m}{p^n c^n}$	$[0,1]$	Beta	0.78	0.07
Ratio of expenditure on non-tradable consumption relative to total	$\frac{p^n c^n}{c^{imp}}$	$[0,1]$	Beta	0.60	0.06
Endogenous propagation parameters θ_{endo}					
Labor supply elasticity regulator	ω	$\mathbb{R}^+$	Gamma	1.455	0.10
Elasticity of substitution regulator between importables and non-tradables	μ	$[-1,+\infty[$	Normal	1.50	0.10
Inverse of the intertemporal elasticity of substitution	γ	$\mathbb{R}^+$	Gamma	1.50	0.10
Domestic capital adjustment cost	ϕ	$\mathbb{R}^+$	Normal	0.03	0.01
Foreign capital adjustment cost	ϕ'	$\mathbb{R}^+$	Normal	0.10	0.01
Interest rate elasticity regulator to debt level	χ_d	$\mathbb{R}^+$	Gamma	0.50	0.10
Interest rate elasticity regulator to capital stock	χ_k	$\mathbb{R}^+$	Gamma	1.50	0.50
Koyck lag	λ	$]0,1]$	Beta	0.75	0.10

continued on next page

Table 6 – continued

Parameter	Symbol	Domain	Distribution	Mean	Standard deviation
Exogenous price of imported input	p^*	$\mathbb{R}^+$	Gamma	1.50	0.20
Share of consumption imports in total imports	γ_1	$[0,1]$	Beta	0.157	0.061
Share of capital imports in total imports	γ_2	$[0,1]$	Beta	0.326	0.053
Share of intermediate input imports in total imports	γ_3	$[0,1]$	Beta	0.411	0.05
Share of exportable production in tradable production	α	$[0,1]$	Beta	0.25	0.10
Share of imported input in the foreign factor composite of the exportable sector	ψ_x	$[0,1]$	Beta	0.40	0.10
Labor share in exportable production	α_x	$[0,1]$	Beta	0.75	0.10
Labor share in importable production	α_{m1}	$[0,1]$	Beta	0.50	0.10
Share of imported input in importable production	α_{m2}	$[0,1]$	Beta	0.20	0.10
Labor share in non-tradable production	α_{n1}	$[0,1]$	Beta	0.56	0.05
Share of imported input in non-tradable production	α_{n2}	$[0,1]$	Beta	0.10	0.05
Share of domestic capital in the capital composite of the non-tradable sector	ψ_n	$[0,1]$	Beta	0.40	0.10
Share of tradable production in aggregate production	κ	$[0,1]$	Beta	0.60	0.10
Exogenous shock parameters θ_{exo}					
Persistence of the export price shock	ρ^p	$[0,1]$	Beta	0.83	0.10

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Table 6 – continued

Parameter	Symbol	Domain	Distribution	Mean	Standard deviation
Persistence of the productivity shock to the exportable sector	ρ^x	$[0,1]$	Beta	0.87	0.10
Persistence of the productivity shock to the importable sector	ρ^m	$[0,1]$	Beta	0.49	0.20
Persistence of the productivity shock to the non-tradable sector	ρ^n	$[0,1]$	Beta	0.58	0.20
Persistence of the import price shock	ρ^f	$[0,1]$	Beta	0.81	0.05
Persistence of the shock to foreign investors' preferences	ρ^{r^*}	$[0,1]$	Beta	0.80	0.01
Persistence of the foreign investment shock	ρ^μ	$[0,1]$	Beta	0.20	0.10
Standard deviation of the export price shock	$\sigma^2_{\varepsilon^p_t}$	$\mathbb{R}^+$	Inverse-Gamma	0.07	0.10
Standard deviation of the productivity shock to the exportable sector	$\sigma^2_{\varepsilon^x_t}$	$\mathbb{R}^+$	Inverse-Gamma	0.0197	0.11
Standard deviation of the productivity shock to the importable sector	$\sigma^2_{\varepsilon^m_t}$	$\mathbb{R}^+$	Inverse-Gamma	0.07	0.10
Standard deviation of the productivity shock to the non-tradable sector	$\sigma^2_{\varepsilon^n_t}$	$\mathbb{R}^+$	Inverse-Gamma	0.10	0.10
Standard deviation of the import price shock	$\sigma^2_{\varepsilon^f_t}$	$\mathbb{R}^+$	Inverse-Gamma	0.05	0.10
Standard deviation of the shock to foreign investors' preferences	$\sigma^2_{\varepsilon^{r^*}_t}$	$\mathbb{R}^+$	Inverse-Gamma	0.01	0.119
Standard deviation of the spread shock	$\sigma^2_{\varepsilon^{rp}_t}$	$\mathbb{R}^+$	Inverse-Gamma	0.02	0.12

continued on next page

Table 6 – continued

Parameter	Symbol	Domain	Distribution	Mean	Standard deviation
Standard deviation of the foreign investment shock	$\sigma^2_{\varepsilon^{i\mu}_t}$	$\mathbb{R}^+$	Inverse-Gamma	0.10	0.10

1/ Parameters specific to specification 2.
2/ Parameters specific to specification 3.
3/ Parameters specific to specification 4.

As is usual in research that uses calibration, the priors of the parameters in the first group (θ_{ss}) were defined based on long-run averages of representative indicators. To prevent the use of data from interfering with the Bayesian learning process, pre-samples covering the period from the first available observation of each indicator up to 1993 were used[13]. Thus, the prior mean of the distribution of the risk-free international interest rate (r^*) was obtained from the yield on 10-year U.S. Treasury bonds; that of the ratio of expenditure on importable consumption relative to non-tradables ($\frac{c^m}{p^n c^n}$) was approximated using the ratio of GDP of all sectors excluding mining and hydrocarbons, fishing, and services to GDP of the services sector; and that of the ratio of expenditure on non-tradable consumption relative to total ($\frac{p^n c^n}{c^{imp}}$) was estimated using the share of the services sector GDP in total GDP. Standard deviations were computed in the same way, with minor adjustments to respect the bounds of each distribution.

Regarding the second group of parameters (θ_{endo}), Herbst and Schorfheide (2016) recommend using microeconometric evidence or consulting the literature that has analyzed or employed the parameters of interest. Therefore, this study reviewed previous works with calibration such as Mendoza (1995) and frequentist parameter estimation such as Schmitt-Grohé and Uribe (2018) to establish the prior mean of the common parameters. Likewise, studies with Bayesian estimation such as Castillo, Montoro, and Tuesta (2013) were reviewed to establish an appropriate standard deviation, which was adjusted according to the authors' judgment to respect the bounds of the proposed distributions. For the parameters that reflect the structure of imports, the same strategy used for θ_{ss} was followed, with a pre-sample covering the period 1985–1993. Finally, priors for parameters with scarce prior evidence were formulated based on the authors' knowledge of the Peruvian economy.

As argued by Herbst and Schorfheide (2016), conditional on θ_{ss} and θ_{endo}, the parameters belonging to the third group (θ_{exo}) determine the volatility and persistence of the model variables affected by shocks. Therefore, the priors of these parameters can

[13]For r^* the period used was 1950–1993, and for the other two parameters 1980–1993.

be formulated based on the computation of these moments in a pre-sample. For empirically observable variables (export prices, import prices, risk-free international interest rate, and foreign investment), this procedure was followed, while for those that are not directly observable (sectoral productivity processes), previous studies combined with the researchers' judgment were used to support the formulation of the priors.

After defining means and standard deviations, prior distributions consistent with the admissible range of values for each parameter were selected. Parameters whose range spans the positive real numbers ($\mathbb{R}^+$) were approximated using Gamma distributions. Ratios, shares (Cobb–Douglas exponents), or persistences (coefficients of autoregressive processes) were assigned Beta distributions, ensuring that these parameters lie between 0 and 1. For parameters with unclear bounds or that may take negative values, a normal distribution was used to allow a wider range of outcomes. Finally, standard deviations were modeled using inverse-Gamma distributions, as is common in the literature, since in addition to ruling out negative values and being flexible, their fat tails ensure that extreme values, while unlikely, are not completely excluded.

The selection of the parameters ultimately included in the estimation was based on the objective of better characterizing the dynamics of Peru's external accounts. Accordingly, priority was given to those appearing in the equations that determine external variables. The remaining parameters, mainly deep parameters such as those related to households (depreciation rate), were calibrated considering approximately their historical average values and those used in other studies. Some of these parameters are linked through underlying relationships, such as the international interest rate and the discount factor.

Table 7: *Calibrated parameters in the model*

Parameter	**Symbol**	**Value**
Total available time	T	100
Total factor productivity	Q	1.0
Depreciation rate	δ	0.05
Inelastic labor in the exportable sector	L^x	5.0
Inelastic labor in the importable sector	L^m	5.0
Inelastic capital in the non-tradable sector	K^n	4.0

4 Results

As mentioned previously in the introduction, this research aims to conduct a formal evaluation of the relevance of the additional shocks proposed in the model section –beyond the traditional terms-of-trade shocks– in explaining fluctuations in Peru's current account. Based on this evaluation, relevant transmission mechanisms from these external shocks to the main components of the current account, and ultimately to other macroeconomic variables, are constructed. These specifications are formed by adding the proposed mechanisms to the baseline model, according to the following table:

Table 8: *Model specifications*

Specification 1	**Specification 2**	**Specification 3**	**Specification 4**
Base model	Specification 1	Specification 2	Specification 3
	Shock to the price of the imported input	Shocks to international interest rates	Shock to foreign investment

The results are organized into four subsections: (i) an evaluation of parameter estimates and Bayesian fit to determine how the inclusion of shocks affects uncertainty and to identify the best-fitting specification; (ii) an impulse response function analysis to characterize internal and external dynamics; (iii) a variance decomposition to quantify the contribution of proposed shocks to the fluctuations of key macroeconomic variables; and (iv) a simulation based on estimated parameters to validate whether the model replicates the stylized facts of the Peruvian economy.

4.1 Parameter Estimation and Model Selection

This section discusses the posterior properties of the structural parameters and evaluates the relative performance of the proposed specifications. Following the Bayesian approach, we assess the degree of identification and the statistical gains from incorporating additional external shocks into a SOE framework.

4.1.1 Posterior estimates and identification analysis

To analyze the parameter estimation results, the skewness, coefficient of variation, and relative percentile range of their posterior distributions are considered.

In the base specification, parameters with a higher proportion of high extreme values include the labor share in non-tradable production (α_{n1}), the elasticity of substitution between importables and non-tradables (μ), and the share of imported inputs in total imports (γ_3). This suggests a significant probability of these parameters taking values

higher than their mode. Conversely, parameters with positive skewness —such as the share of non-tradable consumption expenditure $\left(\frac{(p^n c^n)}{c^{imp}}\right)$, the share of consumption imports (γ_1), and the inverse of the intertemporal elasticity of substitution (γ)— show a higher concentration toward low values. These results are consistent with the Peruvian economy's structural characteristics, where imported inputs represent a larger share of total imports than consumption imports.

Regarding estimation precision, parameters with notably low coefficients of variation (between specifications 1 and 3) include the labor supply elasticity (ω), the risk-free international interest rate (r^*), and the persistence of the export price shock (ρ^p). These results indicate strong identification due to sufficient data variability and well-established functional relationships in the literature. In contrast, higher relative uncertainty is observed in parameters related to sectoral productive structures, such as ψ_x, ψ_n, and α, reflecting the challenge of directly observing these factors through aggregate macroeconomic dynamics.

In particular, when the full model is estimated, several parameters governing external and internal dynamics show significant asymmetries. Parameters such as the share of the tradable sector (κ), labor supply elasticity (ω), and the persistences of foreign investment (ρ^μ) and international interest rate shocks (ρ^r) exhibit a high probability of taking values above the mode. Conversely, positive skewness is more pronounced in the domestic capital share (ψ_n), export price shock persistence (ρ^p), and foreign capital adjustment costs ($\phi^{'}$).

This finding is statistically relevant as it highlights that shocks to foreign investment and interest rates may have more durable effects than their modal values suggest. In contrast, the export price shock persistence is likely to remain below 0.721. Such evidence reinforces the research's core argument regarding the relevance of additional external shocks as they appear more persistent than anticipated. In the context of emerging economies, where external vulnerability is a structural concern, this evidence justifies the explicit inclusion of these shocks in policy analysis and scenario simulations.

4.1.2 Comparison of Posterior Modes and Robustness

The comparison of posterior modes across specifications allows us to identify the sensitivity of structural parameters to the inclusion of new shocks. Parameters such as the foreign interest rate (r^*) and capital adjustment costs (ϕ, ϕ') remain remarkably robust, showing stable modes and narrow 90% probability intervals regardless of the model complexity. In contrast, the export price mode (p^*) and the capital-stock elasticity (χ_k) exhibit significant heterogeneity, making them the least robust to model extensions.

Regarding exogenous shocks, the persistence of the export price shock (ρ^p) is the most robust across specifications, while the non-tradable productivity shock (ρ^n) is the most sensitive. The standard deviations of the base shocks maintain similar levels despite the

inclusion of additional disturbances, whereas the standard deviations of the new shocks —such as the import price shock (σ_{ε^f})— show less stability across specifications 2 and 3.

Table 9: *Posterior distribution of parameters*

Parameter	Base Specification			Specification 2			Specification 3			Full Specification		
	Mode	5%	95%	Mode	5%	95%	Mode	5%	95%	Mode	5%	95%
r^*	0.019	0.019	0.020	0.019	0.018	0.021	0.019	0.018	0.021	0.023	0.022	0.023
$\frac{c^m}{p^n c^n}$	0.531	0.497	0.583	0.796	0.652	0.816	0.797	0.711	0.899	0.740	0.739	0.778
$\frac{p^n c^n}{p^{imp}}$	0.462	0.505	0.555	0.670	0.610	0.707	0.603	0.534	0.724	0.472	0.453	0.490
ω	1.813	1.810	1.874	1.351	1.248	1.457	1.316	1.082	1.434	1.631	1.608	1.633
μ	1.959	1.806	1.924	2.002	1.954	2.117	1.804	1.657	1.949	1.205	1.156	1.238
γ	0.958	0.953	1.029	1.590	1.587	1.773	1.482	1.303	1.655	1.280	1.256	1.286
ϕ	0.059	0.054	0.066	0.039	0.031	0.047	0.059	0.052	0.070	0.019	0.018	0.021
ϕ'	0.105	0.099	0.112	0.109	0.106	0.121	0.100	0.085	0.113	0.112	0.111	0.114
χ_d	0.700	0.580	0.728	0.415	0.364	0.570	0.342	0.264	0.533	0.413	0.387	0.437
χ_k	2.846	2.580	2.957	1.820	1.338	1.784	2.292	1.558	2.872	1.960	1.915	2.020
λ	0.124	0.107	0.203	0.234	0.251	0.394	0.134	0.107	0.188	0.315	0.290	0.340
p^*	2.088	2.052	2.206	0.554	0.554	0.599	0.737	0.626	0.878	0.777	0.748	0.816
γ_1	0.171	0.192	0.280	0.290	0.248	0.372	0.136	0.053	0.301	0.242	0.235	0.271
γ_2	0.218	0.210	0.260	0.273	0.237	0.308	0.321	0.234	0.428	0.353	0.338	0.373
γ_3	0.286	0.234	0.282	0.208	0.159	0.228	0.217	0.164	0.280	0.437	0.433	0.459
α	0.167	0.098	0.196	0.059	0.044	0.113	0.124	0.067	0.206	0.042	0.023	0.050
ψ_x	0.085	0.041	0.115	0.677	0.529	0.687	0.735	0.647	0.811	0.039	0.022	0.049
α_x	0.283	0.255	0.365	0.992	0.993	0.997	0.753	0.691	0.800	0.169	0.150	0.183
α_{m1}	0.782	0.762	0.817	0.591	0.543	0.619	0.568	0.512	0.617	0.599	0.559	0.613
α_{m2}	0.207	0.171	0.225	0.197	0.187	0.247	0.145	0.103	0.194	0.214	0.199	0.254
α_{n1}	0.467	0.408	0.448	0.256	0.256	0.271	0.328	0.256	0.364	0.293	0.280	0.298
α_{n2}	0.295	0.290	0.321	0.028	0.017	0.020	0.006	0.002	0.016	0.086	0.074	0.089
ψ_n	0.064	0.046	0.127	0.062	0.039	0.114	0.129	0.067	0.199	0.182	0.194	0.231
κ	0.877	0.866	0.934	0.048	0.038	0.081	0.146	0.095	0.234	0.980	0.969	0.980
ρ_p	0.980	0.928	0.986	0.903	0.870	0.951	0.822	0.730	0.883	0.721	0.723	0.757
ρ_x	0.996	0.933	0.998	0.469	0.391	0.554	0.536	0.405	0.630	0.991	0.973	0.996
ρ_m	0.669	0.591	0.745	0.491	0.408	0.599	0.475	0.251	0.616	0.006	0.002	0.018
ρ_n	0.415	0.397	0.474	0.228	0.059	0.365	0.297	0.097	0.622	0.965	0.915	0.984
ρ_f	-	-	-	0.721	0.707	0.783	0.804	0.786	0.821	0.795	0.789	0.796
ρ_r	-	-	-	-	-	-	0.762	0.687	0.848	0.694	0.670	0.728
ρ_μ	-	-	-	-	-	-	-	-	-	0.053	0.016	0.055
Standard deviations of shocks												
$\sigma_{\varepsilon_t^p}$	0.019	0.016	0.021	0.031	0.027	0.034	0.033	0.029	0.038	0.016	0.015	0.018
$\sigma_{\varepsilon_t^x}$	0.006	0.005	0.007	0.020	0.018	0.023	0.018	0.016	0.021	0.005	0.005	0.006
$\sigma_{\varepsilon_t^m}$	0.050	0.045	0.058	0.025	0.023	0.030	0.016	0.014	0.019	0.039	0.036	0.044
$\sigma_{\varepsilon_t^n}$	0.034	0.031	0.040	0.045	0.041	0.052	0.042	0.036	0.185	0.040	0.038	0.043
ϵ_f	-	-	-	0.043	0.039	0.053	0.031	0.026	0.037	0.367	0.362	0.405
$\sigma_{\varepsilon_t^{rp}}$	-	-	-	-	-	-	0.151	0.120	0.234	0.476	0.465	0.503
$\sigma_{\varepsilon_{r^*}}$	-	-	-	-	-	-	0.228	0.182	0.356	0.020	0.019	0.024
$\sigma_{\varepsilon_t^\mu}$	-	-	-	-	-	-	-	-	-	0.021	0.020	0.024
Marginal log-density	**-763.62**			**-588.51**			**-571.31**			**-31.17**		

4.1.3 Model fit and Bayes Factor analysis

The formal comparison of specifications relies on the marginal likelihood and the Bayes Factor. As argued by Herbst and Schorfheide (2016), the marginal density plays a critical role in transforming prior probabilities into posterior evidence. Due to the lack of an analytical form, we employ the Modified Harmonic Mean (MHM) estimator following Sims, Waggoner, and Zha (2008) to ensure numerical stability and efficiency.

The estimation reveals that the inclusion of additional transmission mechanisms leads to a monotonic increase in the marginal log-density, indicating a superior fit to the Peruvian data. The Bayes Factor analysis provides **decisive evidence** in favor of the full specification (Specification 4). The BF relative to the base model approaches infinity, while the comparison against Specification 3 yields a factor of 3.8×10^{234}. These results demonstrate that a theoretical approach incorporating multiple external shocks —ranging from import prices to foreign investment— is essential for capturing the empirical dynamics of a SOE accurately. This also highlights the relevance of the selected observables in identifying the model's structural parameters and improving its predictive discipline.

Table 10: *Bayes Factor in favor of the full specification*

Specification	Hypothesis	Symbol	Bayes Factor
Base	H_1	BF_{41}	$+\infty$
2	H_2	BF_{42}	1.1×10^{242}
3	H_3	BF_{43}	3.8×10^{234}
Full	H_4	BF_{44}	1.0×10^{00}
Specification with best fit			**Full**

4.2 Impulse-Response Function Analysis

This subsection analyzes the transmission mechanisms of structural shocks on the current account and its components. Impulse-Response Function (IRF) are based on the posterior median and 90% credibility intervals from Specification 4 (full model), estimated using the 14 observables described in Section 3.1.

4.2.1 Export sector productivity shock

Following a positive shock to export productivity, there is an initial increase in the production of this sector with a magnitude slightly smaller than that of A^x. Consequently, an increase in the marginal productivity of the production factors used occurs, generating changes in equilibrium prices and quantities: (i) an increase in the quantity demanded

of imported inputs, (ii) an increase in the export wage, and (iii) a moderate drop in investment expenditure, which causes a subsequent decline in the sector's capital.

The decline in investment and capital is driven by three factors:

- **Koyck lag:** Causes investment to adjust slowly and be distributed over time, making initial spending unresponsive to the shock.
- **Adjustment costs:** In tandem with the Koyck effect, these costs amplify inertia and induce a lagged response, potentially leading to an initial contraction.
- **Intertemporal incentives:** Firms may temporarily defer capital expansion to evaluate net returns once adjustment costs and lags have stabilized.

In subsequent periods, investment expenditure begins to recover; meanwhile, effective investment continues to fall until quarter 4, at which point it follows the same path as investment expenditure. These dynamics cause capital to continue falling for 14 more quarters before recovering at a moderate pace. The fall in export capital reverses the increase in the sector's production, an effect that is amplified by the return of factor quantities to their steady-state level as the shock dissipates. Higher export production initially boosts exports, which later return to the steady state following the sector's production evolution.

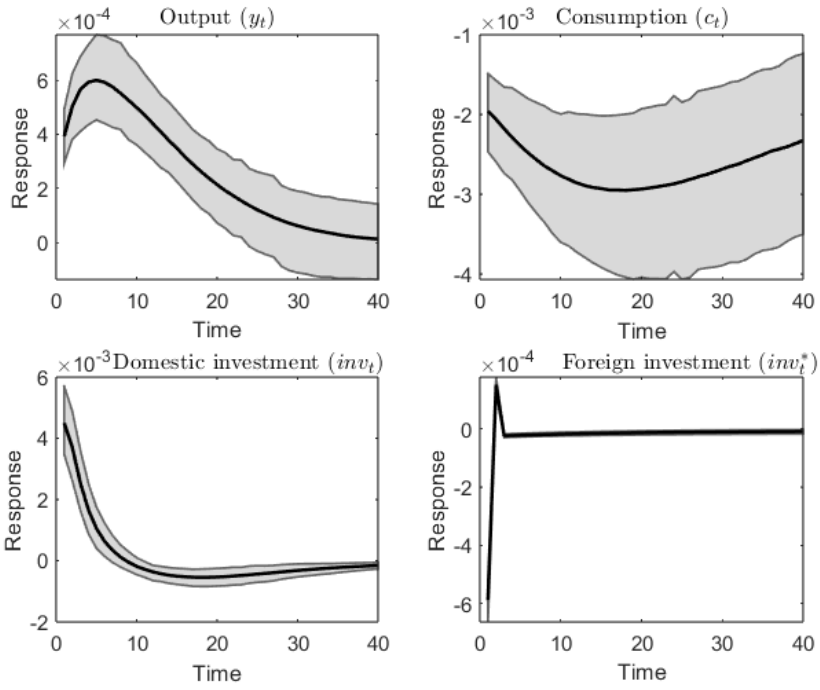
The large drop in foreign direct investment (FDI) —taking place in the initial periods— puts upward pressure on the foreign capital interest rate as a smoothing mechanism aimed at slowing down this flow. This response of the foreign interest rate affects the non-tradable sector, putting upward pressure on the price of these goods (p^n) and the price of the consumer goods basket (p^c). Changes in these prices alter both intertemporal and intratemporal decisions, expanding the effects of this shock toward the importable sector.

First, the increase in p^c and its projected path by agents cause two effects: (i) a negative income effect on consumption and capital and (ii) a negative substitution effect on consumption and a positive one on capital. For its part, the increase in p^n boosts the value of the marginal product of other production factors and, consequently, the demand for them by firms in the sector, resulting in a contemporaneous increase in the wage and the domestic capital interest rate in the non-tradable sector. Given the increase in p^c, the real wage in the non-tradable sector is slightly reduced, generating two other effects: (i) a negative income effect on consumption and leisure and (ii) a negative substitution effect on consumption and a positive one on leisure.

Parameter estimation allowed for posterior distributions where the support for the intertemporal elasticity of substitution of consumption is below 1 and that of the intratemporal elasticity of substitution of labor is above 1. Therefore, the consumer is

reluctant to substitute consumption today for consumption tomorrow but is more willing to substitute leisure for consumption in the present period. This parameter configuration causes families, in the face of the real wage drop, to slightly reduce their consumption and increase investment to an even lesser extent to form capital for the next period. In the current period, given the reduction in the real wage, the consumer must justify not having reduced consumption enough by reducing leisure in a greater proportion, and consequently increasing labor.

Figure 1: *Posterior IRFs of real variables to an export productivity shock*



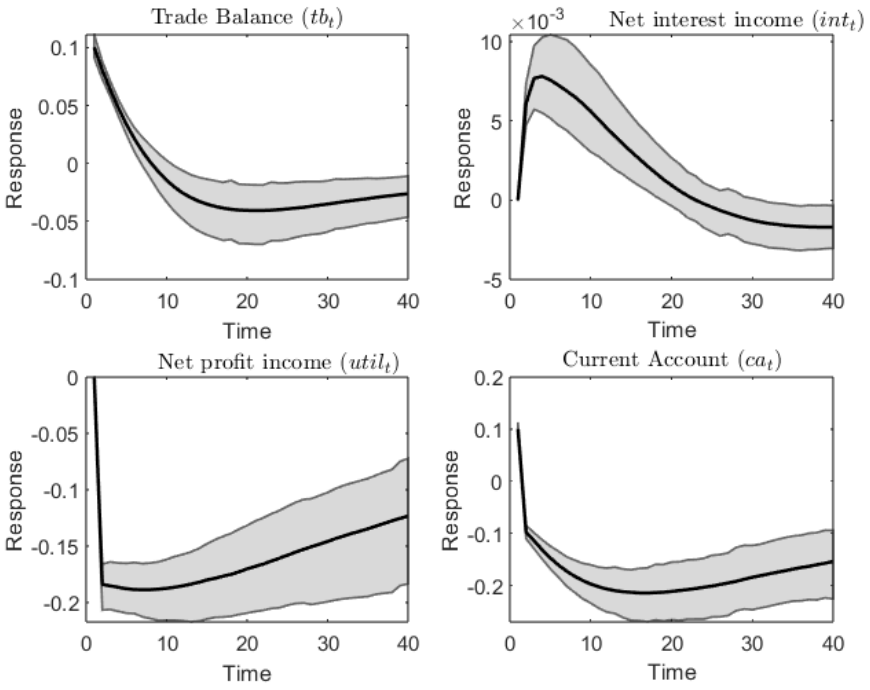
Within the consumption basket, given that the 5th and 95th percentiles of the elasticity of substitution distribution between importables and non-tradables are 0.44 and 0.46, respectively, the negative income effect of a higher CPI prevails, generating a drop in both goods. However, given the increase in p^n, the drop in non-tradable consumption is greater than that of importable consumption. On the production side, the larger amount of importable capital, inputs, and labor described in previous paragraphs increases the output of the two sectors whose production is destined for local consumption. The combination of both effects generates a reduction in consumption imports, which, added to the evident drop in capital imports, results in a reduction of total imports despite higher input imports. In summary, the export productivity shock generates an increase in exports along with a drop in imports, which improves the trade balance, exerting surplus pressure on the current account balance.

The increase in the availability of tradable resources generated by lower domestic absorption exceeds the drop in external financing received as FDI, initially reducing

the country's debt, risk premium, and bond interest rate. The positive impact on these variables reaches its peak a few periods after the shock; from that point, it begins to return to its long-term level. This evolution is in line with the rapid reversal of export production and the moderate recovery of FDI, which together determine the point at which net foreign assets begin to decrease. These dynamics lead to lower interest payments and an increase in net interest income in the early periods. Thus, net interest income behaves similarly to net foreign assets during the study period.

Despite the large initial drop and slow recovery of foreign capital in the export sector, the expansion in the early periods of capital used in the non-tradable sector and its moderate reversal to the steady state cause total foreign capital to also decrease, but to recover sooner. These deviations of foreign capital from the equilibrium level activate the endogenous interest rate determination component, causing it to follow an opposite but larger magnitude evolution than the capital balance. This responds to the Bayesian estimation results for the posterior distribution of the parameter regulating said mechanism (χ_k), whose 5th and 95th percentiles are 1.92 and 2.02, respectively. Thus, in the initial periods, the increase in the rental rate paid for capital use increases profit outflows; then, these outflows decrease again following the evolution of the foreign capital interest rate.

Figure 2: *Posterior IRFs of external variables to an export productivity shock*



Beyond the impact on domestic absorption, the export productivity shock initially expands profit outflows and net interest income. However, as these trends reverse, the decline in net profit income outweighs interest gains, leading to a drop in primary income which pressures the current account toward a deficit. While the current account's

immediate response is driven entirely by the trade balance, the subsequent contractive effect of primary income eventually dominates, causing the current account to fall below its steady-state level. The return to equilibrium is primarily shaped by the evolution of primary income, where profit outflows carry more weight than interest.

These results emphasize the necessity of differentiating between the trade balance and the current account. While they may behave similarly in the short term, financial and factor flows become the primary determinants of the current account in the medium term. Consequently, these elements must be explicitly modeled to accurately understand external dynamics in an economy with high foreign-owned factor participation.

4.2.2 Import sector productivity shock

A positive shock to importable productivity increases sectoral output. This immediately raises the marginal productivity of factors, putting upward pressure on the demand for labor, imported inputs, and domestic capital. The equilibrium response depends on residency and supply characteristics: labor supply is inelastic, so demand pressures raise the equilibrium wage; imported input prices are determined internationally, allowing for increased quantity at a constant price (p^*); domestic capital supply, provided by households, is upward-sloping, leading to increases in both the interest rate and capital quantity.

Consequently, households increase current investment to form capital for subsequent periods, maximizing the impact of a shock expected to dissipate quickly. Notably, the investment response in this sector lacks the conversion lags and high adjustment costs seen in the export sector, allowing for a more immediate reaction. This dynamic causes positive effects on importable production to persist (until quarter 16) even after the shock itself reverses (quarter 9).

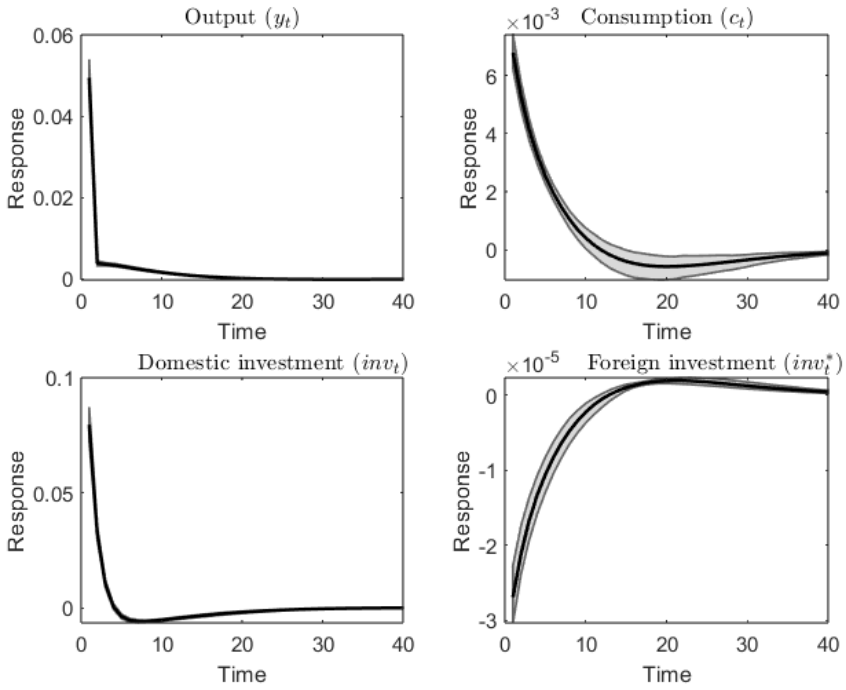
Efficiency gains in the importable sector lower relative costs, making these goods cheaper than non-tradables ($\uparrow p^n$). Higher p^n boosts factor demand in the non-tradable sector, increasing the price and quantity of labor, imported inputs, and capital. For domestic capital, the interest rate rises initially but drops sharply by period 2 before a slow recovery. Meanwhile, the consumer price index (p^c) increases until period 6, raising the contemporaneous real return on domestic capital.

The higher real return induces a positive income effect on consumption and capital, and a negative substitution effect on consumption favoring capital. Parameter γ (inverse of intertemporal elasticity) indicates that families avoid large consumption fluctuations, making the income effect dominant and resulting in a small consumption increase. Simultaneously, the higher real wage in the non-tradable sector triggers a positive income effect on leisure and consumption, and a negative substitution effect on consumption favoring leisure. Given the high intratemporal elasticity, leisure increases significantly,

causing a labor drop that postpones non-tradable production expansion.

Rising non-tradable demand increases the foreign capital interest rate, raising costs for the export sector. Since productivity and prices remain constant there, firms reduce capital demand, leading to a sharp contraction in export investment and capital (recovering only by quarter 10). This reallocation of resources away from the export sector reduces its production.

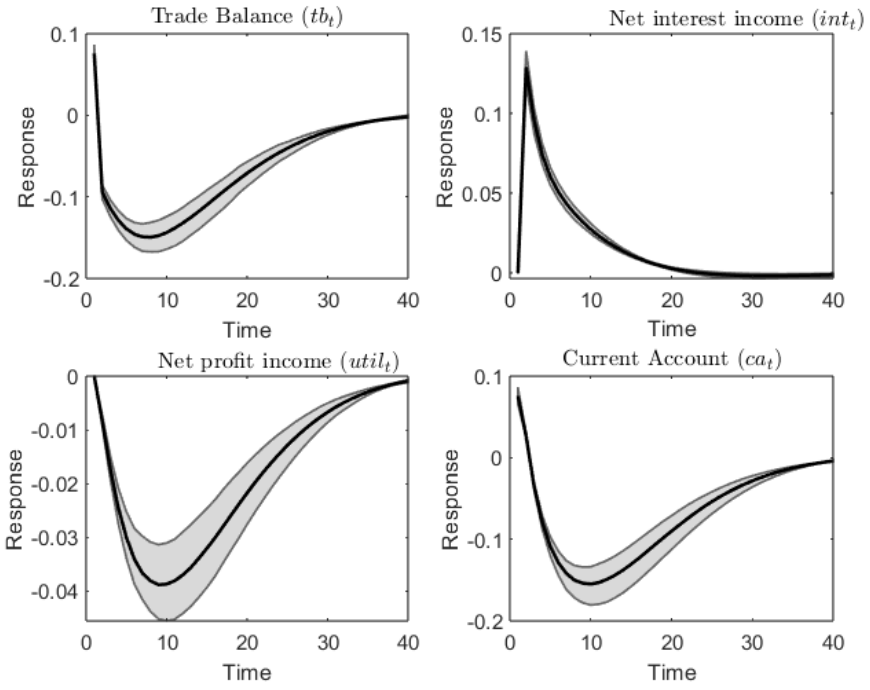
Figure 3: *Posterior IRFs of real variables to an import productivity shock*



Regarding external trade, importable production increases more than consumption due to the smoothing mechanism, reducing consumption imports. Lower export sector investment also reduces capital imports. These declines outweigh the rise in input imports, initially improving the trade balance. However, falling export production eventually pressures exports downward, reversing the trade balance surplus and bringing it below steady-state levels as imports recover.

As in the export productivity shock, domestic absorption initially falls, favoring the trade balance, though the recovery is more accelerated here. Increased net foreign assets, lower risk premiums, and lower debt rates boost net interest income. Conversely, higher rents paid for foreign capital, reinforced by the stabilization mechanism, reduce net profit income. The faster recovery of interest income relative to profit income causes a slight primary income deterioration.

Figure 4: *Posterior IRFs of external variables to an import productivity shock*



The contemporaneous current account surplus is driven solely by lower domestic absorption. In subsequent periods, the higher net return paid on external liabilities amplifies the current account drop, making it slightly more pronounced than the trade balance decline. Eventually, the return to equilibrium is determined primarily by trade balance dynamics.

While the current account follows the trade balance trajectory in the short and long term, factor income acts as an amplifier in the medium term. In this shock, the lower weight of returns paid on liabilities —compared to the export sector shock— is explained by the importable sector's lack of direct links to external financing through FDI.

4.2.3 Non-tradable sector productivity shock

Following a positive non-tradable productivity shock, an immediate increase in the sector's production occurs; for the shock itself implies that, with the same quantity of factors, a greater quantity of goods is produced. The abundance of non-tradable products causes a reduction in their relative price (p^n) compared to importables. The price effect outweighs the productivity effect, causing a drop in the value of the marginal product; that is, in the demand for these inputs. As explained in previous sections, the particular characteristics of the markets in which they operate are what ultimately determine the equilibrium result of the initial periods, consisting of: (i) a smaller quantity of imported inputs; (ii) a drop in the non-tradable domestic capital rent; (iii) a reduction in foreign

capital and its interest rate; and finally, (iv) a drop in employment accompanied by an increase in the wage.

The two production factors that have fixed elements in their supply and/or demand, and therefore only generate responses in either price or quantity, are: the imported input and domestic capital destined for the tradable sector. In the first case, the international determination of the imported input price implies that it is possible to demand a smaller quantity at the same price. In the second case, the fact that the capital supply is completely inelastic causes downward pressure on the interest rate, while the domestic capital used in the sector remains fixed. The internal dynamics taking place in determining the new equilibrium of the remaining two factors (foreign capital and labor) are complex and involve interactions with other sectors and family intertemporal decisions; therefore, each component of such dynamics is explained in more detail in the following paragraphs.

First, we must consider that what happens to the foreign capital balance of the entire economy depends on how the drop in the value of its marginal product in the non-tradable sector affects the other sector receiving FDI: the export sector. In the initial periods, this drop puts downward pressure on both quantities (k^{n*}) and interest rates, diverting FDI from the non-tradable sector toward the export sector, which demands more capital to reduce the value of its marginal product and thus recover equivalence with the interest rate (optimality condition). To meet the higher capital requirements, investment spending increases in the current period and then gradually decreases as the shock's effects fade. It should be noted that while the initial expansion of effective investment is smaller in magnitude, it lasts one period longer before adopting the evolution of investment spending, in line with high adjustment costs and the presence of lags. These dynamics allow the capital stock to continue increasing for 10 more quarters before taking a downward trend toward its long-term value.

The initial expansion of capital used in the export sector is greater in magnitude than the drop in that demanded by the non-tradable sector, causing total foreign capital to increase and start returning toward equilibrium from period 3. These fluctuations activate the interest rate stabilization mechanism, making it follow an opposite dynamic —downward in the early periods— but of greater magnitude, in line with the high support of the posterior distribution of the elasticity χ_k.

Second, the drop in non-tradable prices causes a reduction in the CPI that intensifies over the following 5 quarters, then begins a slow recovery. The lower price of the consumer basket in the initial periods, compared to the recovery expected throughout the analysis horizon, causes 2 opposite effects: (i) a positive income effect on today's consumption and next periods' consumption (today's investment) and (ii) a positive substitution effect on consumption and a negative one on investment spending. The substitution effect outweighs the income effect, causing an initial drop in investment and domestic capital

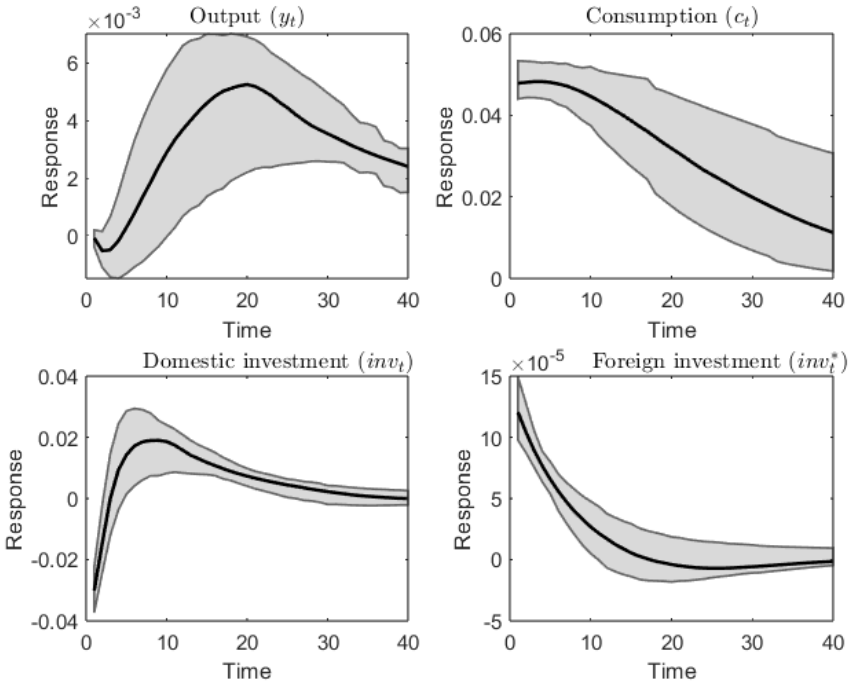
supply in the coming periods. The lower capital supply increases the rent paid for it and decreases the quantity used by firms in the importable sector, as their demand has not shifted. This dynamic causes a drop in the importable product, followed by lower demands for labor and imported inputs, resulting in a lower equilibrium wage and a smaller quantity of input used.

Third, we must consider that the drop in the CPI also generates intratemporal effects; specifically, we have a positive income effect on leisure and consumption, and a positive substitution effect on consumption against leisure. As seen in the previous paragraph, in intertemporal terms, it is optimal to increase consumption, but in a moderate proportion as the intertemporal elasticity of substitution is low. This minimizes the impact of the substitution effect, giving greater weight to the income effect, so the result is an increase in leisure and a reduction in labor supply. The drop in labor supply is greater than the increase in demand in response to the positive productivity shock, causing the wage to be higher in equilibrium but the quantity of labor used by the non-tradable sector to be lower.

On the other hand, the previous analysis makes it clear that a positive non-tradable productivity shock causes a generalized increase in consumption, with the elasticity of substitution between importables and non-tradables determining the distribution of that increase. While the income effect of higher consumption spending increases both types of goods, the substitution effect of the drop in p^n favors spending on non-tradable goods, making their consumption increase more than that of importables. This increase in importable consumption, added to the slight drop in the importable product, causes a notable increase in consumption imports.

Lower purchases of imported inputs by the non-tradable and importable sectors outweigh the higher demand from the export sector, resulting in a drop in input imports. For its part, capital imports increase driven by the export sector. However, in aggregate terms, the effect of higher consumption and capital imports prevails, ultimately generating an increase in total imports. This dynamic exerts initial deficit pressure on the trade balance that is quickly reversed. In the coming periods, exports continue to increase, while the positive effects of the shock on consumption decrease; this combination causes a rapid recovery of the trade balance, which after reaching its peak returns to the steady state.

Figure 5: *Posterior IRFs of real variables to a non-tradable productivity shock*

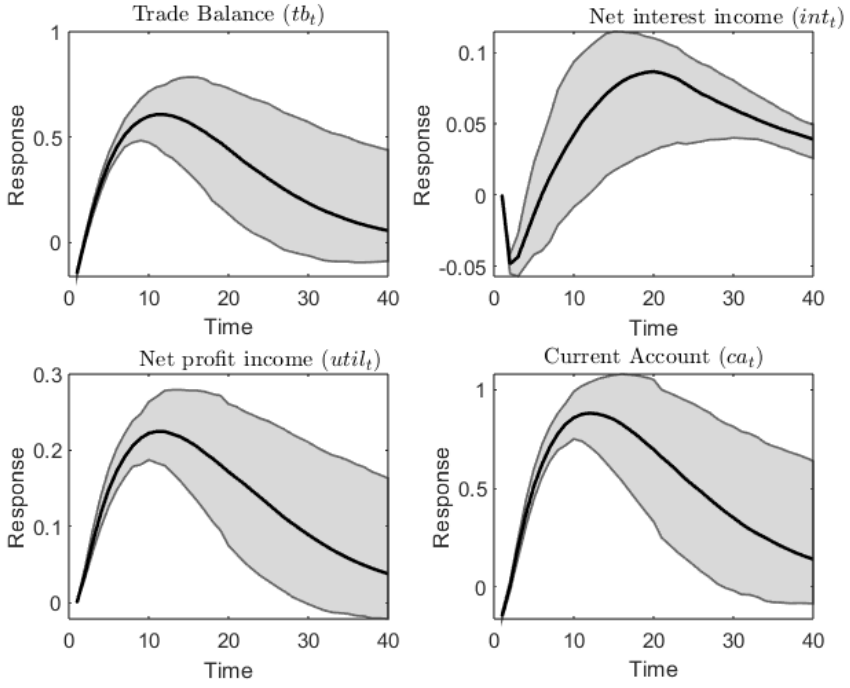


Thus, we find that a positive non-tradable productivity shock generates an initial increase in domestic absorption, which is reflected in a trade deficit and negatively impacts the current account. However, this effect is quickly reversed as export production benefits from greater financing through FDI.

In terms of available tradable resources, the expansion of domestic absorption outweighs the higher external financing of the export sector, tightening the constraint. As a result, there is an initial drop in net foreign assets (increase in debt), which then reverses and follows a path similar to that of domestic absorption. This drop increases the risk premium and the bond interest rate, but in a smaller proportion than the balance, as the debt adjustment mechanism is smaller than that occurring with foreign capital fluctuations. Consequently, net interest income decreases in the initial periods, recovering from period 6 due to the mentioned dynamics.

For its part, the increase in the foreign capital stock produces a larger magnitude drop in the rental rate paid for it, due to the large smoothing adjustment in the interest rate. This effect generates an improvement in net profit income, which outweighs the drop in net interest income in magnitude, thus reducing the return paid on external liabilities. Although these effects do not operate contemporaneously, from period 2 they amplify the positive effects of the trade balance recovery, making the peak reached by the current account higher.

Figure 6: *Posterior IRFs of external variables to a non-tradable productivity shock*



4.2.4 Export price shock

Following a positive export price shock, an initial increase in the value of the marginal product of factors used by the export sector is recorded, implying a higher demand for them. In the imported input market, the perfectly inelastic supply faced by firms means the increase in demand results in an increase in the equilibrium quantity of the imported input, while the price remains fixed at p^*. Similarly, the perfectly inelastic supply of labor determines that higher demand generates upward pressure on the equilibrium wage paid to workers. Estimates for ψ_x and α_x suggest that the importance of the imported input in export production is quite small; specifically, the weight of this input in the production function ($\psi_x(1-\alpha_x)$) is between 0.02 and 0.05. Therefore, the increase in the imported input translates into a slight contemporaneous increase in export production and exports.

On the other hand, higher demand for foreign capital puts upward pressure on the interest rate, a dynamic that international agents interpret as a favorable productivity shock in the export sector. However, investment spending shows an initial negative response; as explained previously, the presence of lags and high adjustment costs causes international investors to postpone investment decisions until evaluating the effective net return. In subsequent periods, investment spending begins to recover, moving above equilibrium from quarter 7; meanwhile, effective investment takes one more quarter to exceed its steady-state value.

These dynamics generate a drop in capital supply, causing it to show a downward trend until period 6, then recover at an accelerated pace and enter positive territory by quarter 26. The drop in export capital in the initial periods (after quarter 1) causes a downward trend in export production, which is reinforced by the return of the imported input to its steady-state level as the shock dissipates. The evolution of export production and exports in the rest of the horizon is in line with the evolution of foreign capital. The drop in supply, combined with the increase in demand, causes a notable increase in the foreign capital interest rate, which ends up affecting the other sector dependent on external financing, non-tradables.

What occurred in the export sector implies that non-tradable sector firms pay a higher rent to use the same amount of capital as before the shock; these higher input costs put upward pressure on the price of non-tradables. The increase in p^n boosts the value of the marginal product of production factors used by the sector and, consequently, the demand for them by firms in the sector, resulting in a contemporaneous increase in the imported input and the domestic capital interest rate in the non-tradable sector. Additionally, note that although export sector dynamics determine a drop in the total foreign capital balance, this drop is smaller than that faced by the export sector due to a reallocation of external resources toward non-tradables. From the above, it is inferred that we have a higher level of foreign capital used by firms in this sector remunerated at a higher interest rate.

Since non-tradable goods are part of the consumption basket, the increase in p^n causes a CPI increase. The increase in p^c and its projected path by agents —given the expected evolution of foreign investment and capital— cause two effects: (i) a negative income effect on consumption and investment, and (ii) a negative substitution effect on consumption and a positive one on investment. On the other hand, given the smaller increase in w^n compared to p^c, the real wage in the non-tradable sector is slightly reduced, generating two other effects: (i) a negative income effect on consumption and leisure and (ii) a negative substitution effect on consumption and a positive one on leisure.

The combination of inter- and intratemporal effects results in a drop in current consumption and an increase in investment, which increases the capital supply for subsequent periods. The current configuration of parameters related to elasticities of substitution causes families, in the face of the p^c increase, to slightly reduce consumption and increase investment to form capital for the next period even less (slight increase in capital supply). In the current period, the consumer must justify not having reduced consumption enough by reducing leisure in a greater proportion, and consequently expanding labor supply. In the labor market, the result is a higher level of employment and a slightly higher wage, while the capital market result consists of a higher level of domestic capital putting downward pressure on the interest rate.

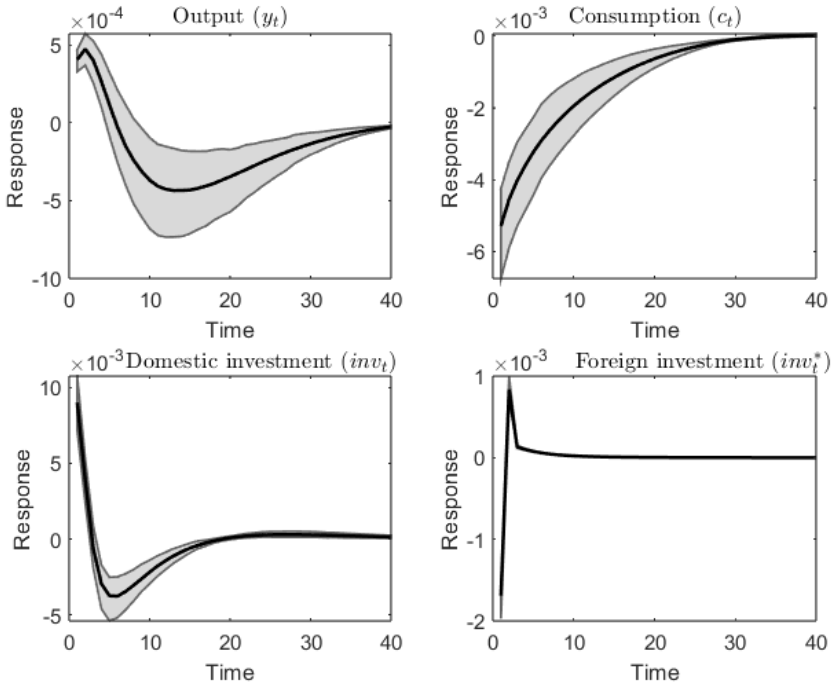
In the importable sector, the higher equilibrium capital quantity generates an increase in production, which in turn motivates higher input demand. The labor demand shift translates into a higher wage, the imported input demand into a larger quantity, and finally, the capital demand cushions the supply increase, generating a small drop in the interest rate. The described effects on investment and capital in the importable sector begin to reverse in the second and third quarters, respectively. Like importable investment, consumption, its components, leisure, and employment show a downward trend in the projection horizon after the initial jump. For its part, importable production closely follows the evolution of domestic capital.

Regarding consumption, it is necessary to analyze how the shock affects the basket's composition. Thus, the low elasticity of substitution between importables and non-tradables allows the negative income effect of lower consumption spending to prevail over the substitution effect of the p^n increase. Nevertheless, given the cheapening of importable goods, the drop in non-tradable consumption is greater than that of importable consumption. This lower absorption, combined with the increase in importable production, generates a reduction in consumption imports, which, added to the significant drop in capital imports, puts downward pressure on total imports.

However, unlike the export productivity shock, the initial increase in input imports is larger, reaching and even exceeding the negative effect of the other two components. The structure of Peruvian imports allowed for posterior distributions of γ_i that favor input purchases. Therefore, the final result is an increase in total imports in the current quarter and a reversal toward their equilibrium level from quarter 2. For its part, the exported value also increases in response to the export price shock and, to a lesser extent, the slight initial increase in export production, exceeding the import increase.

In summary, the export productivity shock generates a drop in domestic absorption that improves the trade balance result in the current period, exerting surplus pressure on the current account balance. Subsequently, the recovery of consumption and investment in the export sector, along with the drop in export production, determine a rapid drop in the trade balance, which later recovers when the investment made becomes operational capital.

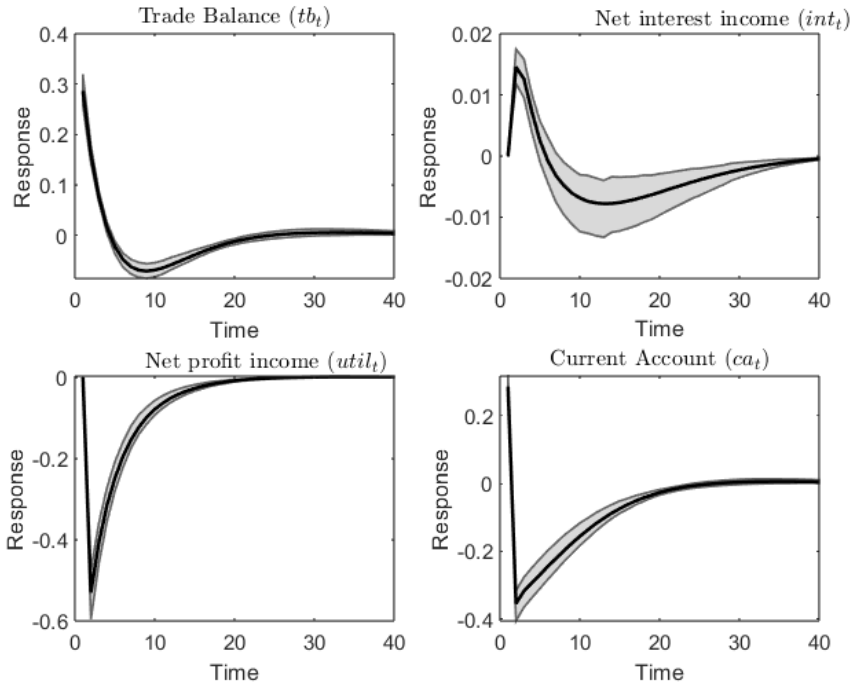
Figure 7: *Posterior IRFs of real variables to an export price shock*



The increase in tradable resource availability generated by lower domestic absorption exceeds the drop in external financing received as FDI, initially reducing country debt, risk premium, and bond interest rate. The positive impact on debt reverses quickly, while that on the interest rate is somewhat more long-lasting. These dynamics generate lower interest payments and an increase in net interest income in early periods, benefits that then start reducing until disappearing. Thus, net interest income behaves similarly to the interest rate and risk premium during the study period.

On the other hand, the initial drop in foreign capital in the export sector exceeds the early-period expansion of capital used in the non-tradable sector, resulting in a lower initial foreign capital stock. The rapid recovery in the export sector and slow reversal to equilibrium in the non-tradable sector trace an upward trend for total capital. As explained, this generates an opposite evolution in the foreign rental rate. Thus, in quarter 2, the higher interest rate increases profit outflows, which start reducing rapidly in line with the evolution of the rate paid for foreign capital.

Figure 8: *Posterior IRFs of external variables to an export price shock*



In addition to the impact on domestic absorption, the export price shock initially generates an increase in profit outflows and an increase in net interest income, which then reverse. The drop in net profit income outweighs the improvement in net interest income, resulting in a drop in primary income. The higher return paid on external liabilities amplifies the negative impact of the trade balance drop on the current account.

Finally, just as in the export productivity shock, the immediate current account response is explained solely by the trade balance. The difference between the two becomes noticeable starting the following quarter, a period in which the contractive effect on primary income has greater weight than the trade balance, making the current account decrease more than the trade balance. The return to equilibrium is marked by the evolution of the rent paid for foreign capital use in the real sector.

4.2.5 Import price shocks

A positive shock to the price of imported inputs can be interpreted as a negative supply shock; since all sectors depend on this factor, the shock raises production costs throughout the economy, reducing firm profitability. Specifically, given the lower supply of the imported input, immediate decreases are observed in the equilibrium quantity of inputs used by each sector, as well as in their production, and consequently, in total production. Despite the general downward trend, contraction magnitudes differ across sectors, with the importable sector being the most affected given the greater importance

of imported inputs in its production function. After the shock occurs, the quantity of inputs demanded returns to its equilibrium level quickly, while output has a different steady-state reversal dynamic.

The output drop in turn reduces demand (value of the marginal product) for other factors, causing downward pressure on capital and labor prices and quantities. Given labor supply inelasticity in the tradable sector, equilibrium results in decreased wages in the export and importable sectors. Similarly, capital inelasticity in the non-tradable sector produces a drop in the interest rate paid for it. For its part, since foreign capital supply is fixed for the initial period, a demand drop from export sector firms reduces the quantity used and the rent paid for its use. One exception to this generalized contraction in factor quantities used in equilibrium is non-tradable sector capital. The reason for the difference lies in the fact that the elasticity of labor supply to the sector allows demand changes from firm optimization decisions to be met without abrupt wage movements. This makes it possible for the optimal factor ratio to adjust quickly to align with market prices and marginal productivity. Consequently, to correctly analyze what occurred with non-tradable firm demand, we must understand how domestic capital and employment supply move, as they ultimately establish equilibrium quantities.

The increase in the price of imported inputs not only affects production but also reduces real household income; they face higher relative prices for importable goods and a lower supply of non-tradable goods. Consequently, we have an increase in p^n and the CPI, generating a negative income effect on consumption, leisure, and investment. In addition to the negative income effect, the p^c increase represents a drop in the real wage and causes a negative intratemporal substitution effect on consumption and a positive one on leisure. Intertemporally, current higher prices and their expected decrease in following periods increase the expected real return on investment, generating a substitution effect against consumption and in favor of investment. The combination of these effects leaves a consumption drop as the only clear result.

The leisure and investment result depends on the magnitude of our model's substitution elasticities. As mentioned, the data used for parameter estimation revealed a consumption smoothing mechanism over time that will cause consumption to decrease moderately, making the income effect prevail over the substitution effect. Consequently, domestic investment will contract, reducing the next period's capital supply and putting upward pressure on interest rates in the following quarters. At the intratemporal level, the elasticity of substitution is larger, so the slight consumption drop —faced with the negative income effect— is offset by a drop in leisure that increases labor supply.

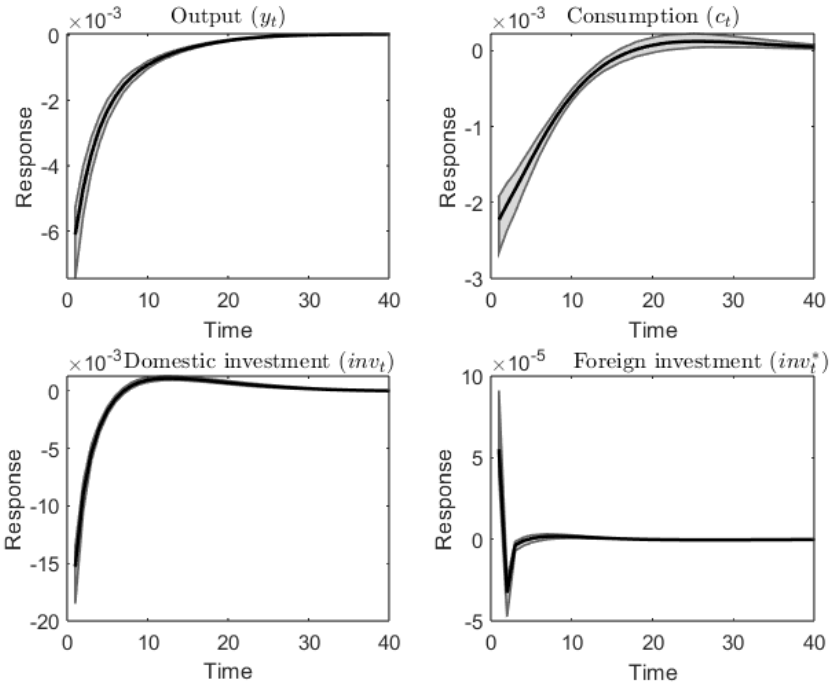
The labor supply increase is larger than the demand drop, thus determining a higher equilibrium employment, which is remunerated at a lower wage. The higher quantity of labor reduces its marginal productivity and, given firm optimality conditions, requires

demanding slightly more of the other factors. This explains why the drops in the non-tradable domestic capital interest rate and the imported input are smaller than those recorded in other sectors. Since foreign capital supply is the same, the slight demand increase causes a small increase in non-tradable sector capital, which then reverses as employment supply does when the shock dissipates. Consequently, total FDI increases slightly and the foreign capital interest rate decreases by a similar magnitude due to greater resource availability.

The effective income reduction causes consumers to decrease consumption of both importable and non-tradable goods, reflecting the agents' loss of purchasing power. Although consumers adjust their importable goods demand downward due to lower real income, this reduction is less than the drop observed in the production of such goods. Local supply constraints on importable goods push agents to increase consumption imports. After the initial drop, consumption shows a recovery dynamic toward its equilibrium level that is less accelerated than importable production due to the smoothing mechanism. For this reason, consumption imports fall rapidly and after 5 quarters are below their long-term level, starting to recover from period 9, in line with importable consumption evolution.

On the other hand, the impact this shock exerts on each sector's capital equilibrium return dynamic is differentiated and opposite to the initial impact, which responds only to small demand changes. Of the two sectors competing for foreign capital, non-tradables record a higher share of imported inputs. In that sector, the shock significantly increases marginal costs, reduces expected profitability, and discourages foreign investment. Conversely, the export sector, being less exposed to the shock, maintains its expected profitability and becomes a more attractive destination for foreign capital flows. Even if the foreign investment increase is gradual due to lags, the shift of capital from the non-tradable sector ensures a recovery in the quantity of capital used in the export sector. The result of this resource reallocation is a small initial increase in foreign investment, causing a total capital supply increase in quarter 2, followed by a drastic drop due to the greater negative impact in the non-tradable sector and a rapid recovery as export sector net returns start to show. This determines that capital imports follow a similar evolution.

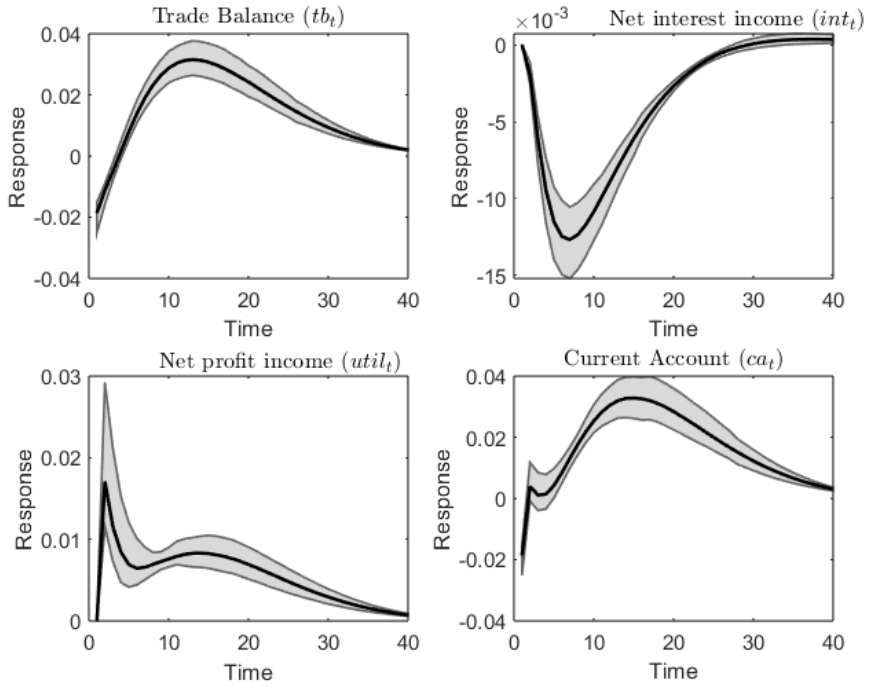
Figure 9: *Posterior IRFs of real variables to an import price shock*



The expansion of consumption and capital imports, combined with reduced exports, implies an increase in domestic absorption, exerting an initial negative impact on the trade balance and current account. Trade balance recovery is driven by the rapid drop in consumption and capital imports, slow recovery of input imports, and greater dynamism in the export sector.

Regarding the financial channel, lower tradable resource availability from the negative supply shock generates a reduction in net foreign assets that lasts until export production recovery —due to higher sector foreign investment— consolidates. This higher net debt level increases the risk premium and interest rate, causing net interest income to decrease. For its part, total economy foreign investment is the product of opposing dynamics in the two sectors using it, with initial negative impacts and subsequent recovery in the non-tradable sector prevailing. This evolution generates an initial reduction in the interest rate paid for capital, of greater magnitude than its balance increase. Consequently, net profit income closely follows the interest rate evolution; i.e., it shows a rapid increase that reverses slowly.

Figure 10: *Posterior IRFs of external variables to an import price shock*



The combination of all these factors determines a negative impact of the return paid on net external liabilities on the current account. Unlike the trade balance, current account recovery is halted in period 3, delaying consolidation until quarter 15. In the final quarters, primary income evolution supports trade balance dynamics, facilitating the current account's return to its long-term equilibrium.

4.2.6 International interest rate shocks

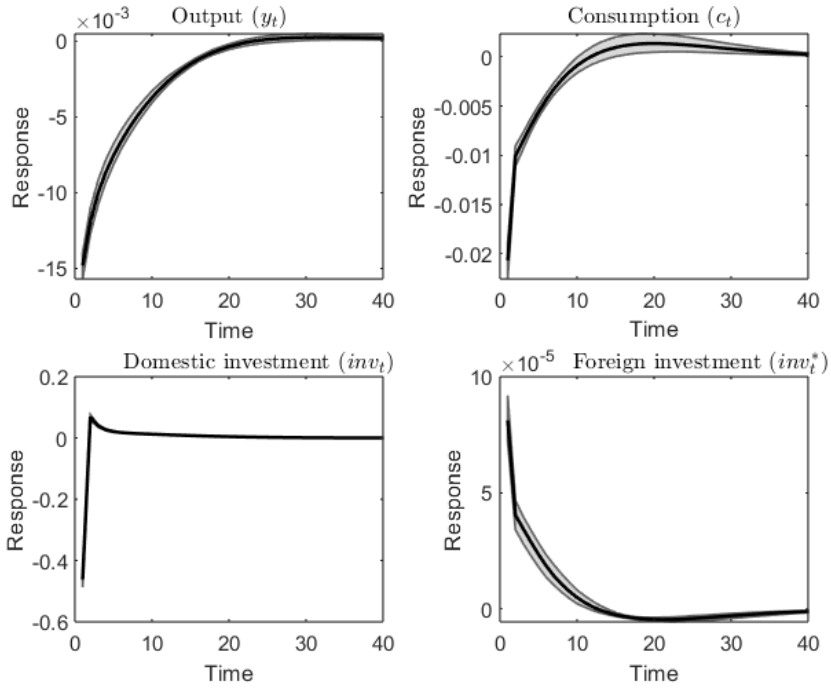
A positive shock to a country's risk premium causes an increase in the interest rate paid on external debt by the same magnitude as the shock. Since this economy is a net debtor, the risk premium increase causes an intratemporal negative income effect reducing leisure and consumption, and an intertemporal one reducing current consumption and investment, both physical (domestic capital formation) and financial (bond purchase). The interest rate increase also implies a change in the relative price of today's consumption versus tomorrow's; the ratio $\frac{(1+r_t^f)}{p_{t+1}^c}$ increases, making consumption more expensive. Consequently, a negative substitution effect occurs in favor of bond investment and against consumption. Additionally, financial assets become more attractive than real assets because the payment generated per unit invested in them is higher following the shock.

Given the parameter configuration determined by estimation with Peruvian data, the income effect outweighs the substitution effect, causing investment and consumption to

decrease, the latter by a moderate magnitude due to low intertemporal elasticity of substitution. For its part, the investment drop is differentiated and responds to higher bond yields; thus, domestic investment mainly destined for the importable sector decreases, but net foreign assets increase. In intratemporal terms, leisure decreases more than consumption to compensate for consumption falling less than it should, and also due to high substitution elasticity between them. Leisure reduction implies an increase in labor supply in the non-tradable sector which, in the absence of demand changes, generates a new sectoral equilibrium with higher employment and a lower wage.

While employment increase causes a slight contemporaneous increase in non-tradable production, in following quarters the sector is affected by lower domestic capital supply putting upward pressure on the interest rate firms pay families. Supply inelasticity in the non-tradable sector translates lower domestic investment into higher rents, meaning higher costs for sector firms. Consequently, they are forced to reduce demand for other factors (foreign capital and imported inputs) to compensate for lower profitability. This lower non-tradable profitability causes a resource allocation favoring the export sector, thus increasing foreign investment and capital in that sector, which in turn favors export production. Higher production increases labor and imported input demands, resulting in a higher export wage and larger input quantity in the sector. This productivity boom in the export sector translates into an export expansion.

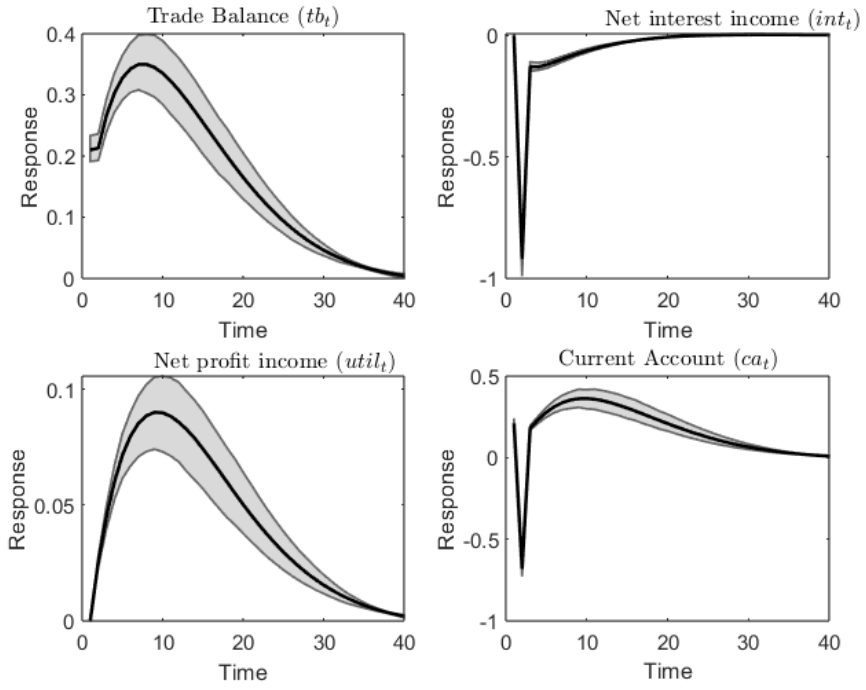
Figure 11: *Posterior IRFs of real variables to a risk premium shock*



Despite the positive impact on the export sector, lower capital supply negatively affects the importable sector, increasing costs and quantities demanded of that production

factor. Importable production contraction reduces demands for other factors, putting downward pressure on the importable wage and decreasing the imported input quantity. Given the importable sector's greater importance in tradable production, total economy output decreases, enhancing the negative income effect of the higher risk premium, reinforcing the consumption drop. Price drops from lower demand, added to the gradual risk premium reduction, allow domestic investment to recover, reversing negative impacts in the importable sector. In the study horizon, we have a gradual recovery of total production and consumption, though the latter has other nuances in its evolution.

Figure 12: *Posterior IRFs of real variables to a risk premium shock*



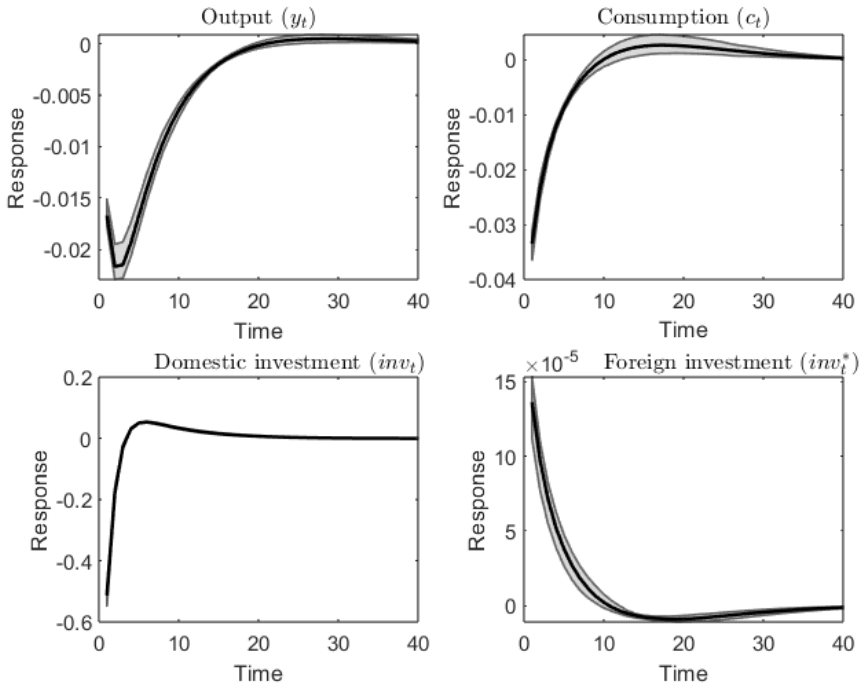
The strong reduction in importable consumption outweighs the production drop, putting downward pressure on consumption imports. Meanwhile, imported input decreases in the importable and non-tradable sectors are more important than the larger input quantity in the export sector, causing an input import reduction. These factors cannot be offset by the slight capital import increase, causing a total import contraction. This import drop, added to export growth, causes a domestic absorption drop that initially improves the trade balance. Quarter 1 trade balance behavior explains the positive jump the current account exhibits immediately after the shock. However, in following periods, their dynamics start separating notably due to the negative impact from higher return paid on net external liabilities.

Return paid on external liabilities increases as a direct consequence of the interest rate spread shock; the debt balance actually reduces due to the substitution effect favoring financial over real investment. For its part, foreign capital stock in the economy increases

due to export sector expansion. As an adjustment mechanism to maintain long-term equilibrium, the rent paid for that type of capital reduces by a magnitude greater than said stock increase, causing an improvement in net profit income which, together with trade balance dynamism, slightly cushions the negative interest impact. However, in this specific shock, net interest income determines current account evolution and its return to the steady state.

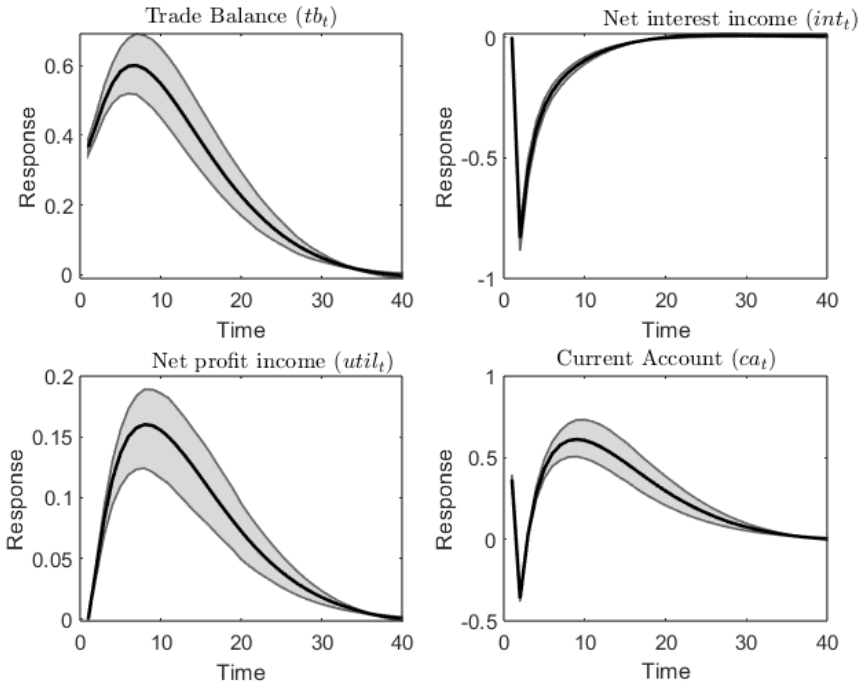
A positive shock to **foreign investor risk aversion** operates through similar channels but differs in persistence and origin. Unlike the transitory risk premium spread, this shock is persistent and stems from global uncertainty.

Figure 13: *Posterior IRFs of real variables to a foreign investor preference shock*



Key differences include: (i) a more durable drop in importable sector investment; (ii) a larger trade surplus, as importable production falls less than consumption; and (iii) a smaller net interest income deficit, as the risk aversion shock is partially offset by a falling risk premium due to rapid net foreign asset accumulation. The shock's durability enhances the investment boom in the export sector, leading to a larger non-resident capital stock and more expansionary net profit income, which facilitates a gradual current account recovery.

Figure 14: *Posterior IRFs of external variables to a foreign investor preference shock*



4.2.7 Foreign investment shock

A positive foreign investment shock increases capital goods production efficiency, implying a larger capital stock for the same investment flow. Under standard conditions, this would directly boost future foreign capital supply and motivate current investment. However, as noted in previous subsections, the presence of investment lags and high adjustment costs in this research causes an optimal capital response that differs from Raffo (2010).

In this model, reduced net investment profitability makes it optimal for the external sector to reduce investment spending. This occurs without affecting long-term stability because the efficiency gain allows capital formation at an accelerated rate with smaller supply changes. While foreign investment and effective investment show an initial generalized drop, recovery is faster in the export sector, reaching levels above equilibrium after several quarters. Conversely, recovery in the non-tradable sector is slow and incomplete until period 40, as it also relies on domestic capital supply.

Given the projected investment path, capital is expected to decrease slightly before recovering quickly, causing initial scarcity. Consequently, firms —primarily in the export sector— reduce contemporaneous demand to avoid pressure on the foreign rental rate. Non-tradable firms leverage this adjustment to increase their demand, causing a small increase in foreign capital used by the sector and slightly pushing up the foreign interest rate. Analysis hereafter focuses on recovery trends starting from period 2.

As effective investment recovers, capital supply increases, consistent with the downward trend in the foreign interest rate during early periods. At the sector level, the initial response reverses: capital demand recovers in the export sector and drops in the non-tradable sector. This reallocation toward the export sector boosts its production, increasing marginal productivity and demand for imported inputs and labor. Between periods 2 and 12, the shock mimics a positive productivity shock in traditional models before effects dissipate toward the steady state.

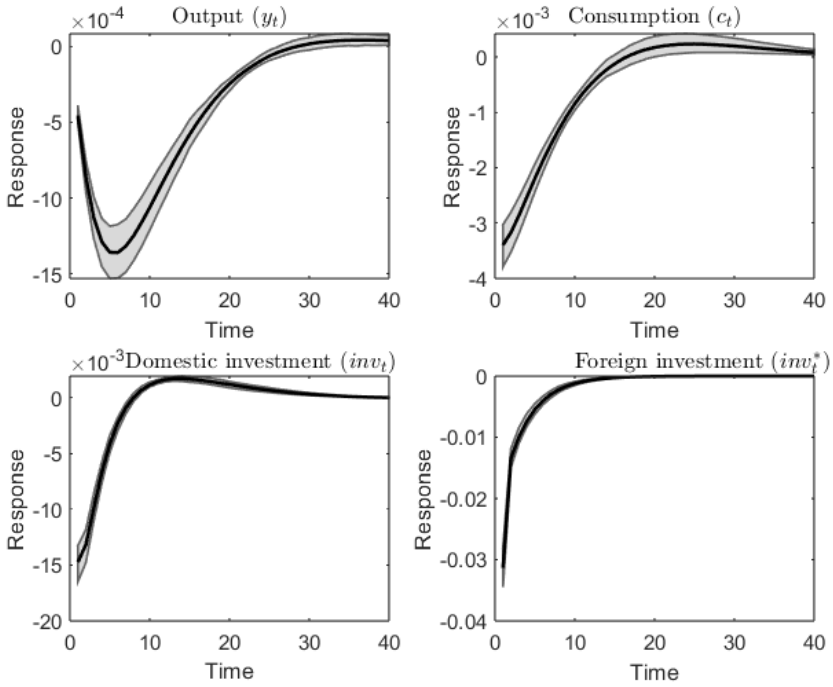
In the non-tradable sector, declining foreign capital increases domestic capital demand, raising its interest rate. This negatively affects capital demand in the importable sector, leading to a lower equilibrium quantity and reduced production. Lower output subsequently reduces demand for imported inputs and labor, simulating a negative productivity shock that reduces total tradable production.

Falling total production exerts a negative income effect on households. In the present period, agents reduce consumption and leisure, increasing labor supply. Intertemporally, they reduce current and future consumption, investing less in capital formation. This reinforces the decline in importable production. The increased labor supply is absorbed by the non-tradable sector at a lower wage, which, combined with the initial capital increase, raises non-tradable production and reduces the CPI.

The CPI drop is more pronounced than the wage decline, increasing the real wage. This generates a positive income effect on consumption and leisure, and a substitution effect from leisure toward consumption. Meanwhile, lower domestic prices induce a substitution effect favoring consumption over investment. Given the existing negative income effect, the intratemporal substitution effect dominates, reducing consumption and further increasing labor supply.

Consumption drop is generalized for both importable and non-tradable goods. This decline is more marked than the importable production drop, reducing consumption imports. Foreign investment evolution causes capital goods imports to fall initially before recovering in line with export sector demand. Finally, lower input use in the importable and non-tradable sectors reinforces these effects. The trade balance improves, returning quickly before increasing again due to lagged positive impacts on export production.

Figure 15: *Posterior IRFs of real variables to a foreign investment shock*

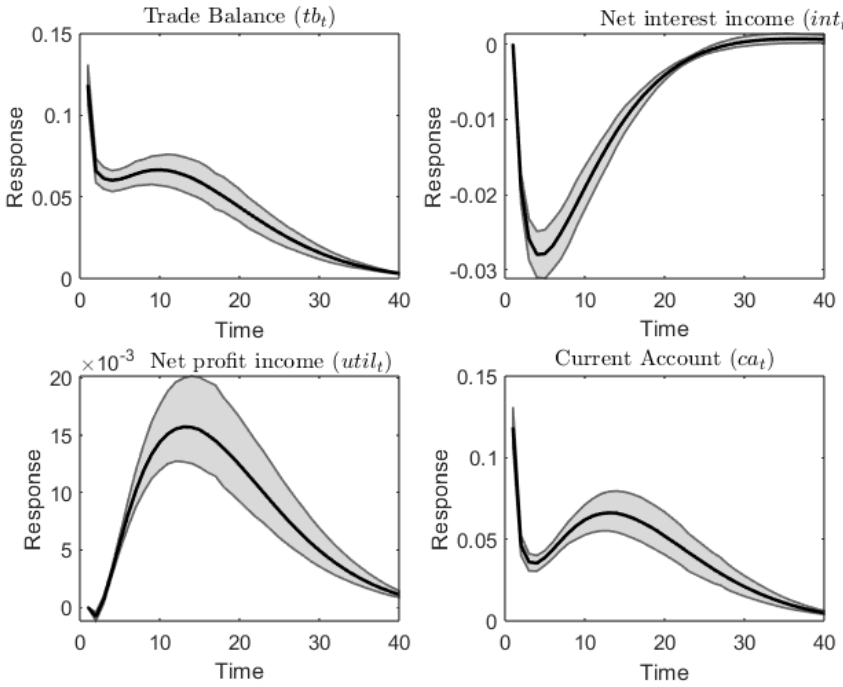


In summary, a positive foreign investment shock generates an initial drop in domestic absorption, causing a trade surplus and positively impacting the current account. This result differs from Raffo (2010) for three reasons: (i) only sectors linked abroad receive the shock, yielding differentiated responses; (ii) investment lags and high adjustment costs reduce net profitability, delaying positive impacts; and (iii) the trade balance structure incorporates three types of imported goods, including capital goods that evolve with investment.

Regarding the financial channel, lower tradable product availability and the initial FDI drop reduce net foreign assets. This increases the risk premium and debt interest rates, reducing net interest income in early quarters. As shown in Figure 16, this amplifies the negative trade balance impact on the current account.

Conversely, higher foreign capital from recovering investment reduces the rental rate. Consequently, net profit income shows a positive evolution that reinforces the trade balance expansion, making current account recovery more noticeable. This confirms that the return paid on net external liabilities can exert effects opposite to the trade balance, leading to distinct dynamics between the two.

Figure 16: *Posterior IRFs of external variables to a foreign investment shock*



4.3 Variance Decomposition

This subsection analyzes the contribution of structural shocks to the variance of key endogenous variables, comparing the base specification against the full model to evaluate the impact of the additional proposed transmission mechanisms.

4.3.1 Base specification and traditional shocks

In the base specification, export price shocks are the primary driver of external volatility, explaining 69.28% of the current account variance. Notably, this shock accounts for 76.46% of the variance in net profit income, providing evidence that terms-of-trade fluctuations affect the current account predominantly through the factor income channel rather than just the trade balance (36.42%). Regarding supply shocks, exportable productivity is the most significant internal factor (20.56%) due to its direct impact on exports, FDI flows, and foreign capital payments. In the real sector, output and investment are almost entirely driven by importable productivity shocks (over 96%), while consumption variability is shared between non-tradable productivity (37.92%) and export prices (32.81%).

Table 11: *Variance decomposition with the base specification*

Shocks	Output	Consumption	Investment	Terms of trade	Trade balance	Net interest income	Net profit income	Current account
Supply shocks								
Exportable sector productivity	1.19	9.27	0.12	0.00	8.22	1.61	22.79	20.56
Importable sector productivity	98.14	20.00	96.83	0.00	53.79	63.60	0.65	8.68
Non-tradable sector productivity	0.16	37.92	2.24	0.00	1.58	19.06	0.10	1.48
External shocks								
Export prices	0.50	32.81	0.81	100.00	36.42	15.73	76.46	69.28

4.3.2 Full Specification: persistence substitution and financial shocks

Under the full model, the explanatory power of export prices over the current account drops drastically to 2.82%. This shift is explained by two fundamental reasons:

- Persistence Substitution: The introduction of external financial shocks absorbs the long-run persistence of external variables. This reduces the estimated persistence of export prices (ρ^x falls from 0.980 to 0.721), allowing non-tradable productivity (ρ^n rises to 0.965) to become the dominant driver of domestic absorption and the trade balance (49.67%).
- Financial Constraints: Combined interest rate shocks become the main determinants of external accounts (excluding profits). This is due to their high volatility (0.47) and the negative income effect they impose on a net-debtor economy.

Table 12: *Variance decomposition with the full model*

Shocks	Output	Consumption	Investment	Terms of trade	Trade balance	Net interest income	Net profit income	Current account
Supply shocks								
Exportable sector productivity	0.09	1.43	0.01	0.00	0.91	0.03	43.43	10.46
Importable sector productivity	39.83	0.23	1.41	0.00	2.25	1.80	0.52	1.29
Non-tradable sector productivity	9.07	91.82	0.92	0.00	49.67	6.21	27.78	57.68
External shocks								
Export prices	0.06	0.29	0.02	83.28	1.10	0.05	17.61	2.82
Import prices	1.59	0.04	0.07	16.72	0.11	0.06	0.05	0.06
Risk premium	11.82	1.45	39.73	0.00	12.16	37.58	2.80	8.94
International investors' preferences	37.27	4.63	55.69	0.00	33.12	54.01	7.72	18.40
Foreign investment	0.27	0.10	2.15	0.00	0.60	0.26	0.10	0.34

In the real sector, the inclusion of external shocks significantly diminishes the role of the import-substituting sector. External shocks now explain over half of output volatility and 95% of investment variance. Consumption remains dependent on domestic productivity (91.82% from non-tradables) due to a strong smoothing mechanism that is only disrupted by the high persistence of the non-tradable shock. Finally, in the full model, the terms of trade have two sources of variation: the additional source explains 16.72% of their variance. This fact means that the impact of shocks to these relative prices is no longer unique; rather, it depends on the origin of the shock, which reinforces the stylized

fact of a weakening in the expansionary effect traditionally associated with the terms of trade, which has been studied in external sector research.

In comparative terms between the simplest and the full specification, it can be concluded that while some of the additional mechanisms –such as the import price shock and the foreign investment shoc– do not explain a large proportion of the current account variance and other real sector variables, their inclusion allows for a consistent identification of the impact of domestic sectors less linked with international shocks, such as the non-tradable sector; such impact is underestimated in traditional models like Mendoza (1995). Thus, on average, the most important shock in the base specification was to importable sector productivity, and it became the non-tradable productivity shock in the full specification.

Crucially, these results contradict traditional literature by showing that a positive terms-of-trade shock does not automatically yield a current account surplus, as the negative impact on factor income can offset the trade surplus.

4.4 Simulation with Posterior Modes

In this subsection, the modes of the posterior distributions of the most relevant parameters resulting from the estimation of each model specification are used to calibrate and simulate artificial data. With the simulated data of the endogenous variables of interest, several statistics were calculated to validate the most significant stylized facts of the Peruvian economy. The emphasis of this validation lies in replicating various empirical regularities of the external sector that more traditional works fail to find, while also addressing those regularities related to the business cycle, which are well-documented in such research.

In this vein, persistences, volatilities, and correlations between variables were calculated to characterize the business cycle and the external dynamics generated by each model specification. The main results are shown in Table (13), which also summarizes the main statistics of the Peruvian data —previously presented in the introduction— to facilitate comparison and evaluation of the proposed model's performance. Although the descriptive statistics vary from one specification to another, in general, the main characteristics of the variables and the essence of the relationships between them are maintained.

Regarding the business cycle, we find that: (i) output exhibits moderate volatility, being much lower in the full specification; (ii) output shows an adequate degree of persistence, which is high only in the base model; (iii) consumption is less volatile than output and investment in all specifications, except for the base model; and (iv) private investment is more volatile than output in specification 3 and the full model, whereas in

the base model it proves to be less volatile, contradicting empirical observations.

Regarding external dynamics, we have that: (i) the trade balance and the current account are much more volatile than the national accounts; this volatility skyrockets in the base specification and is significantly reduced when only import price shocks are added; (ii) the trade balance is countercyclical across all models; (iii) the existence of a low HML effect is verified in specifications 1 and 4; and (iv) the countercyclicality of the current account is replicated, remaining robust to the inclusion of additional shocks and supported by the negative relationship between net profit income and the current account.

Table 13: *Statistics of the data simulated by the model*

Variable	Data	Base Spec.	Spec. 2	Spec. 3	Full Spec.
Business cycle characteristics					
σ_y	0,06	0,30	0,31	0,25	0,09
ρ_y	0,34	0,92	0,54	0,47	0,45
σ_c/σ_y	0,79	8,29	0,63	0,78	0,43
σ_{inv}/σ_y	1,89	0,27	0,48	1,56	2,55
External dynamics characteristics					
σ_{tb}/σ_y	1,59	142,47	3,12	4,11	9,70
σ_{ca}/σ_y	9,25	54,84	2,53	3,40	22,80
ρ_{tot}	0,83	0,96	0,88	0,80	0,73
$\rho_{tb,tot}$	0,47	0,12	-0,45	-0,14	0,06
$\rho_{tb,y}$	0,02	-0,88	-0,96	-0,97	-0,69
$\rho_{int,y}$	0,00	0,95	0,92	0,76	0,04
$\rho_{util,y}$	-0,49	-0,50	-0,97	-0,97	-0,93
$\rho_{ca,y}$	-0,48	-0,93	-0,98	-0,52	-0,61

Across the specifications, it is clear that the specification with all incorporated shocks is the one that most closely approximates the stylized facts of the Peruvian economy, as it replicates the following facts: the magnitude of current account countercyclicality, low volatility and moderate persistence of GDP, consumption smoothing, the magnitude of the higher volatility of investment relative to output, the fact that external accounts are more volatile than GDP, the persistence of terms of trade, and the correlations of both net interest income and net profit income with output. However, it overestimates the extent of the relative excess volatility of external accounts regarding GDP; it obtains a low HML effect compared to the data; and it allows for a countercyclicality of the trade balance, even though in the data this correlation is nearly null.

Although the full model has a clearly superior performance, all specifications represent improvements in replicating stylized facts compared to the traditional small and open economy model with export price shocks. In this sense, some aspects to highlight from the other specifications are that the relative volatilities of consumption, investment, and

current account relative to output are closer to the data when foreign investment shocks are not included; meanwhile, the relative volatility of the trade balance relative to GDP is closer to the data when import price shocks are also excluded. Additionally, the magnitude of terms of trade persistence and current account countercyclicality are closer to the data in specification 3. Finally, the HML effect and the correlation between net profit income and output have values more similar to the empirical evidence in the base specification. This latter fact is not surprising because that model, based on Mendoza (1995), has as its main strength the proper simulation of trade balance dynamics.

In summary, this exercise demonstrated that the dynamics of the trade balance and the current account in the data exhibit distinct characteristics that theoretical models must not overlook. A specification that allows for defining the trade balance in a different way than the current account, but contains only traditional shocks, fails to replicate the magnitude of volatilities and the sign of some correlations, exacerbating the volatility of consumption and external accounts. However, the inclusion of additional shocks modulates the initial results, and each one, in particular, allows for replicating an important aspect of external and internal dynamics, thus presenting evidence in favor of the work carried out in this research.

5 Conclusions

This study shows that the proposed model, together with the additional mechanisms incorporating shocks to import prices, international interest rates, and foreign investment, generates dynamics that are consistent with economic theory and performs satisfactorily in explaining the stylized facts of the Peruvian economy. The sequential extension of the baseline specification allows for a richer representation of the transmission channels through which external shocks affect the current account and its components.

The estimation results across different model specifications provide insight into the robustness of structural parameters to the inclusion of additional shocks. Each parameter is linked to a specific equation that shapes the transmission mechanisms influencing the current account, the trade balance, and primary income. Parameters associated with productive structures display greater variability across specifications, while those related to household preferences exhibit tighter confidence intervals. Persistence parameters and shock standard deviations are among the most stable, indicating robustness to changes in model structure.

The analysis of posterior distributions relative to prior beliefs reveals clear Bayesian learning. For most parameters, posterior variances are smaller than their prior counterparts, suggesting that the incorporation of data improves parameter identification across all specifications. This reduction in uncertainty confirms that the estimation process refines prior assumptions and enhances the credibility of the inferred parameter values. Evaluating parameter robustness jointly also helps clarify the strengths and limitations of the model in capturing current account dynamics.

Model comparison based on marginal data densities indicates that the complete specification —including all proposed shocks— provides the best fit to the data. Consequently, this specification is used to analyze impulse response functions and variance decompositions. The superior performance of the full model highlights the importance of import prices, net interest income, and net profit income as key drivers of current account fluctuations.

Impulse response analysis supports the distinction between the trade balance and the current account, showing that their dynamics are similar only in the short run. Over longer horizons, financial flows and factor income become increasingly relevant, jointly determining the evolution of the current account. The results also emphasize the differing roles of the trade channel, associated with domestic absorption, and the financial channel, linked to returns on external liabilities. These channels operate with different timings and magnitudes depending on the shock considered.

Variance decomposition results indicate that current account volatility is driven by multiple shocks, particularly export prices and productivity in the exportable and non-

tradable sectors. Interest rate shocks emerge as key determinants of most external variables. While the additional mechanisms explain a limited share of current account variance, their inclusion allows for a more accurate assessment of the role of sectors less directly exposed to international shocks, such as the non-tradable sector —an effect understated in traditional frameworks.

Simulations using posterior mode parameters successfully replicate key empirical regularities of the Peruvian economy, most notably the countercyclicality of the current account. These results provide robust evidence that extending the analysis beyond the trade balance –by explicitly incorporating primary income flows– is fundamental for a comprehensive understanding of external dynamics in Small Open Economies like Peru.

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