2024, Volume 47, Issue 94, 76-105/ ISSN 2304-4306

ECONOMÍA

FONDO EDITORIAL

revistas.pucp.edu.pe/economia

www.fondoeditorial.pucp.edu.pe

Dirty Float, Commodity Prices, and Macroeconomic Fluctuations: A Model for Peru

Waldo Mendoza [a,*], Rafael Vilca [b]

[a]Pontificia Universidad Católica del Perú
✉ waldo.mendoza@pucp.pe *Corresponding author

[b]Pontificia Universidad Católica del Perú
✉ rafael.vilca@pucp.edu.pe

Abstract

This paper presents a macroeconomic model that replicates the key stylized facts of the Peruvian economy, namely the strong dependence of private investment and GDP on mineral export prices, within a framework where the Central Reserve Bank of Peru (BCRP) operates under a dirty float regime and the Ministry of Economy and Finance (MEF) follows fiscal rules that endogenize public spending. The model is designed for undergraduate students and instructors of economics and builds on the work of Dancourt (2009), Dancourt & Mendoza (2016), and Mendoza (2019).

Article History: Received: 15 December 2023 / Revised: 21 May 2024 / Accepted: 15 December 2024
Keywords: Dirty float, commodities, macroeconomic fluctuations
JEL Classification: E32, F31, F32

https://doi.org/10.18800/economia.202402.004

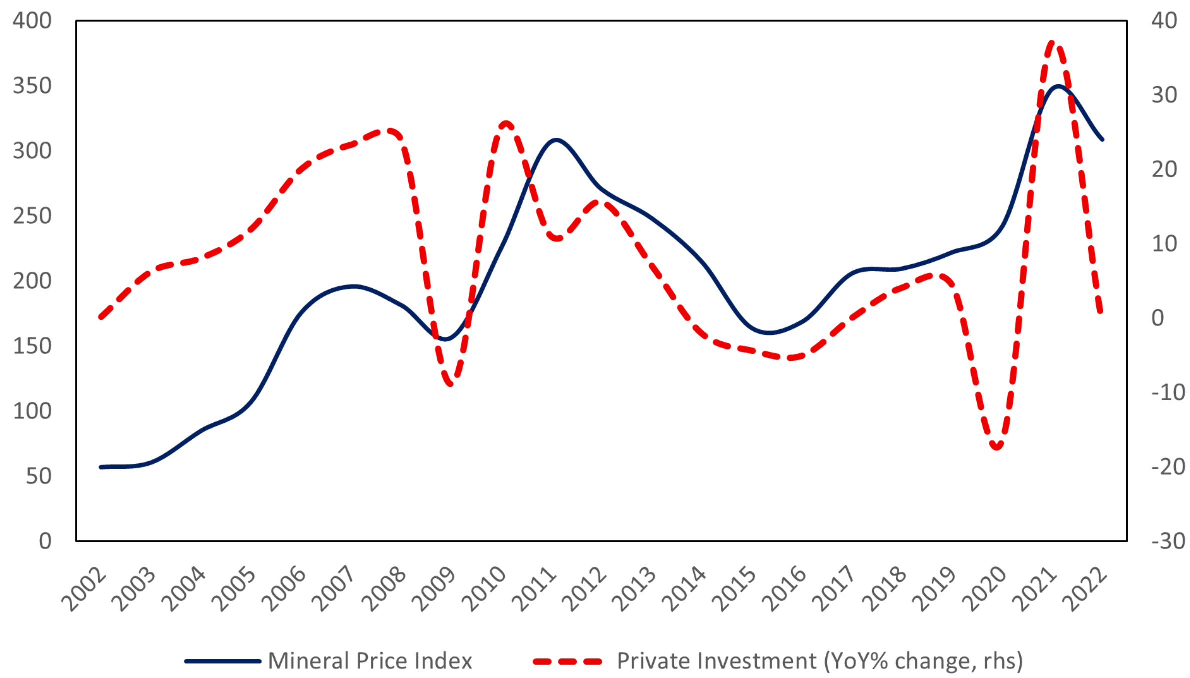
Introduction

Peru's macroeconomic performance has historically been shaped by external conditions, particularly global commodity prices. Exports are dominated by mining products, which account for around 60% of total export value.

Fluctuations in mineral prices affect the economy through several channels.[1] When prices rise, higher profitability encourages mining investment, particularly from foreign investors. Production also expands, both in operating mines and in previously unprofitable sites. Rising profits lead to higher corporate tax payments, half of which are allocated to regional governments, municipalities, and public universities through the *canon minero* (a revenue-sharing mechanism that distributes a portion of mining tax revenues at the subnational level for public investment). As a result, government spending increases. The Central Reserve Bank of Peru (BCRP) also benefits from higher mineral prices. FX inflows increase as export revenues rise, leading to currency appreciation, which helps contain inflation. To prevent excessive appreciation, the BCRP intervenes through FX purchases, increasing its international reserves.

In short, higher mineral prices drive increases in private and public investment, GDP, tax revenue, and international reserves while pushing the exchange rate lower. The link between mineral prices[2] and private investment is illustrated in Time Series 1.

Time Series 1: Peru – Private Investment and Mineral Price Index



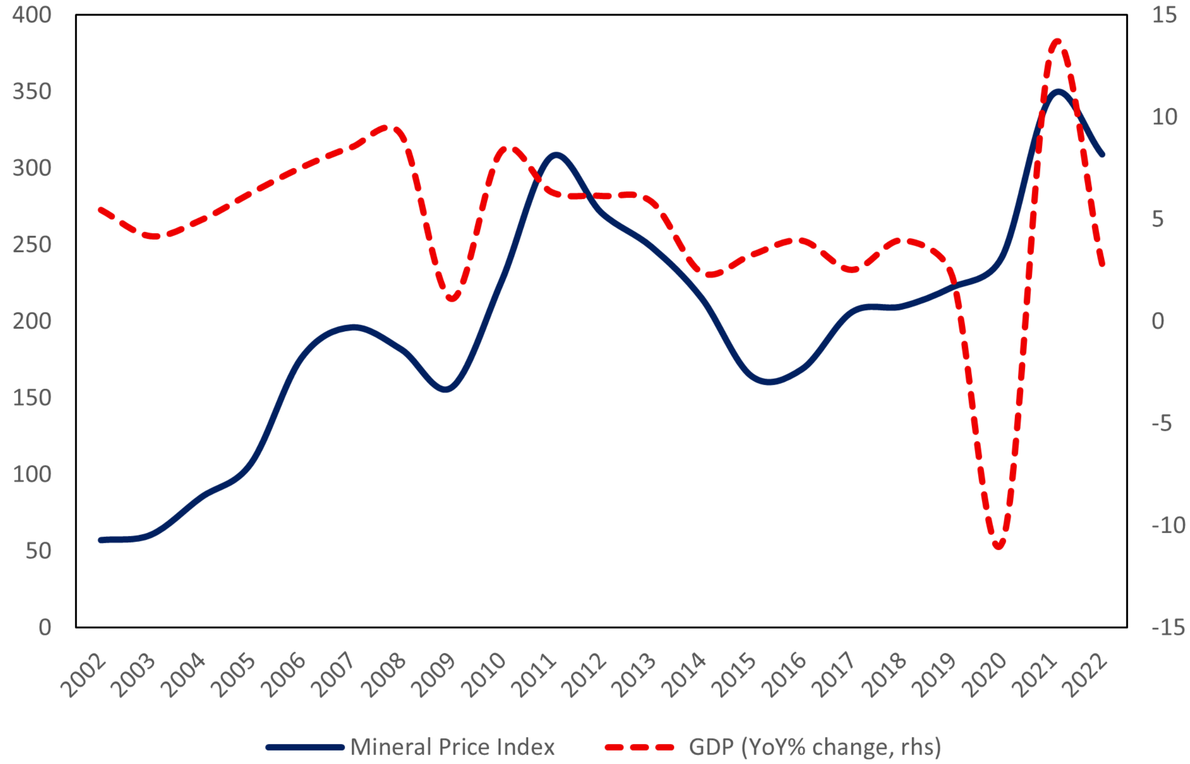
Source: BCRP. Authors' calculations.

[1] See Lanteri (2008), Gondo and Vega (2019), Alberola et al. (2019), IMF (2018), Mendoza (2017), and Rodríguez and Vasallo (2021).

[2] The price of mining products is a weighted average of Peru's mineral exports. The weights are based on each mineral's annual share in the total value of mining exports.

Time Series 2 shows the close link between mineral prices and GDP. Upturns in economic activity largely coincide with commodity price booms, while slowdowns tend to follow periods of declining global prices.

Time Series 2: Peru – GDP and Mineral Prices, 2002–2022



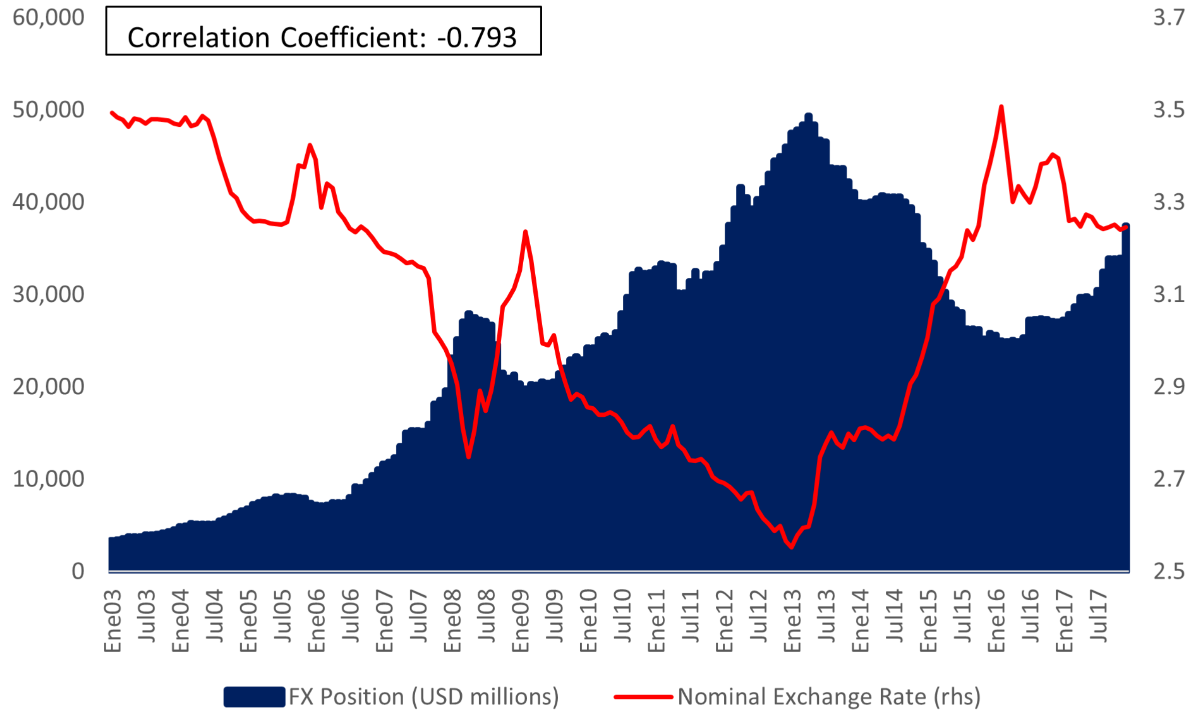
Source: BCRP. Authors' calculations.

These dynamics unfold within an institutional framework shaped by two key factors. First, the BCRP operates a dirty float exchange rate regime, in place since 1990. During the 1990s, interventions were informal and unstructured,[3] but they became systematic with the adoption of inflation targeting in 2003. Under this framework, the exchange rate serves as a secondary policy tool to smooth short-term fluctuations.[4]

In this hybrid regime, positioned between fixed and floating exchange rate systems, the BCRP intervenes to limit volatility, buying FX when the exchange rate falls below an implicit, unannounced threshold and selling FX when it rises above it. As a result, international reserves increase when the currency strengthens and are drawn down when it weakens (Time Series 3).

[3]See Pasco-Font (2000).
[4]The primary tool is the short-term interest rate, aimed at controlling inflation.

Time Series 3: Peru – Exchange Rate and International Reserves



Source: BCRP.

The second defining element is the fiscal framework of the Ministry of Economy and Finance (MEF), which sets limits on public spending, public debt (as a share of GDP), and the growth rate of government expenditures. As a result, public spending is endogenous, rather than exogenous as assumed in standard textbook models.

This paper develops a macroeconomic model that captures these stylized facts and reflects Peru's monetary and fiscal policy framework. Accordingly, the paper is structured as follows: the next section presents the macroeconomic model. Section 2 simulates the effects of a commodity price increase on economic activity, the exchange rate, international reserves, and inflation. It also examines the effects of an expansionary monetary policy (a reduction in interest rates) and an expansionary fiscal policy, which, under fiscal rules, is modeled as an increase in the fiscal deficit limit. Additionally, we simulate a supply shock, specifically a rise in the cost of inputs such as oil. These simulations allow us to compare the model's predictions with the stylized facts described earlier. Finally, section 3 presents conclusions and policy implications.

1. The Model

This model determines the non-primary GDP of an open economy—a variation of the extended Mundell-Fleming framework adapted to the Peruvian economy.

On the aggregate demand side, there is a goods market with two sectors: primary and non-primary. The primary sector produces raw materials, mainly for export—such as minerals—and operates at full capacity, meaning it follows a non-Keynesian structure. The non-primary sector, in contrast, produces goods for the domestic market, exports, and competes with imports. Unlike the primary sector, it operates with idle capacity and follows a Keynesian framework, giving rise to the *IS* curve of an open economy.

The model also includes an external sector, which reflects the interaction between the balance of payments under imperfect capital mobility and the BCRP's intervention rule—a defining feature of a dirty float regime. This interaction determines the external equilibrium curve, *EE*.

The *IS*–*EE* system determines equilibrium output and the exchange rate, assuming a fixed and exogenous price level. The equilibrium condition for output defines the aggregate demand (AD) curve for the non-primary sector. Given the exchange rate, the intervention rule determines equilibrium international reserves.

With an exogenous interest rate and endogenous domestic credit, the LM curve is only relevant for determining the equilibrium domestic credit (B^b).

Once aggregate demand is established, it combines with the aggregate supply (AS) to form the AD–AS system for the non-primary sector.

Throughout the analysis, we use linear equations, as their graphical representations serve as a useful teaching tool for undergraduate courses.

Aggregate Demand

Goods Market

In the Keynesian sector, non-primary GDP (Y) is determined by demand (D), which is the sum of consumption by non-primary sector workers (C_{NP}) and primary sector workers (C_P), along with investment (I), government spending (G), and net exports of non-primary goods (XN_{NP}):

$$Y = D = C_{NP} + C_P + I + G + XN_{NP} \tag{1}$$

Workers in the non-primary sector consume based on their disposable income, which equals total income (Y) minus tax revenue (T). Since taxes are proportional to economic activity ($T = tY$), disposable income is $(1 - t)Y$. Their consumption function is:

$$C_{NP} = C_0 + c_1(1 - t)Y \tag{2}$$

where C_0 captures factors affecting consumption beyond disposable income.

Workers in the primary sector follow the same propensity to consume, but their real income is given by $E + P_P^* + X_0 - P$, where E is the nominal exchange rate, P_P^* is the FX price of primary exports, X_0 is the export volume, and P is the price of non-primary goods, which serves as the *numéraire*[5]. Their consumption function is:

[5] The real income of workers in the primary sector is derived from their nominal income from exports, deflated by the *numéraire*, which in this case is the price of non-primary goods (P). Nominal income is calculated by multiplying the dollar value of primary exports ($P_P^* X_0$) by the nominal exchange rate (E). Consequently, real income in terms of non-primary goods is given by $\frac{EP_P^* X_0}{P}$, and disposable income is $(1 - t)\frac{EP_P^* X_0}{P}$. To maintain the linearity of the equations, we use the linear approximation: $(1 - t)\frac{EP_P^* X_0}{P} \cong (1 - t)(E + P_P^* + X_0 - P)$, which appears in equation (3).

$$C_P = c_1(1-t)(E + P_P^* + X_0 - P) \tag{3}$$

Private investment (I) is negatively related to the domestic interest rate (r) and the international interest rate (r^*). The existence of two interest rates reflects that investors can finance projects domestically (in domestic currency) or externally (in FX). Studies by Magud and Sosa (2015) for Latin America and the Caribbean, and by Rodríguez and Villanueva (2014), Ross and Tashu (2015), and Gondo and Vega (2019) for Peru, highlight that commodity price fluctuations play a key role in investment cycles. Therefore, the real exchange rate relevant to the primary export sector $(E + P_P^* - P)$[6] is introduced as an additional determinant:

$$I = I_0 - br - b^*r^* + b^X(E + P_P^* - P) \tag{4}$$

Fiscal policy follows a primary balance rule. The primary fiscal deficit (PFD) is defined as the difference between primary (non-financial) government spending (G) and tax revenue, which includes collections from both the non-primary sector (tY) and the primary sector $t(E + P_P^* - P + X_0)$. Under this rule, PFD must equal a fixed share (α) of non-primary GDP:[7]

$$PFD = G - tY - t(E + P_P^* + X_0 - P) = \alpha Y \tag{5}$$

Since fiscal policy adheres to this primary balance rule, G is endogenous, determined by government revenue and the fiscal deficit limit (α):

$$G = Y(t + \alpha) + t(E + P_P^* + X_0 - P) \tag{6}$$

The non-primary goods market includes net exports (XN_{NP}), or the trade balance for the non-primary sector. As expected, net exports depend positively on global GDP (Y^*) and the real exchange rate for the non-primary sector $(E + P_{NP}^* - P)$, where P_{NP}^* is the FX price of non-primary goods.[8] The trade balance also depends negatively on disposable income in both sectors, given a common marginal propensity to import (m).

$$XN_{NP} = a_0Y^* + a_1(E + P_P^* - P) - m(1-t)(Y + E + P_P^* + X_0 - P) \tag{7}$$

Substituting equations (2), (3), (4), (6), and (7) into equation (1) yields the equilibrium condition for the goods market:

$$\begin{aligned} Y = D = {} & C_0 + c_1(1-t)Y + c_1(1-t)(E + P_P^* + X_0 - P) + I_0 - br - b^*r^* + b^X(E + P_P^* - P) \\ & + Y(t+\alpha) + t(E + P_P^* + X_0 - P) + a_0Y^* + a_1(E + P_{NP}^* - P) \\ & - m(1-t)(Y + E + P_P^* + X_0 - P) \end{aligned} \tag{8}$$

[6] Here too, we use an approximation so that $\frac{EP_p^*}{P} \cong E + P_p^* - P$.

[7] Peru's fiscal rule (Law 31541) limits the fiscal deficit and public debt to a percentage of GDP and constrains the growth of real public spending. In both the official rule and our model, primary public spending becomes an endogenous variable, as highlighted in equation (6).

[8] Here too, we use a linear approximation so that $\frac{EP_{NP}^*}{P} \cong E + P_{NP}^* - P$.

Rearranging equation (8) gives the expression for non-primary GDP (Y):

$$Y = k\Big[A_0 + [(c_1 - m)(1-t) + t + b^x]P_P^* + [(c_1 - m)(1-t) + t]X_0 + t\alpha + a_1 P_{NP}^* - [(c_1 - m)(1-t) + t + a_1 + b^x]P + [(c_1 - m)(1-t) + t + a_1 + b^x]E\Big] \quad (9)$$

where $k = \frac{1}{(1-c_1+m)(1-t)-\alpha}$ is the Keynesian multiplier, which is greater than 1, and $A_0 = c_0 + a_0 Y^* + I_0 - br - b^* r^*$ is the autonomous component of demand.

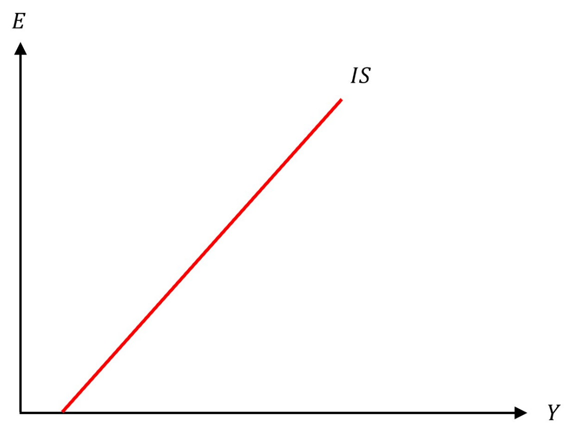
For the Keynesian multiplier to be positive, the model assumes that the fiscal deficit limit approaches zero—that is, fiscal policy follows a rule that keeps public spending close to budget balance.

The equilibrium condition for the non-primary goods market, given by equation (9), can therefore be graphed primarily in terms of the nominal exchange rate and output, following Chapter 10 of Blanchard and Fischer (1989).[9]

$$E = \frac{-[(c_1 - m)(1-t) + b^x + t]P_P^* - [(c_1 - m)(1-t) + t]X_0 + [(c_1 - m)(1-t) + b^x + t + a_1]P - A_0 - a_1 P_{NP}^*}{(c_1 - m)(1-t) + t + a_1 + b^x} + \frac{Y}{k[(c_1 - m)(1-t) + t + a_1 + b^x]} \quad (10)$$

Equation (10) represents the IS,[10] illustrating the combinations of nominal exchange rate and output that maintain equilibrium in the goods market. Its positive slope reflects that a currency depreciation increases non-primary GDP—that is, depreciation is expansionary in this model.

Figure 1. IS



[9]When the interest rate is endogenous, as in IS-LM or Mundell-Fleming models, using the interest rate-output space is appropriate.

[10]The *IS* designation remains appropriate even in the exchange rate-non-primary GDP space, as equilibrium in the goods market—where output equals demand—is equivalent to the balance between saving and investment.

BCRP Interest Rate and the Money Market

In this model, the monetary authority's policy instrument is the short-term interest rate (r). In practice, the BCRP sets a policy rate for the interbank market and intervenes by buying and selling financial assets to align the interbank rate with the policy rate:

$$r = r_0 \tag{11}$$

In the money market, the real money supply (m^s) is defined as the nominal money supply (M^s) deflated by the price level (P).[11] The nominal money supply consists of international reserves (B^{*bcr}) and outstanding domestic bonds and credit (B^b):

$$m^s = B^b + B^{*bcr} - P \tag{12}$$

Real money demand (m^d) typically depends positively on output and negatively on the short-term interest rate:[12]

$$m^d = b_0 Y - b_1 r \tag{13}$$

In equilibrium, real money supply equals real money demand:

$$B^b + B^{*bcr} - P = b_0 Y - b_1 r \tag{14}$$

In this model, the interest rate (r) is exogenous, while nominal money supply is endogenous. Domestic credit (B^b) adjusts to clear the money market:

$$B^b = -B^{*bcr} + P + b_0 Y - b_1 r \tag{15}$$

The money market equilibrium, given by equation (14), can be represented in terms of the nominal exchange rate and output:

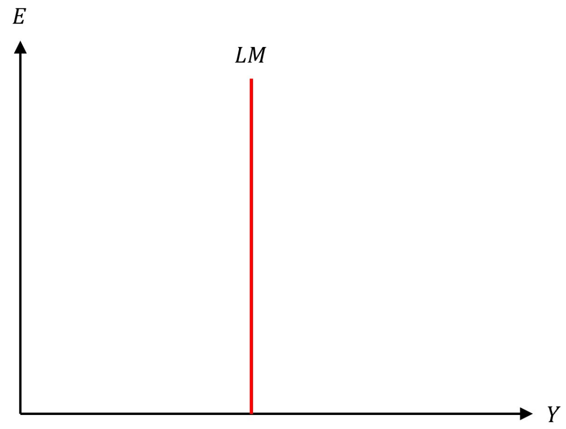
$$Y = \frac{B^b + B^{*bcr} - P + b_1 r}{b_0} \tag{16}$$

Figure 2 shows the LM curve given by equation (16), illustrating the relationship between output and the nominal exchange rate in money market equilibrium.

[11] To maintain the model's linearity, real money supply $\left(\frac{M^s}{P}\right)$ is linearized as $m^s = M^s - P$.

[12] It is important to clarify an imperfection that simplifies the model's mechanics without affecting the comparative statics exercises: the demand for money depends on aggregate GDP, not just on non-primary GDP, as assumed here.

Figure 2. LM



This model features an asymmetric relationship between the goods market and the money market. Output, determined in the goods market, influences the money market by affecting domestic credit through its impact on real money demand. However, the reverse does not hold: the nominal money supply (or more precisely, domestic credit) does not influence the goods market, i.e., non-primary GDP is independent of domestic credit.

Thus, the primary role of equation (16) is to determine the stock of outstanding domestic bonds and credit (B^b). It does not influence the determination of aggregate demand for the non-primary sector.

External Sector

This model assumes imperfect capital mobility. Unlike models based on perfect capital mobility, where the interest rate parity condition defines the external sector, the balance of payments equation is used instead. This modification provides a more realistic depiction of how the exchange rate is determined in an economy with imperfect capital mobility. Under this framework, the exchange rate is no longer determined solely by domestic and foreign interest rates or expected depreciation. Instead, it is also influenced by domestic variables, such as domestic GDP, and international market conditions, such as commodity export prices and global GDP. Incorporating this approach allows the model to reflect a dirty float exchange rate regime, rather than the fixed or freely floating regimes typically found in textbook models.

The balance of payments summarizes transactions with the rest of the world, consisting of the current and financial accounts. However, this model abstracts from certain components and focuses on the trade balance (XN) and net financial capital inflows (FKI). The trade balance consists of the primary goods trade balance (XN_p), which includes only exports, as there are no primary goods imports, and the non-primary goods trade balance (XN_{NP}). Thus, the balance of payments (BP)—which, in accounting terms, reflects changes in the BCRP's international reserves ($B^{*bcr} - B^{*bcr}_{t-1}$)—is the sum of the total trade balance and net capital inflows:

$$BP = B^{*bcr} - B^{*bcr}_{t-1} = XN_p + XN_{NP} + FKI = XN + FKI \tag{17}$$

The total trade balance combines the primary and non-primary goods trade balances. The primary goods trade balance (XN_p) equals total exports of primary goods ($E + P_p^* + X_0 - P$).[13] The non-primary goods trade balance (XN_{NP}) depends positively on global GDP (Y^*) and the real exchange rate for non-primary goods ($E + P_{NP}^* - P$)[14] and negatively on disposable income in both sectors $m(1-t)(Y + E + P_p^* + X_0 - P)$, given a marginal propensity to import (m). Thus, the total trade balance is:

$$XN = XN_p + XN_{NP} = E + P_p^* + X_0 - P + a_0 Y^* + a_1(E + P_{NP}^* - P) - m(1-t)(Y + E + P_p^* + X_0 - P) \quad (18)$$

Net financial capital inflows (FKI) depend on the return differential between domestic and foreign assets. Domestic asset returns are determined by the domestic interest rate, adjusted for a risk premium (θ), while foreign asset returns are given by the foreign interest rate (r^*), adjusted for expected depreciation ($E^e - E$).[15] Thus, capital inflows increase with the domestic interest rate (adjusted for risk premium) and decline with the foreign interest rate (adjusted for expected depreciation):

$$FKI = a_2(r - \theta - r^* - E^e + E) \quad (19)$$

Since the balance of payments is the sum of the trade balance and net capital inflows, we obtain:

$$B^{*bcr} - B_{t-1}^{*bcr} = E + P_p^* + X_0 - P + a_0 Y^* + a_1(E + P_{NP}^* - P) - m(1-t)(Y + E + P_p^* + X_0 - P) + a_2(r - \theta - r^* - E^e + E) \quad (20)$$

Expressed in terms of the nominal exchange rate and international reserves, the balance of payments equilibrium is:

$$E = \frac{[1 + a_1 - m(1-t)]P - [1 - m(1-t)](P_p^* + X_0) - D_0 - a_1 P_{NP}^* + m(1-t)Y - B_{t-1}^{*bcr}}{a_1 + a_2 + 1 - m(1-t)} + \frac{B^{*bcr}}{a_1 + a_2 + 1 - m(1-t)} \quad (21)$$

where

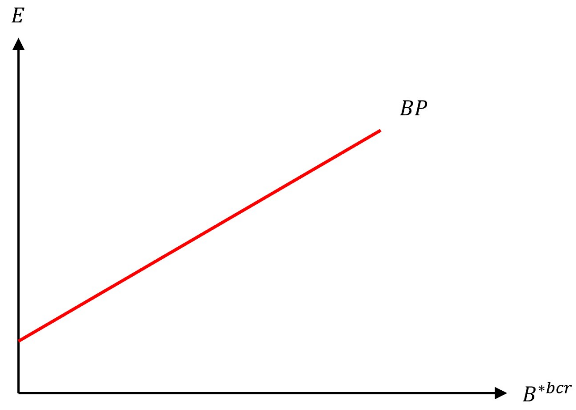
$$D_0 = a_0 Y^* + a_2(r - \theta - r^* - E^e)$$

[13] Which is equivalent to the real income of workers in the commodity-producing sector ($E + P_p^* + X_0 - P$).

[14] Here too, we use a linear approximation so that $\frac{EP_{NP}^*}{P} \cong E + P_{NP}^* - P$.

[15] Here too, we use a linear approximation so that $\frac{E^e - E}{E} \cong E^e - E$.

Figure 3. Balance of Payments



As in Dancourt (2009), Dancourt and Mendoza (2016), and Mendoza (2019), this model assumes a hybrid exchange rate system, combining elements of fixed and floating regimes. This system, known as a dirty float, provides exchange rate flexibility while allowing the central bank to intervene to curb excessive fluctuations. The BCRP's intervention rule is based on an implicit, unpublished exchange rate target (E^m). The BCRP buys FX when the exchange rate falls below this target and sells FX when it rises above it.

$$B^{*bcr} - B^{*bcr}_{t-1} = \beta_0(E^m - E) \tag{22}$$

This rule implies three possible scenarios:

1. $E^m < E$: The exchange rate exceeds the target, so the BCRP sells FX ($B^{*bcr} - B^{*bcr}_{t-1} < 0$), causing the exchange rate to fall.

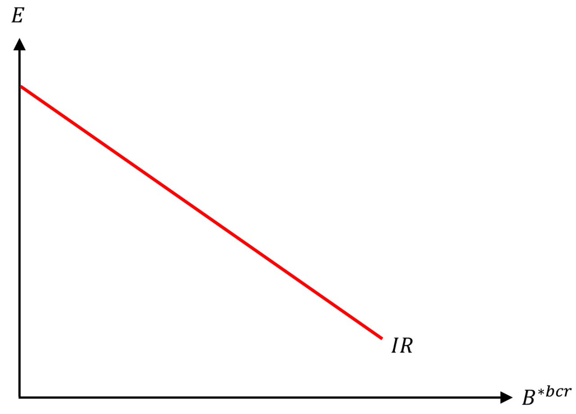
2. $E^m > E$: The exchange rate is below the target, so the BCRP buys FX ($B^{*bcr} - B^{*bcr}_{t-1} > 0$), pushing the exchange rate up.

3. $E^m = E$: The exchange rate matches the target, so no intervention occurs, and international reserves remain unchanged ($B^{*bcr} - B^{*bcr}_{t-1} = 0$).

Rearranging equation (22) gives the intervention rule (IR) as a function of the exchange rate and international reserves, as illustrated in Figure 4:

$$E = E^m + \frac{B^{*bcr}_{t-1}}{\beta_0} - \frac{B^{*bcr}}{\beta_0} \tag{23}$$

Figure 4. Intervention Rule



Under a dirty float, the exchange rate and international reserves are endogenous. The exchange rate is determined by the balance of payments equation (20), while international reserves are set by the intervention rule (22). This model differs from Mundell-Fleming-type models, where the exchange rate is endogenous under a floating regime, while international reserves are endogenous under a fixed exchange rate.

By combining equations (20) and (22), we obtain:

$$B^{*bcr} = B^{*bcr}_{t-1} + \frac{\beta_0[1 + a_1 + a_2 - m(1-t)]}{\mu}E^m + \frac{\beta_0}{\mu}\Big\{[1 - m(1-t)](P^*_p + X_0) - [1 - m(1-t) + a_1]P + a_1 P^*_{NP} - m(1-t)Y + D_0\Big\} \tag{24}$$

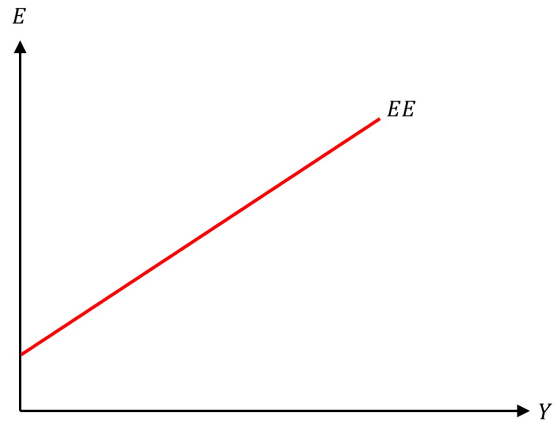
$$E = \frac{\beta_0 E^m + [1 - m(1-t) + a_1]P - [1 - m(1-t)](P^*_p + X_0) - D_0 - a_1 P^*_{NP}}{\mu} + \frac{m(1-t)Y}{\mu} \tag{25}$$

where $\mu = \beta_0 + a_1 + a_2 + 1 - m(1-t)$.

Equation (25) is called the external equilibrium (EE) equation, as it results from combining the balance of payments equation with the BCRP's intervention rule.[16] This equation defines the EE curve, plotted in terms of the nominal exchange rate and output in Figure 5.

[16]Strictly speaking, this is not an external equilibrium line, as the equation does not ensure balance in either the balance of payments or the current account. However, in the comparative statics exercises, both in the initial and final situations, the observed exchange rate and the target exchange rate are equal, ensuring balance in the balance of payments. For this reason, we retain the term "external equilibrium."

Figure 5. EE



Both the IS and EE curves have positive slopes. For the model to remain stable[17] and produce meaningful comparative statics,[18] the IS curve must be steeper than the EE curve:

$$\left.\frac{dE}{dY}\right|_{IS} = \frac{(1-c_1+m)(1-t)-\alpha}{[(c_1-m)(1-t)+t+a_1+b^x]} > \left.\frac{dE}{dY}\right|_{EE} = \frac{m(1-t)}{\beta_0+a_1+a_2+1-m(1-t)}$$

Solving this inequality yields:

$$(a_2+\beta_0)+k(1-t)[(1+a_1)(1-c_1)-mb^x+m\alpha]>0$$

From this expression, we can infer a sufficient condition for model stability: $1-c_1 > mb^x$.[19] This condition requires the multiplier effect of non-primary output growth, given by,

$$k=\frac{1}{(1-c_1+m)(1-t)-\alpha},$$

to be relatively low. For this to hold, $1-c_1$ must be sufficiently high, ensuring that the initial impact on the nominal exchange rate dominates over the effect of successive increases in non-primary GDP.

Thus, if $1-c_1 > mb^x$, we can conclude that the IS curve is steeper than the EE curve. In this model, output is determined in the goods market, the exchange rate is determined by the balance of payments, and international reserves are determined by the BCRP's intervention rule. With these relationships established, domestic credit equilibrium can be determined in the money market.

[17] To demonstrate the stability of the model, we followed a process similar to that in Mendoza (2015), where a phase diagram illustrates that the $IS-EE$ framework is dynamically stable.

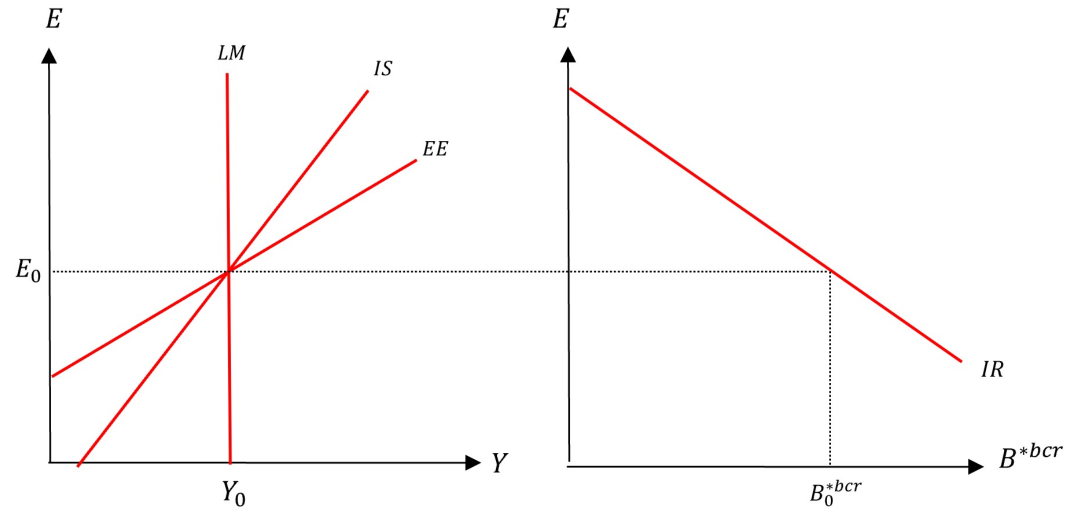
[18] For example, in a model like this, where the goods market follows a Keynesian framework, an increase in autonomous consumption should stimulate the non-primary sector of the economy.

[19] The sufficient conditions are quite stringent, ensuring model stability in a relatively straightforward manner. Additionally, these conditions allow for reasonable comparative statics results.

Aggregate Demand and Equilibrium

Equilibrium in aggregate demand is achieved when the goods market (IS), the money market (LM), and the external sector (EE) are in balance. Graphically, the IS, LM, and EE curves determine output, the exchange rate, and the stock of domestic credit. Given the exchange rate, the stock of international reserves can be found along the RI curve (Figure 6).

Figure 6. Aggregate Demand Equilibrium



To derive the equilibrium values, where the model's key endogenous variables [20] (output, nominal exchange rate, and international reserves) depend solely on exogenous aggregate demand variables, we proceed as follows. First, we combine equations (10) and (25) to obtain equilibrium output and the equilibrium exchange rate, given by equations (26) and (27), respectively. Then, substituting equation (27) into the intervention rule (22) gives equilibrium international reserves, expressed in equation (28).

$$
\begin{aligned}
Y^{eq} = & \left\{ \frac{k}{(a_2+\beta_0)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]} \right\} \Bigg\{ \Big\{ \Big(a_2 \\
& + \beta_0)[(c_1-m)(1-t)+b^x+t] - a_1[(1-t)(1-c_1)-b^x] \Big\} P_P^* \\
& + \{(a_2+\beta_0)[(c_1-m)(1-t)+t] - a_1(1-t)(1-c_1) \\
& - b^x[1-m(1-t)]\} X_0 - Z(\beta_0+a_2)P \\
& + [(1-t)(1-c_1)+a_2+\beta_0-b^x]P_{NP}^* + \mu A_0 - ZD_0 + Z\beta_0 E^m \Bigg\}
\end{aligned} \tag{26}
$$

[20] Fundamental variables are those that, once determined, are sufficient to derive the value of any other endogenous variable.

$$E^{eq} = \left\{ \frac{1}{(a_2+\beta_0)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]} \right\} \left\{ -k\{(1-t)[(1-c_1)-mb^x] \right.$$
$$+\lambda a_1[(1-c_1)(1-t)-b^x]-\alpha[1-m(1-t)]\}P_P^* - k\{(1-c_1)(1-t)-\alpha[1-m(1-t)]\}X_0$$
$$+\{(1-t)[(1+a_1)(1-c_1)-mb^x]-\alpha[1-m(1-t)+a_1]\}P - ka_1[(1-t)(1-c_1)-\alpha]P_{NP}^*$$
$$\left. +\beta_0 E^m - D_0 + km(1-t)A_0 \right\} \tag{27}$$

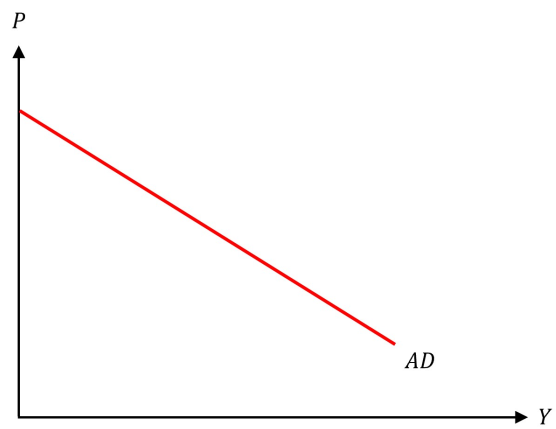
$$B^{*bcreq} = B_{t-1}^{*bcr} + \left\{ \frac{\beta_0}{(a_2+\beta_0)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]} \right\} \left\{ k\{(1-t)[(1-c_1)-mb^x] \right.$$
$$+\alpha[1-m(1-t)]\}P_P^* + k\{(1-c_1)(1-t)-\alpha[1-m(1-t)]\}X_0$$
$$-\{(1-t)[(1+a_1)(1-c_1)-mb^x]-\alpha[1-m(1-t)+a_1]\}P$$
$$+ka_1[(1-t)(1-c_1)-\alpha]P_{NP}^* + \{a_2+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]\}E^m$$
$$\left. +D_0 - k[m(1-t)]A_0 \right\} \tag{28}$$

where $Z = (c_1-m)(1-t)+t+a_1+b^x$ and $\mu = \beta_0+a_1+a_2+1-m(1-t)$.

Equation (26) yields the aggregate demand (AD) curve, given by equation (29) and illustrated in Figure 7. It is important to note that this is not a full aggregate demand model, but rather one that focuses on the non-primary sector of the economy.

$$P = \frac{\{(a_2+\beta_0)[(c_1-m)(1-t)+b^x+t]-a_1[(1-t)(1-c_1)-b^x]\}P_P^*}{kZ(\beta_0+a_2)}$$
$$+\frac{\{(a_2+\beta_0)[(c_1-m)(1-t)+t]-a_1(1-t)(1-c_1)-b^x[1-m(1-t)]\}X_0}{kZ(\beta_0+a_2)}$$
$$+\frac{[(1-t)(1-c_1)+a_2+\beta_0-b^x]P_{NP}^*+\mu A_0-ZD_0+Z\beta_0E^m}{kZ(\beta_0+a_2)}$$
$$-\frac{(a_2+\beta_0)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]}{kZ(\beta_0+a_2)}Y \tag{29}$$

Figure 7. Aggregate Demand



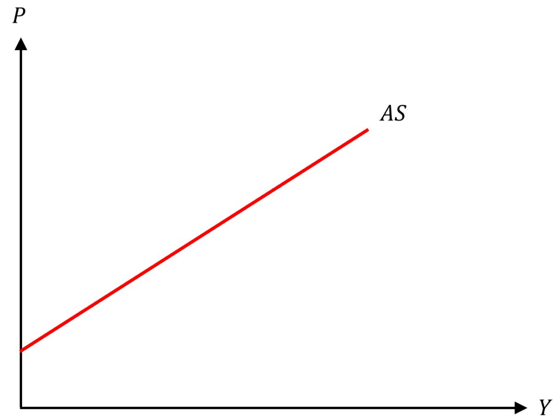
Aggregate Supply

Aggregate supply depends on the expected price level (P^e), the output gap ($Y - \bar{Y}$), and a component that captures the effects of supply shocks on prices.

Aggregate supply is given by equation (30) and illustrated in Figure 8:

$$P = P^e + \lambda(Y - \bar{Y}) + x \tag{30}$$

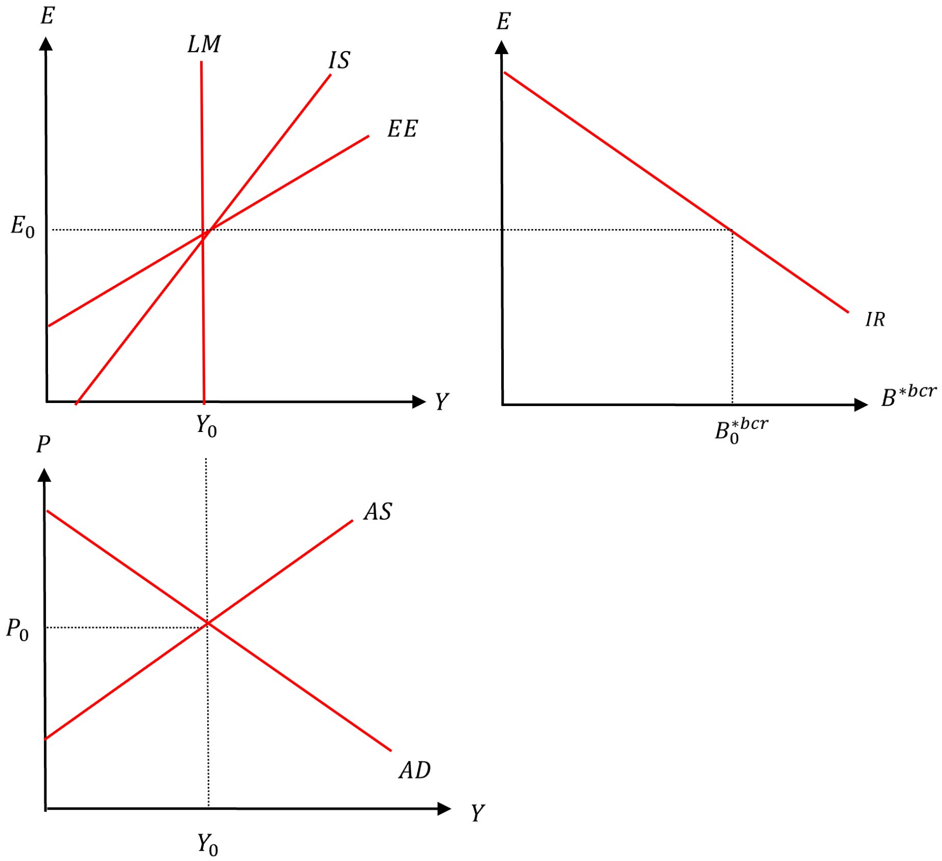
Figure 8. Aggregate Supply of Non-Primary Goods



General Equilibrium

The general equilibrium of the model, represented in Figure 9, is determined by the *IS* (equation 10), *LM* (equation 16), *EE* (equation 25), *AD* (equation 29), *AS* (equation 30), and *RI* (equation 22) curves.

Figure 9. General Equilibrium



With aggregate supply now defined, we can determine the equilibrium values for output, the nominal exchange rate, international reserves, and the price level.

$$
\begin{aligned}
Y^{eq} = &\left\{\frac{k}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]}\right\}\Bigg\{\Big\{(a_2 \\
&+\beta_0)[(c_1-m)(1-t)+b^x+t]-a_1[(1-t)(1-c_1)-b^x]\Big\}P_P^* \\
&+\Big\{(a_2+\beta_0)[(c_1-m)(1-t)+t]-a_1(1-t)(1-c_1)-b^x[1-m(1-t)]\Big\}X_0 \\
&-Z(\beta_0+a_2)(P^e+x)+Z\lambda(\beta_0+a_2)\bar{Y} \\
&+[(1-t)(1-c_1)+a_2+\beta_0-b^x]\,P_{NP}^*+\mu A_0-ZD_0+Z\beta_0E^m\Bigg\}
\end{aligned} \tag{31}
$$

$$E^{eq} = \left\{\frac{1}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]}\right\}\Bigg\{-k\Big\{(1-t)[(1-c_1)-mb^x]$$
$$+\lambda a_1[(1-c_1)(1-t)-b^x]-\alpha[1-m(1-t)]\Big\}P_P^*$$
$$-k\Big\{(1-c_1)(1-t)(1+\lambda a_1)+(\lambda b^x-\alpha)[1-m(1-t)]\Big\}X_0$$
$$-ka_1[(1-\lambda)(1-t)(1-c_1)+\lambda b^x-\alpha]P_{NP}^*+k\big[(1-t)[(1-c_1)(1+a_1)-mb^x]$$
$$-\alpha[1-m(1-t)+a_1]\big](P^e+x)$$
$$+\beta_0(1+k\lambda Z)E^m-(1+k\lambda Z)D_0+k\big[\lambda(1+a_1)+m(1-t)(1-\lambda)\big]A_0$$
$$-k\lambda(1-t)[(a_1+1)(1-c_1)-mb^x]-\alpha[a_1+1-m(1-t)]\}\bar{Y}\Bigg\} \tag{32}$$

$$B^{*bcreq} = B_{t-1}^{*bcr} + \left\{\frac{\beta_0}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]}\right\}\Bigg\{$$
$$k\{(1-t)[(1-c_1)-mb^x]+a_1[(1-c_1)(1-t)-b^x]+\alpha[1-m(1-t)]\}P_P^*$$
$$+k[(1-c_1)(1-t)(1+\lambda a_1)+(\lambda b^x-\alpha)[1-m(1-t)]]X_0$$
$$+ka_1[(1-\lambda)(1-t)(1-c_1)+\lambda b^x-\alpha]P_{NP}^*$$
$$-k\{(1-t)[(1-c_1)(1+a_1)-mb^x]-\alpha[1-m(1-t)+a_1]\}(P^e+x)$$
$$+\{a_2(1+k\lambda Z)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]\}E^m$$
$$+(1+k\lambda Z)D_0-k[a_1(1+a_1)+m(1-t)(1-\lambda)]A_0$$
$$+k\lambda\{(1-t)[(a_1+1)(1-c_1)-mb^x]-\alpha[a_1+1-m(1-t)]\}\bar{Y}\Bigg\} \tag{33}$$

$$P^{eq} = \left\{\frac{1}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]}\right\}\Bigg\{k\Big\{(a_2+\beta_0)(1-c_1-m)(1-t)$$
$$+b^x+t-a_1[(1-t)(1-c_1)-b^x]\Big\}P_P^*$$
$$+k\Big\{(a_2+\beta_0)[(c_1-m)(1-t)+t]-a_1(1-t)(1-c_1)$$
$$-b^x[1-m(1-t)]\Big\}X_0$$
$$+\Big\{(\beta_0+a_2)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]\Big\}(P^e+x)$$
$$-\Big\{\lambda(\beta_0+a_2)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]\Big\}\bar{Y}$$
$$+k[(1-t)(1-c_1)+a_2+\beta_0-b^x]P_{NP}^*$$
$$+k\mu A_0-kZD_0+kZ\beta_0E^m\Bigg\} \tag{34}$$

2. Comparative Statistics

With the complete model in place, we can now conduct comparative statics exercises to analyze its predictions. Each exercise starts from a general equilibrium where non-primary output equals demand, real money supply matches money demand, the balance of payments is in equilibrium (implying a stable level of international reserves), the observed exchange rate equals the implicit exchange rate target, and the expected return on domestic assets equals the expected return on foreign assets.

To solve these exercises analytically, we use the equilibrium conditions for the goods market (equation 8), money market (equation 14), balance of payments (equation 20), intervention rule (equation 22), and aggregate supply (equation 30). Recall that output is determined in the goods market, the exchange rate in the balance of payments, international reserves in the intervention rule, and the price level in the aggregate supply equation. With this information, equilibrium domestic credit can be determined in the money market.

$$\mathrm{Y} = \mathrm{D} = \mathrm{C}_0 + c_1(1-t)Y + c_1(1-t)(E + P_P^* + X_0 - P) + I_0 - br - b^*r^* + b^x(E + P_P^* - P) + t(Y+\alpha) + t(E + \mathrm{P}_P^* + X_0 - P) + a_0Y^* + a_1(E + P_{NP}^* - P) - m(1-t)(Y + E + P_P^* + X_0 - P) \tag{8}$$

$$\mathrm{B}^b + B^{*bcr} - P = b_0Y - b_1r \tag{14}$$

$$\mathrm{B}^{bcr} - B_{t-1}^{*bcr} = E + P_P^* + X_0 - P + a_0Y^* + a_1(E + P_{NP}^* - P) - m(1-t)(Y + E + P_P^* + X_0 - P) + a_2(r - \theta - r^* - E^e + E) \tag{20}$$

$$\mathrm{B}^{*bcr} - B_{t-1}^{*bcr} = \beta_0(E^m - E) \tag{22}$$

$$\mathrm{P} = \mathrm{P}^e + \lambda(Y - \bar{Y}) + x \tag{30}$$

To solve these exercises graphically, we use the *IS*, *LM*, *EE*, *AD*, *AS*, and *IR* curves.

$$E = \frac{-[(c_1-m)(1-t)+b^x+t]P_P^* - [(c_1-m)(1-t)+t]X_0 + [(c_1-m)(1-t)+b^x+t+a_1]P - A_0 - a_1P_{NP}^*}{Z} + \frac{Y}{kZ} \tag{10}$$

$$Y = \frac{B^b + B^{bcr} - P + b_1r}{b_0} \tag{16}$$

$$E = \frac{\beta_0E^m + [1-m(1-t)+a_1]P - [1-m(1-t)](P_P^* + X_0) - D_0 - a_1P_{NP}^*}{\mu} + \frac{m(1-t)Y}{\mu} \tag{25}$$

$$\begin{aligned} P = {} & \frac{\{(a_2+\beta_0)[(c_1-m)(1-t)+b^x+t] - a_1[(1-t)(1-c_1)-b^x]\}P_P^*}{kZ(\beta_0+a_2)} \\ & + \frac{\{(a_2+\beta_0)[(c_1-m)(1-t)+t] - a_1(1-t)(1-c_1) - b^x[1-m(1-t)]\}X_0}{kZ(\beta_0+a_2)} \\ & + \frac{[(1-t)(1-c_1)+a_2+\beta_0-b^x]P_{NP}^* + \mu A_0 - ZD_0 + Z\beta_0E^m}{kZ(\beta_0+a_2)} \\ & - \frac{(a_2+\beta_0)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]}{kZ(\beta_0+a_2)}Y \end{aligned} \tag{29}$$

$$P = P^e + \lambda(Y - \bar{Y}) + x \tag{30}$$

$$E = E^m + \frac{B_{t-1}^{bcr}}{\beta_0} - \frac{B^{bcr}}{\beta_0} \tag{23}$$

where:

$$A_0 = c_0 + a_0 Y^* + I_0 - br - b^* r^*,$$
$$D_0 = a_0 Y^* + a_2(r - \theta - r^* - E^e),$$
$$Z = (c_1 - m)(1 - t) + t + a_1 + b^x$$
$$\mu = \beta_0 + a_1 + a_2 + 1 - m(1 - t)$$

For mathematical solutions, we can use the same equations needed for analytical solutions or derive results directly from the reduced-form model, which consists of equations (31), (32), (33), and (34).

$$\begin{aligned} Y^{eq} = &\left\{\frac{k}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]}\right\}\Bigg\{\Big\{(a_2 \\ &+\beta_0)[(c_1-m)(1-t)+b^x+t]-a_1[(1-t)(1-c_1)-b^x]\Big\}P_P^* \\ &+\Big\{(a_2+\beta_0)[(c_1-m)(1-t)+t]-a_1(1-t)(1-c_1)-b^x[1-m(1-t)]\Big\}X_0 \\ &-Z(\beta_0+a_2)(P^e+x)+Z\lambda(\beta_0+a_2)\bar{Y} \\ &+[(1-t)(1-c_1)+a_2+\beta_0-b^x]\,P_{NP}^*+\mu A_0-ZD_0+Z\beta_0E^m\Bigg\} \end{aligned} \tag{31}$$

$$\begin{aligned} E^{eq} = &\left\{\frac{1}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]}\right\}\Bigg\{-k\Big\{(1-t)[(1-c_1)-mb^x] \\ &+\lambda a_1[(1-c_1)(1-t)-b^x]-\alpha[1-m(1-t)]\Big\}P_P^* \\ &-k\Big\{(1-c_1)(1-t)(1+\lambda a_1)+(\lambda b^x-\alpha)[1-m(1-t)]\Big\}X_0 \\ &-ka_1[(1-\lambda)(1-t)(1-c_1)+\lambda b^x-\alpha]P_{NP}^*+k\big[(1-t)[(1-c_1)(1+a_1)-mb^x] \\ &-\alpha[1-m(1-t)+a_1]\big](P^e+x) \\ &+\beta_0(1+k\lambda Z)E^m-(1+k\lambda Z)D_0+k\big[\lambda(1+a_1)+m(1-t)(1-\lambda)\big]A_0 \\ &-k\lambda(1-t)[(a_1+1)(1-c_1)-mb^x]-\alpha[a_1+1-m(1-t)]\}\bar{Y}\Bigg\} \end{aligned} \tag{32}$$

$$
\begin{aligned}
B^{*bcreq} = B^{*bcr}_{t-1} + \left\{ \frac{\beta_0}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]} \right\} \Bigg\{ \\
& k\{(1-t)[(1-c_1)-mb^x]+a_1[(1-c_1)(1-t)-b^x]+\alpha[1-m(1-t)]\}P^*_P \\
& + k[(1-c_1)(1-t)(1+\lambda a_1)+(\lambda b^x-\alpha)[1-m(1-t)]]X_0 \\
& + ka_1[(1-\lambda)(1-t)(1-c_1)+\lambda b^x-\alpha]P^*_{NP} \\
& - k\{(1-t)[(1-c_1)(1+a_1)-mb^x]-\alpha[1-m(1-t)+a_1]\}(P^e+x) \\
& + \{a_2(1+k\lambda Z)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]\}E^m \\
& + (1+k\lambda Z)D_0 - k[a_1(1+a_1)+m(1-t)(1-\lambda)]A_0 \\
& + k\lambda\{(1-t)[(a_1+1)(1-c_1)-mb^x]-\alpha[a_1+1-m(1-t)]\}\bar{Y} \Bigg\}
\end{aligned} \tag{33}
$$

$$
\begin{aligned}
P^{eq} = \left\{ \frac{1}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]} \right\} \Bigg\{ k\Big\{ (a_2+\beta_0)(1-c_1-m)(1-t) \\
& + b^x + t - a_1[(1-t)(1-c_1)-b^x] \Big\} P^*_P \\
& + k\Big\{ (a_2+\beta_0)[(c_1-m)(1-t)+t] - a_1(1-t)(1-c_1) \\
& - b^x[1-m(1-t)] \Big\} X_0 \\
& + \Big\{ (\beta_0+a_2)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha] \Big\}(P^e+x) \\
& - \Big\{ \lambda(\beta_0+a_2)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha] \Big\}\bar{Y} \\
& + k[(1-t)(1-c_1)+a_2+\beta_0-b^x]P^*_{NP} \\
& + k\mu A_0 - kZD_0 + kZ\beta_0 E^m \Bigg\}
\end{aligned} \tag{34}
$$

where:

$$
Z = (c_1-m)(1-t)+t+a_1+b^x \qquad \mu = \beta_0+a_1+a_2+1-m(1-t)
$$

The following section presents the comparative statics exercises.

Increase in Commodity Export Prices ($dP^*_P > 0$)

An increase in commodity export prices has multiple effects in this model. The direct effect is higher real export earnings, which raise real income in the commodity sector.

This rise in real income triggers several secondary effects. First, in the goods market, aggregate demand increases for three reasons. (i) Higher earnings in the commodity export sector raise workers' disposable income, boosting their consumption and, consequently, demand for goods. However, it also raises imports, which offsets part of this effect. Since the marginal propensity to consume exceeds the marginal propensity to import, the net effect is an increase in demand.[21] (ii) Given the primary balance rule, higher fiscal revenues from commodity exports lead to higher

[21] The consumption of workers in the commodity sector minus their imports.

public spending, further stimulating demand for non-primary goods. (iii) The rise in the real exchange rate relevant to the commodity sector spurs private investment. These three channels collectively increase non-primary GDP.

Second, higher real export earnings impact the balance of payments through two channels. Directly, they increase total export revenues. Indirectly, they raise imports of non-primary goods. However, since the increase in imports is only a fraction of the increase in exports, the balance of payments improves overall. This surplus causes the nominal exchange rate to appreciate, prompting the BCRP to purchase FX to prevent excessive appreciation, thereby increasing international reserves. Under the BCRP's monetary framework, this FX purchase must be sterilized through bond sales, reducing the stock of domestic bonds.[22]

The appreciation of the nominal exchange rate moderates the increase in primary GDP. (i) By reducing the real value of commodity exports, it lowers net consumption of imported goods by commodity-sector workers and reduces public spending. (ii) The lower nominal exchange rate decreases the real exchange rate for the primary sector, discouraging private investment. (iii) It also reduces the real exchange rate for the non-primary sector, worsening the non-primary trade balance.

The increase in non-primary GDP has two direct effects. First, higher income in the non-primary sector raises disposable income, leading to higher net consumption of imported goods. This, in turn, increases demand in the non-primary sector, reflecting the multiplier effect. Additionally, as higher non-primary GDP boosts tax revenue, government spending increases, providing further stimulus to demand. Finally, the rise in non-primary GDP raises real money demand, creating an excess demand in the money market, which results in an expansion of domestic credit. Second, higher non-primary GDP widens the output gap, leading to economic overheating and, consequently, higher prices. The resulting increase in prices reduces the real value of primary exports, lowering consumption in the primary sector, private investment, government spending, and the non-primary trade balance. Together, these effects dampen demand for goods and, consequently, non-primary GDP. Additional effects of rising prices include a deficit in the primary trade balance, which translates into a balance of payments deficit and a higher exchange rate. Furthermore, the increase in prices reduces the real money supply, which, to restore equilibrium in the money market, leads to an increase in domestic credit. However, as with non-primary GDP, these effects do not alter the initial direction of the exchange rate's movement.

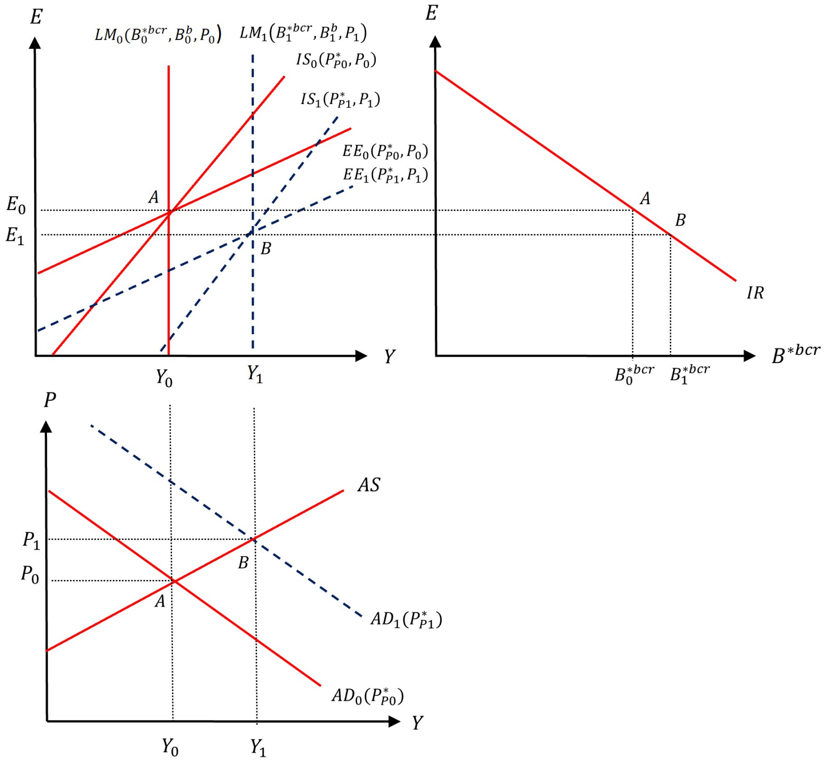
In summary, a rise in commodity prices stimulates the non-primary sector, depreciates the exchange rate, increases BCRP's international reserves, and raises the price level. The effect on domestic credit is ambiguous.

Figure 10 illustrates the impact of higher commodity export prices. In the aggregate supply and demand framework, this positive shock shifts the demand curve to the right, increasing output and the price level. In the exchange rate-output space, the shock shifts both the *IS* and *EE* curves rightward, reflecting a lower exchange rate and higher output. The LM curve moves toward the *IS*-*EE* equilibrium point, as domestic credit—an endogenous adjustment variable—responds accordingly. Finally, on the right side of the figure, given the intervention rule, the

[22] Otherwise, the interest rate would adjust.

exchange rate depreciation leads to an increase in international reserves.

Figure 10. Increase in Global Commodity Prices



The mathematical results are given by:

$$
\begin{aligned}
dY &= \left\{\frac{k\left[(a_2+\beta_0)[(c_1-m)(1-t)+b^x+t]+a_1[b^x-(1-t)(1-c_1)]\right]}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]}\right\}dP_P^*>0\\
dE &= \left\{\frac{-k[(1-t)[(1-c_1)-mb^x]+\lambda a_1[(1-c_1)(1-t)-b^x]-\alpha[1-m(1-t)]]}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]}\right\}dP_P^*\\
&<0\\
dB^{*bcr} &= \left\{\frac{k\beta_0[(1-t)[(1-c_1)-mb^x]+\lambda a_1[(1-c_1)(1-t)-b^x]-\alpha[1-m(1-t)]]}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]}\right\}dP_P^*\\
&>0\\
dP &= \left\{\frac{k\lambda[(a_2+\beta_0)[(c_1-m)(1-t)+b^x+t]-a_1[(1-t)(1-c_1)-b^x]]}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1-c_1)(1+a_1)-mb^x+m\alpha]}\right\}dP_P^*>0
\end{aligned}
\tag{22}
$$

A sufficient condition for output to increase is:

$$b^x > (1-t)(1-c_1)$$

Finally, recall that the fiscal deficit limit approaches zero, rendering its additional effect on the Keynesian multiplier irrelevant for determining the mathematical results.

Expansionary Monetary Policy: Lowering the Domestic Interest Rate ($dr < 0$)

A reduction in the domestic interest rate has three direct effects. First, it reduces the attractiveness of domestic assets relative to foreign ones, leading to lower financial capital inflows and a balance of payments deficit, which drives up the exchange rate. Second, the lower cost of domestic credit boosts investment and demand, increasing non-primary GDP. Third, the lower interest rate raises real money demand, creating excess demand in the money market, prompting BCRP to expand domestic credit.

The increase in the exchange rate has several consequences. First, under the dirty float regime, when the observed exchange rate exceeds the target, the BCRP sells dollars to moderate depreciation, reducing international reserves. This loss of reserves requires sterilization through higher domestic credit. Second, the higher exchange rate also raises the real value of primary exports, which, in turn, increases net import consumption among primary sector workers and raises public spending, both of which boost demand and non-primary GDP. Third, the rise in the nominal exchange rate encourages private investment by improving the real exchange rate in the primary sector, further stimulating demand. Finally, a higher nominal exchange rate raises the real exchange rate in the non-primary sector, improving its trade balance and reinforcing demand and non-primary GDP growth.

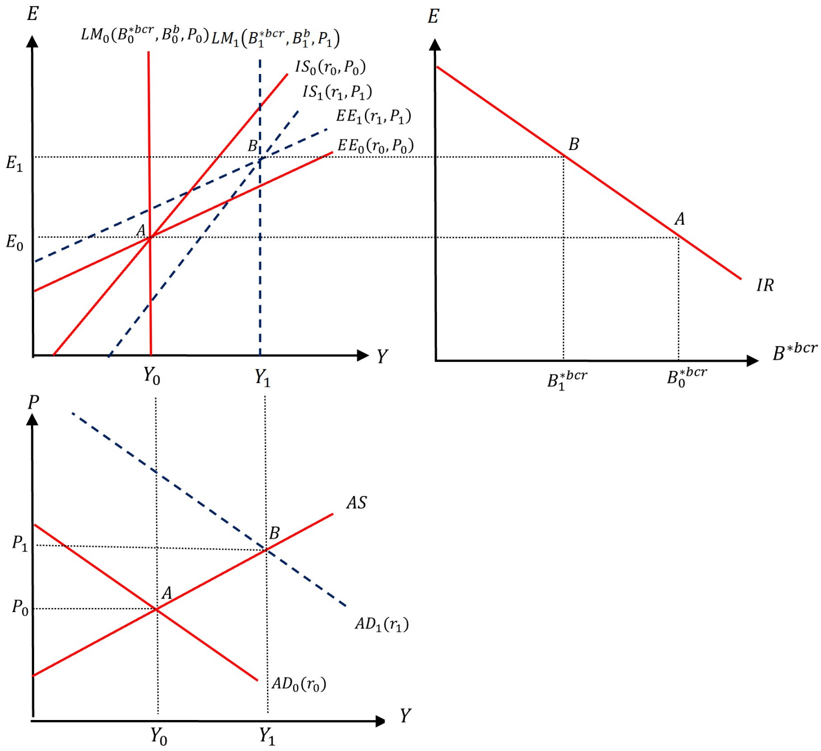
As non-primary GDP rises, disposable income for non-primary sector workers increases, leading to higher net import consumption and further demand expansion. Government revenues also rise, driving additional public spending, which further stimulates the non-primary sector. At the same time, greater non-primary GDP increases real money demand, generating excess demand in the money market and requiring BCRP to expand domestic credit. The widening output gap causes economic overheating, leading to a higher price level.

The rise in prices has a contractionary effect on aggregate demand, reducing net import consumption among primary sector workers, private investment, public spending, and non-primary exports. However, this contractionary effect is weaker than the initial stimulus from the interest rate cut.

In summary, a lower domestic interest rate raises non-primary GDP, increases the nominal exchange rate, drives up prices, reduces BCRP's international reserves, and expands domestic credit.

A lower interest rate shifts aggregate demand to the right, increasing both output and the price level. In the exchange rate-output space, it shifts the *IS* curve to the right and the *EE* curve to the left, resulting in a new equilibrium with a higher nominal exchange rate and non-primary GDP. As in the previous case, the *LM* curve adjusts to the new *IS*-*EE* equilibrium. Finally, in the right panel of the figure, the rise in the nominal exchange rate leads to a decline in international reserves.

Figure 11. Reduction in the Domestic Interest Rate



The mathematical results are the following:

$$dY = -\left\{\frac{ka_2\left[(c_1 - m)(1-t) + b^x + t + a_1\right] + kb\left[\beta_0 + a_1 + a_2 + 1 - m(1-t)\right]}{(a_2 + \beta_0)(1 + k\lambda Z) + k(1-t)[(1+a_1)(1-c_1) - mb^x + m\alpha]}\right\} dr > 0$$

$$dE = \left\{\frac{-\{kmb(1-t)(1-\lambda) + kb\lambda(1+a_1) + a_2 + ka_2\lambda[(c_1 - m)(1-t) + b^x + t + a_1]\}}{(a_2 + \beta_0)(1 + k\lambda Z) + k(1-t)[(1+a_1)(1-c_1) - mb^x + m\alpha]}\right\} dr > 0$$

$$dB^{*bcr} = \left\{\frac{\beta_0\left[kmb(1-t)(1-\lambda) + kb\lambda(1+a_1) + a_2 + ka_2\lambda[(c_1 - m)(1-t) + b^x + t + a_1]\right]}{(a_2 + \beta_0)(1 + k\lambda Z) + k(1-t)[(1+a_1)(1-c_1) - mb^x + m\alpha]}\right\} dr < 0$$

$$dP = \left\{\frac{k\lambda\{a_2\left[(c_1 - m)(1-t) + b^x + t + a_1\right] + b\left[\beta_0 + a_1 + a_2 + 1 - m(1-t)\right]\}}{(a_2 + \beta_0)(1 + k\lambda Z) + k(1-t)[(1-c_1)(1+a_1) - mb^x]}\right\} dr < 0 \qquad (23)$$

Increase in the Fiscal Deficit Limit ($d\alpha > 0$)

Raising the fiscal deficit limit has one direct effect: higher public spending. This increase in spending boosts non-primary demand, leading to higher non-primary GDP.

The rise in non-primary GDP sets off three key effects in the model. First, higher non-primary imports create a balance of payments deficit, driving up the nominal exchange rate. In response, the central bank sells foreign currency to moderate the depreciation, reducing international reserves. To prevent this decline from disrupting the money market, domestic credit expands. Second, the increase in non-primary GDP widens the output gap, pushing up the price level. Third, higher non-primary production raises money demand, requiring additional domestic credit to restore equilibrium in the money market.

Through the Keynesian multiplier effect, the increase in non-primary GDP feeds back into the goods market. Higher disposable income in the non-primary sector raises net import consumption, while increased tax revenues lead to additional public spending. Together, these effects further boost non-primary demand and non-primary GDP.

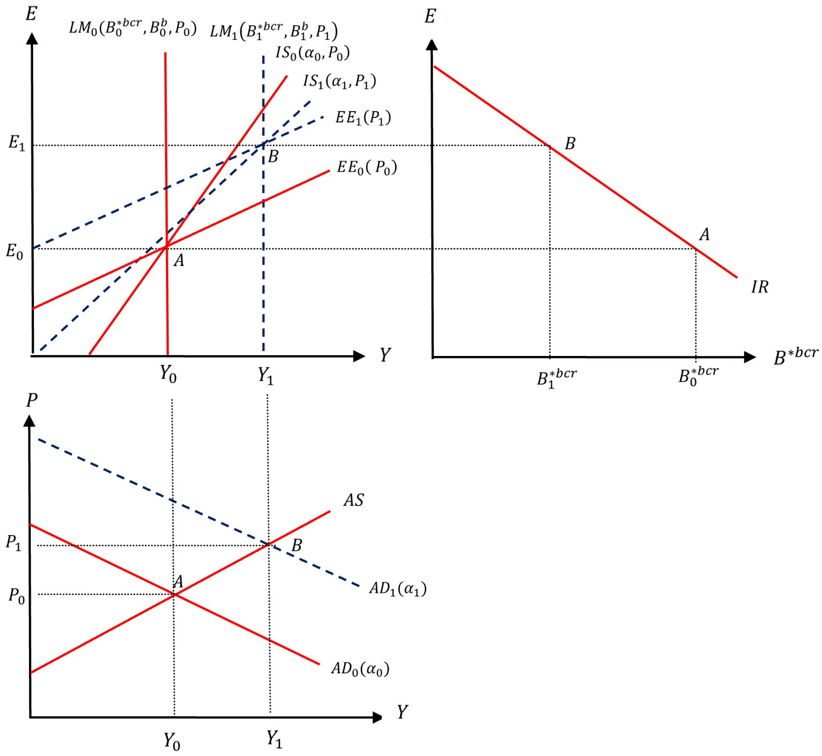
At the same time, the rise in the nominal exchange rate influences the goods market through multiple channels. It raises the real value of primary exports, improves the real exchange rate for both the primary and non-primary sectors, and increases net consumption by primary sector workers, private investment, public spending, and non-primary exports. These factors provide an additional boost to non-primary aggregate demand and GDP.

Conversely, the increase in the price level erodes the real value of primary exports and reduces the real exchange rates of both the primary and non-primary sectors. This lowers net consumption among primary sector workers, private investment, public spending, and non-primary exports, partially offsetting the initial rise in non-primary GDP. However, as the mathematical results later confirm, the initial positive impact on non-primary GDP outweighs the contractionary effect of higher prices.

In summary, increasing the fiscal deficit limit raises non-primary GDP, the price level, and the nominal exchange rate while reducing international reserves.

Figure 12 illustrates the effects of an increase in the fiscal deficit limit. In the aggregate supply and demand space, this shock shifts the aggregate demand curve to the right, leading to a higher equilibrium output and price level. In the exchange rate-output space, the *IS* and *EE* curves shift left, reflecting the increase in the exchange rate and non-primary GDP. The *LM* curve moves to the *IS*-*EE* equilibrium, as domestic credit adjusts within the model. Finally, in the nominal exchange rate-international reserves space, intervention policy results in movement along the curve, illustrating the decline in international reserves.

Figure 12. Increase in the Fiscal Deficit Limit



$$dY = \frac{kY[(c_1 - m)(1-t) + b^x + t + a_1]}{(a_2+\beta_0)(1+k\lambda Z) + k(1-t)[(1+a_1)(1-c_1) - mb^x + m\alpha]} d\alpha > 0$$

$$dE = \frac{kY[\lambda(1+a_1) + m(1-t)(1-\lambda)]}{(a_2+\beta_0)(1+k\lambda Z) + k(1-t)[(1+a_1)(1-c_1) - mb^x + m\alpha]} d\alpha > 0$$

$$dB^{*bcr} = \frac{-k\beta_0 Y[\lambda(1+a_1) + m(1-t)(1-\lambda)]}{(a_2+\beta_0)(1+k\lambda Z) + k(1-t)[(1+a_1)(1-c_1) - mb^x + m\alpha]} d\alpha < 0$$

$$dP = \frac{k\lambda Y[(c_1 - m)(1-t) + b^x + t + a_1]}{(a_2+\beta_0)(1+k\lambda Z) + k(1-t)[(1+a_1)(1-c_1) - mb^x + m\alpha]} d\alpha > 0$$

Supply Shock ($dx > 0$)

A cost shock directly affects aggregate supply by driving up the price level. This, in turn, reduces the real value of exports and real income in the commodity-producing sector.

The decline in real income triggers four key effects. First, in the goods market, demand contracts for three reasons. (i) Lower disposable income for workers in the commodity sector reduces both their consumption and imports. Since the marginal propensity to consume domestic goods is higher than for imported goods, aggregate demand increases. (ii) Given the fiscal rule, lower government revenue from commodity exports leads to a reduction in primary public spending, weakening demand for non-primary goods. (iii) The real exchange rate relevant to the commodity sector declines, discouraging private investment. (iv) The real exchange rate relevant to the non-primary sector also falls, reducing non-primary exports. As a result, the contraction in consumption, public spending, private investment, and non-primary exports leads to a decline in non-primary GDP.

Second, lower real export revenues affect the balance of payments through two channels. Directly, they reduce the real value of commodity exports; indirectly, they lower non-primary imports. Additionally, the drop in the price level reduces the real exchange rate relevant to the non-primary sector, further dampening exports. These effects create a balance of payments deficit, leading to exchange rate depreciation. In response, the central bank intervenes by purchasing dollars to limit exchange rate fluctuations, reducing international reserves. To maintain monetary equilibrium, the intervention is sterilized through an expansion of domestic credit (via bond purchases).

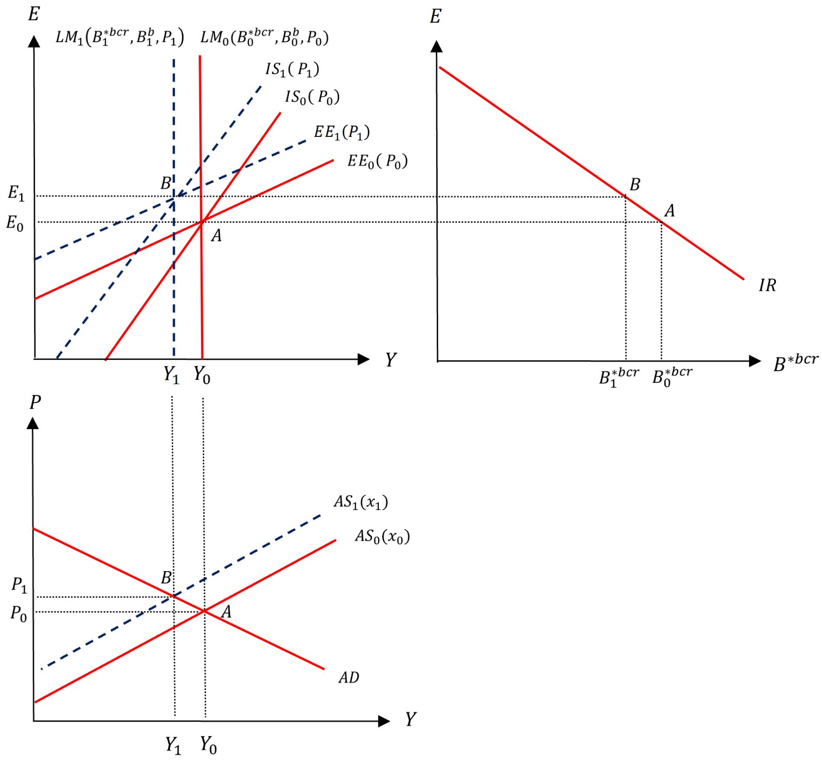
The higher nominal exchange rate partially offsets the decline in non-primary GDP through five channels. (i) A stronger real value of commodity exports increases net import consumption by workers in the commodity sector and raises public spending. (ii) A higher nominal exchange rate raises the real exchange rate relevant to the commodity sector, stimulating private investment. (iii) It also strengthens the real exchange rate relevant to the non-primary sector, improving trade competitiveness and boosting non-primary exports. These effects mitigate, but do not fully offset, the contractionary impact of the supply shock, as shown in the mathematical results.

Additionally, the drop in non-primary GDP has two direct effects. First, lower incomes in the non-primary sector reduce net import consumption, further weakening demand. The resulting decline in fiscal revenue leads to lower public spending, reinforcing the contraction. At the same time, lower money demand creates excess liquidity in the money market, prompting a reduction in domestic credit. This Keynesian multiplier effect amplifies the contraction in demand, deepening the decline in non-primary GDP. The second direct effect appears on the supply side: a shrinking output gap leads to a decrease in the price level. However, this price reduction does not outweigh the initial cost shock, meaning the overall price level rises.

In summary, a cost shock reduces non-primary GDP, raises the price level and the nominal exchange rate, and lowers international reserves.

Figure 13 illustrates the effects of a cost shock. In the aggregate supply and demand space, the shock shifts the aggregate supply curve leftward, resulting in lower output and a higher price level. In the exchange rate-output space, the *IS* and *EE* curves shift left, reflecting exchange rate depreciation and a decline in non-primary production. The *LM* curve moves to the *IS–EE* equilibrium, as domestic credit adjusts. Finally, in the exchange rate-reserves space, intervention policy leads to movement along the curve, illustrating the decline in international reserves.

Figure 13. Cost Shock



$$dY = \left\{ \frac{-k(a_2+\beta_0)[(c_1-m)(1-t)+b^x+t+a_1]}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1+a_1)(1-c_1)-mb^x+m\alpha]} \right\} dx < 0$$

$$dE = \left\{ \frac{k[(1-t)[(1+a_1)(1-c_1)-mb^x]-\alpha[1-m(1-t)+a_1]]}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1+a_1)(1-c_1)-mb^x+m\alpha]} \right\} dx > 0$$

$$dB^{*bcr} = \left\{ \frac{-\beta_0 k[(1-t)[(1+a_1)(1-c_1)-mb^x]-\alpha[1-m(1-t)+a_1]]}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1+a_1)(1-c_1)-mb^x+m\alpha]} \right\} dx < 0$$

$$dP = \left\{ \frac{a_2+\beta_0+k(1-t)[(1+a_1)(1-c_1)-mb^x+m\alpha]}{(a_2+\beta_0)(1+k\lambda Z)+k(1-t)[(1+a_1)(1-c_1)-mb^x+m\alpha]} \right\} dx > 0$$

3. Conclusions and implications

This paper develops a macroeconomic model that incorporates commodity export prices as a key driver of business cycles in Peru. The model accounts for a central bank that uses the interest rate and FX intervention as policy instruments, alongside a ministry of finance that operates under a fiscal rule that endogenizes public spending.

The model is used to simulate the effects of higher commodity prices, a lower interest rate, a relaxation of the fiscal deficit limit, and a supply shock. The results align with the core stylized facts of the Peruvian economy, providing insights into the transmission mechanisms of these shocks and their macroeconomic implications.

References

Alberola, E., Aizenman, J., Moreno, R., and Zampolli, F. (2019). The commodity cycle: Macroeconomic and financial stability implicationsâan introduction. *Journal of International Money and Finance*, 96:259–262.

Blanchard, O. and Fischer, S. (1989). *Lectures on Macroeconomics*. MIT Press.

Dancourt, O. (2009). Choques externos y política monetaria. *Economía*, 32(64):127–173.

Dancourt, O. and Mendoza, W. (2016). Intervención cambiaria y política monetaria en el perú. Technical Report 422, Departamento de Economía, Pontificia Universidad Católica del Perú (PUCP).

Gondo, R. and Vega, M. (2019). The dynamics of investment projects: Evidence from peru. *Journal of International Money and Finance*, 96:324–340.

Lanteri, L. N. (2008). Choques de precios de materias primas, desempeño fiscal y crecimiento. una propuesta de var estructural para la economía argentina. *Estudios Económicos*, pages 163–202.

Magud, N. and Sosa, S. (2015). Investment in emerging markets. we are not in kansas anymore...or are we? Technical report, International Monetary Fund.

Mendoza, W. (2015). Is-lm stability revisited: Samuelson was right, modigliani was wrong. *Economía*, 38(75):123–150.

Mendoza, W. (2017). Salvo el cobre, todo es ilusión. *El Comercio*.

Mendoza, W. (2019). The mundell-fleming model: A dirty float version. Technical Report 477, Departamento de Economía, PUCP.

Pasco-Font, A. (2000). *Políticas de estabilización y reformas estructurales: Perú*.

Rodríguez, G. and Vasallo, R. (2021). Impacto de choques externos sobre la economía peruana. aplicación empírica usando modelos tvp-var-sv. Technical Report 001-2021, Consejo Fiscal del Perú.

Rodríguez, G. and Villanueva, P. (2014). Driving economic fluctuations in peru: the role of the terms of trade. Technical Report 389, Departamento de Economía, PUCP.

Ross, K. and Tashu, M. (2015). Investment dynamics in perú. In Santos, A. and Werner, A., editors, *Peru. Staying the Course of Economic Success*. International Monetary Fund.