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Inflation targeting in open economies: the contradictions of determinacy and stability

Esteban Pérez Caldentey and Matías Vernengo[1]

Abstract

Since 1999, more than half of Latin American countries have put in practice inflation targeting regimes with the objective of maintaining price stability within a low inflation environment. Building on previous work, we argue that the adoption of this monetary regime was the result of a policy shift that began with the Washington Consensus, and which materialized sequentially in increased financial openness, greater exchange rate flexibility, leading eventually to the implementation of inflation targeting. We further sustain that in the case of an open economy, the use of inflation targeting leads to incoherent and contradictory results that severely question its alleged superiority over other monetary frameworks. Finally, we posit the need for comprehensive regulatory frameworks to deal with the complex dynamics and transmission mechanisms that characterize economies that have a high degree of financial openness such as those of Latin America.

Key Words: Closed and open economy, determinacy, exchange rate, inflation targeting, Latin America, macroprudential policy, stability.
JEL Codes: E42, E58, F41.

Introduction

Since 1999, more than half of Latin American countries have adopted inflation targeting regimes with the hierarchical objective of maintaining price stability within a low inflation environment. Building on previous work, we argue that this choice of monetary regime was a result of a policy shift that began with the Washington Consensus, and which materialized sequentially in increased financial openness, greater exchange rate flexibility, and eventually led to the implementation of inflation targeting.[2] We further sustain that in the case of an open economy the use of inflation targeting leads to incoherent and contradictory results that severely question its alleged superiority over other monetary frameworks. Finally, we posit the need for comprehensive regulatory frameworks to deal with the complex dynamics and transmission mechanisms that characterize economies that have a high degree of financial openness such as those of Latin

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[2] See, Pérez Caldentey and Vernengo (2013; 2019; 2020)

America. As a result, countries in the region reverted to accumulation of reserves in dollars and central bank interventions in foreign exchange markets to effectively operate their anti-inflationary policies.

Domestic conditions are the primary focus of inflation targeting. Its proponents also argue that this framework is applicable to an open economy context. According to this view, managing the policy rate of interest can control both domestic spending and exchange rate upward/downward pressures on prices, that is for demand-pull and cost-push factors. The rate of interest is also one of the determinants of financial flows. Inflation or deflation in both a closed and open economy reflect a disequilibrium between *ex ante* savings and investment. As a result, varying the rate of interest with the objective of achieving price stability also ensures its tendency towards equality with the natural rate of interest thus ensuring that 'voluntary savings' are fully used and channeled towards investment.

Hence, the case for inflation targeting and its avowed superiority over other monetary policy regimes rests on the claim that it can deliver a combination of nominal stability with a tendency towards the full employment of resources. This can be proven for a canonical inflation targeting model for a closed economy model built from very stringent conditions with the additional proviso that the monetary authorities react to any inflationary threat by increasing the real rate of interest. The extension of that model to an open economy setting shows that, even in the best of worlds, the dynamics of an open economy puts in doubt the well-behaved properties of inflation targeting frameworks and justify the need for intervention in the external sector. The mainstream recommendation is to complement inflation targeting regimes with macroprudential regulation. However, the main aim of macroprudential regulation is to severe the linkage between savings and investment and it fails to address of challenges posed by the type of open economy dynamics highlighted in this paper.

The paper is divided into seven sections. The second section explains that the adoption of inflation targeting regimes followed a process of financial outward orientation and increased dependency on financial flows that led Latin American countries to adopt more flexible exchange rate regimes. This view is contrary to the traditional narrative that contends that more flexible exchange rate regimes were a consequence of the decision to adopt inflation targeting frameworks. The third section provides some stylized facts on inflation targeting regimes in Latin America. Using a canonical inflation targeting model for a closed economy, the fourth section demonstrates that the stability and determinacy of an equilibrium solution are sufficient to ensure price stability and the tendency towards the full employment of resources. The fifth section extends the canonical model to an open economy. The sixth section shows that the equilibrium solution for the canonical model for an open economy is determinate and stable. Even so, simulation exercises for the open economy model yield ambiguous and incoherent results. These results illustrate the complex dynamics of an open economy even within the context of a very simple model. In guise of conclusion the last section describes the transmission mechanisms that underlie these dynamics and argues for comprehensive regulatory policies beyond those associated with mainstream macroprudential regulation.

Trade and financial openness led to the adoption of inflation targeting

In the 1990s, Latin American governments adopted economic policies associated to the Washington Consensus and its mantra: liberalize, deregulate, and privatize.[3] Latin America became over time an increasingly open region to external trade and foreign finance The countries of the region completed their adhesion to the GATT and World Trade Organization (WTO), significantly reduced their tariff rates, and opened-up their economies.[4]

Around the same time, Latin American countries implemented financial liberalization policies. The arguments supporting external financial liberalization are an extension of the classical static arguments of the gains in international trade to trade in financial assets. As explained by Henry (2007: 887-888): "In the neoclassical model, liberalizing the capital account facilitates a more efficient allocation of resources and produces all kinds of salubrious effects. Resources flow from capital-abundant developed countries, where the return to capital is high. The flow of resources in developing countries reduces their cost of capital, triggering a temporary increase in investment and growth that permanently raises their standard of living."

This set of policies made LAC's performance highly dependent on the vagaries of the external sector and particularly on the behavior of financial flows. Financial flows, including both short and long-term flows, began to increase in the 1990s and continued their upward trend throughout the 2000s, with temporary interruptions caused by the East Asian Crisis (1997-1998) and the Global Financial Crisis (2008-2009) and reached a peak in 2014 (Figure 1). The reduction in financial flows after 2014 is explained in part by the fall in commodity prices and, also responds to the trend decline in GDP growth and investment that the region experienced after 2010.[5]

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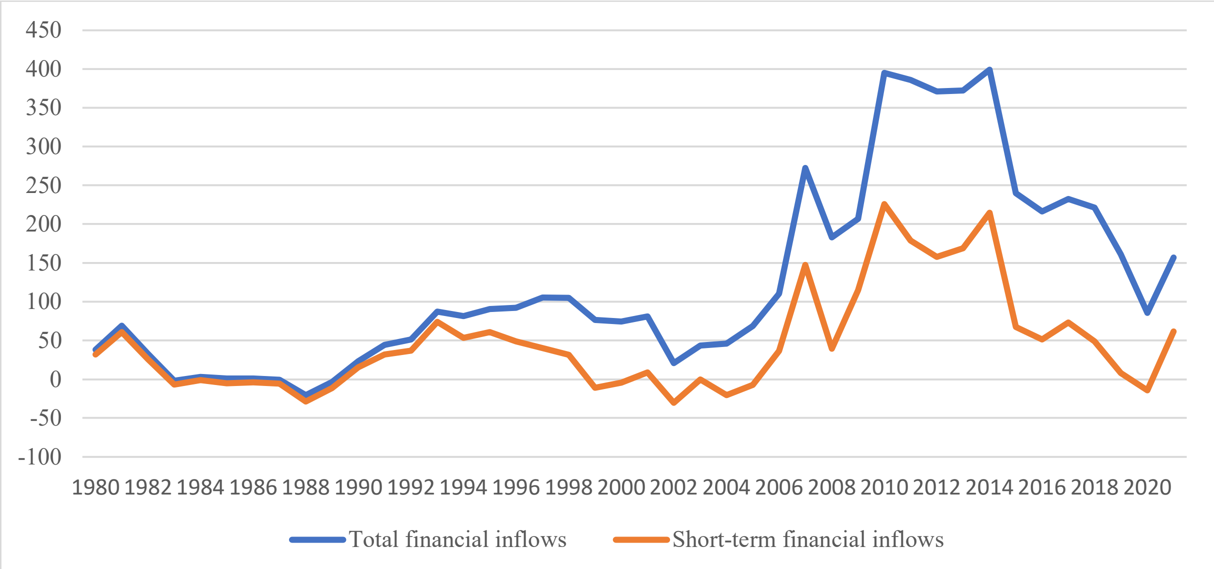
[3] See, Rodrik (2006). The original Washington Consensus consisted of nine reform policies: 1) fiscal discipline; 2) reorientation of public expenditure; 3) tax reform; 4) liberalization of financial markets; 5) competitive exchange rate; 6) liberalization of trade policies; 7) openness to foreign direct investment; 8) privatization; 9) deregulation and secure property rights. See, Williamson (1990).

[4] Between 1995 and 1997 all Latin American countries excepting Cuba adhered to the WTO. The regional average tariff rate fell from roughly 37% in the 1980s to 12% at the beginning of the 1990s. See Moreno-Brid and Pérez Caldentey (2010).

[5] Between 2010 and 2019 the rate of growth of regional GDP and gross formation of fixed capital fell from 6.4% to 0.7%, and from 12.8% to -1.1% respectively.

Figure 1
Latin America: evolution of total financial gross inflows and short-term financial inflows 1980-2021. Billions of US$ dollars



Note: Short-term inflows include portfolio inflows and other investment. Total financial inflows include short-term flows plus foreign direct investment inflows.
Source: Based on ECLAC (2021).

This context pressured governments to adopt more flexible exchange rate regimes to accommodate this greater financial and trade openness. Reliance on financial flows, especially on short-term flows could be disruptive to an economy. It could lead to increasing nominal and real volatility, cause unwanted contractions in the real economy through 'sudden stops,' and be a source of financial bubbles.[6] Moreover, towards the middle and end of the 1990s, the experience of Mexico (1995) and Thailand (1996) showed that adhering to a fixed exchange rate regime within a context of financial liberalization was unsustainable and led to economic and social crises. More flexible exchange rate arrangements could mitigate the impact of these effects and lessen the possibility of crises. Flexible exchange rate regimes were defended, by the mainstream, on the basis that these provided an important shock absorber to external fluctuations preventing the passthrough of their effects to the domestic economy.

The available empirical evidence for the period 1980-200 shows a clear shift from fixed exchange rate regimes or hard pegs to more flexible exchange rate regimes. Currently, El Salvador, Ecuador, Haiti, and Panama have this type of exchange rate regime. At the opposite end the number of countries that have adopted floating exchange rate regimes expanded significantly (Table 1). Note that floating regimes did still imply some degree of intervention and fear floating.

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[6] See Calvo (1998 and 2016).

Table 1
Classification of Latin American countries by exchange rate regimes
1980, 1990, 1995, 2004, 2010, 2020

Year	Fixed exchange rate or "hard peg"	Intermediate regimes	Floating exchange rates
1980	Chile, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Nicaragua, Panama, Paraguay, Venezuela	Mexico, Peru, Uruguay	Bolivia, Brazil
1990	Dominican Republic, Haiti, Honduras, Panama	Bolivia, Chile, Colombia, Costa Rica, Ecuador, Mexico, Nicaragua, Uruguay	Argentina, Brazil, El Salvador, Guatemala, Paraguay, Peru, Venezuela
1995	Argentina, El Salvador, Haiti, Panama, Venezuela	Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Honduras, Nicaragua, Uruguay	Dominican Republic, Guatemala, Mexico, Paraguay, Peru
2000	Argentina, Ecuador, Haiti, Panama, El Salvador	Bolivia, Costa Rica, Honduras, Nicaragua, Uruguay, Venezuela	Brazil, Chile, Colombia, Dominican Republic, Guatemala, Mexico, Paraguay, Peru, Uruguay
2010	El Salvador, Ecuador, Haiti, Panama, Honduras, Venezuela	Bolivia, Costa Rica, Nicaragua,	Argentina, Brazil, Chile, Colombia, Dominican Republic, Guatemala, Mexico, Paraguay, Peru, Uruguay
2020	El Salvador, Ecuador, Haiti, Panama	Bolivia, Costa Rica, Dominican Republic, Honduras, Nicaragua	Argentina, Brazil, Chile, Colombia, Guatemala, Mexico, Paraguay, Peru, Uruguay

Note: Intermediate regimes include crawling pegs, crawling bands, and stabilization arrangements.
Source: Prepared by the authors, based on International Monetary Fund (IMF), *Annual Report on Exchange Arrangements and Exchange Restrictions 2019*, Washington, D.C., 2020 and on the basis of official data.

Some stylized facts of inflation targeting in Latin America

In response to this context of financial openness and greater exchange rate flexibility several countries in Latin American adopted inflation targeting regimes. Inflation targeting is defined by the mainstream as a strategic monetary framework consisting in the public announcement of numerical targets for the rate of inflation, keeping in mind that the hierarchical goal of monetary policy is low and stable inflation, and maintaining a firm commitment to transparency and accountability.[7] Since 1999, more than half of Latin American countries have adopted inflation targeting frameworks (table 2).

[7] See, Bernanke, and Woodford (2005); Bernanke et Al. (1999); Svensson (2007).

Table 2
Inflation targeting regimes in Latin America

Country	Adoption of target	Inflation measure	Target (2022)	Target horizon
Argentina	Jan 17/ Dic. 19	CPI	19.8% and declining	3 years
Brazil	Jun-99	CPI	3.5% (+/- 1.5%)	12 months
Chile	Jan-91	CPI	2%-4% centered at 3%	24 months
Colombia	Sep-99	CPI	2%-4% centered at 3%	None
Guatemala	Jan-05	CPI	4% (+/-1%)	Medium term
Mexico	Jan-99	CPI	3% (+/-1%)	None
Peru	Jan-02	CPI	1%-3%	None
Paraguay	May-11	CPI	4% (+/-2%)	…
Dominican Republic	Jan-12	CPI	4% (+/-1%)	24 months
Uruguay	Jan-05	CPI	3%-6% centered at 5%	24 months
Costa Rica	Jan-18	CPI	3% (+/-1%)	24 months
Jamaica	Apr-21	CPI	4%-6%	3 Fiscal Years

Note: …not available.
Source: Based on official information

While inflation targeting proponents recognize that the primary focus of monetary policy is placed on domestic economic conditions, they argue that this monetary framework also creates the conditions that are consistent with the long-run stability of the exchange rate. According to their analysis inflation targeting provides a superior alternative to exchange rate targeting which makes the economy more vulnerable to external conditions and lacks credibility as a nominal anchor and thus provides 'little guidance to policy makers.'[8] The available evidence shows that, in fact, vulnerability to external conditions may arise in fixed, mixed and floating exchange rate regimes. Moreover, an exercise for the period 1990-2010 for Latin America shows that 71% of all currency crises occurred in period of managed or floating exchange rate regimes.[9]

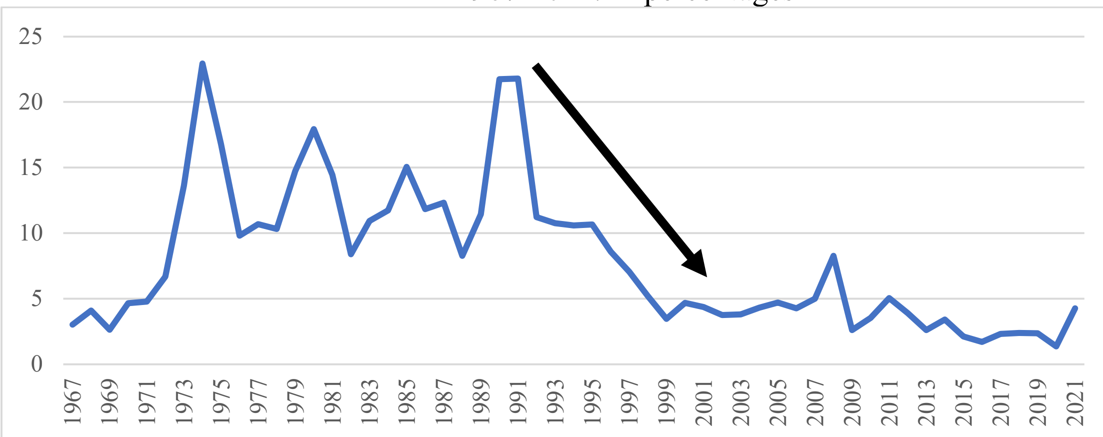
In all cases, Latin American countries adopted inflation targeting regimes within a low inflation context. Between 1971 and 1995, the rate of inflation remained for the most part above the two-digit level. Since 1995, the rate of inflation at the regional level has remained below the two-digit level and even below the 5% level (Figure 2).

An analysis at the country level shows a similar trend. The percentage of countries whose rates of growth of the GDP deflator and headline inflation were above 10% for the period 1970-1995 reached 63% and 72% respectively, declining to 9% and 16% for the period 1996-2021

[8] Bernanke et Al. (1999: 250).
[9] This result was obtained using the database of Laeven and Valencia (2018).

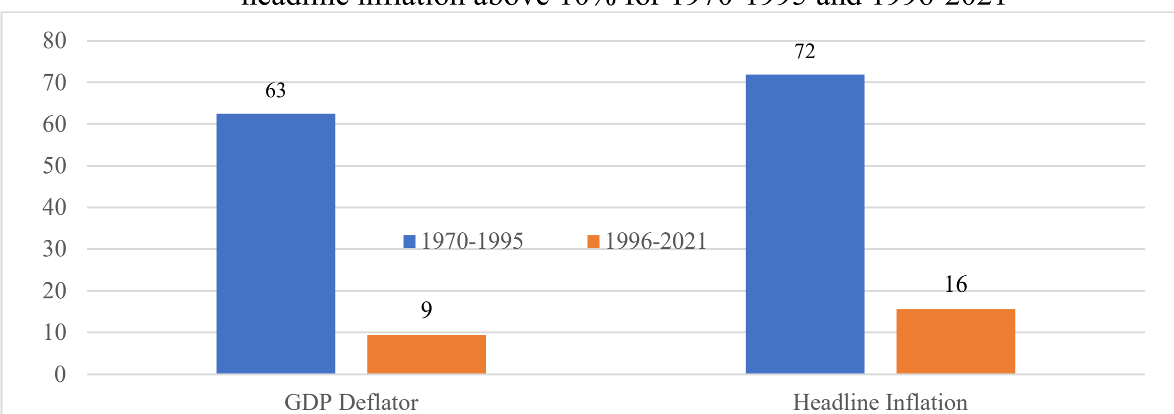
(Figure 3). A further analysis shows that the decline in the rate of inflation between 1970-1995 and 1996-2021 is also present in all the different regions of the developing world.[10]

Figure 2
Latin America and the Caribbean. Annual consumer price inflation
1967-2021. In percentages



Source: World Bank Development Indicators (2022).

Figure 3
Latin America and the Caribbean. Percentage number of countries with GDP deflator and headline inflation above 10% for 1970-1995 and 1996-2021



Source: World Bank Development Indicators (2022).

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Table 3
Headline consumer price inflation for developing regions. 1970-1995 and 1996-2021. Percentages

Developing Regions	1970-1995	1996-2021
East Asia and the Pacific	8.0	3.5
Economic Commission for Africa	85.1	8.4
Latin America and the Caribbean	12.2	3.8
Middle East and North Africa	7.6	3.2
South Asia	9.4	6.1
Sub Saharan Africa	10.9	5.5

Source: World Bank (2022b).

This shows that the decline in inflation was not the result or success of a particular type of monetary framework, but was rather a worldwide phenomenon that was reflected, as expected, in the behavior of prices in Latin America and the Caribbean. The exceptions are Argentina and Venezuela, that returned to high level of inflation in the 2000s.

The practice of inflation targeting consists in varying countercyclically the short-term policy rate of interest so that it converges to the natural rate of interest. This is tantamount to narrowing the gap between *ex ante* savings and investment. In a closed economy setting, this ensures an important result that is the basis for claiming the superiority of inflation targeting frameworks over other monetary policy regimes. This is the combination of nominal stability with the tendency towards the full employment of resources.

As shown in the following section this result can be derived using a canonical inflation targeting model for a closed economy with all the stringent simplifications used in Neo-classical economics. These include among others a continuum of households (which is another name for an infinitely lived consumer), competitive labor markets, ownership of firms by consumers, linear production functions (all inputs are perfect substitutes), and the literal absence of financial markets and financial frictions ('all financial considerations are swept under the rug').[11] The model consists of three equations: an aggregate demand function (IS curve), a Phillips Curve and a Taylor-based interest rate rule equation. The specification of the interest rule equation is crucial to prove that inflation targeting leads to the combination of nominal stability with the tendency towards the full employment of resources. More specifically, the monetary authorities must ensure that any rise in the rate of inflation must be offset by a concomitant increase in the real interest rate.

The canonical targeting inflation model: determinacy and stability[12]

The canonical targeting inflation model is derived from the minimization of a central bank loss function subject to the constraints imposed by the structure of an economy. Formally the loss function can be expressed as a standard optimal control problem, according to which the path of the price level is chosen that minimizes a quadratic loss function subject to the constraint imposed by the linear structure of the economy reflected in a Phillips and IS curves (Cecchetti and Kim, 2006:176). Formally,

$$(1)\ Min\ E_o \sum_{t=0}^{\infty} \eta^t ((y_a - y_n)^2 + \beta(\pi_t - \pi^T)^2 - \gamma(i_t - i_{t-1})^2);$$

.

s.t.

$$(2) \pi_t = \mu E_t \pi_{t+1} + \alpha(y_a - y_n) \qquad \text{(Phillips Curve)}$$

$$(3) y_t^g = -\varphi\,(i_t - E\pi_{t+1}) + E y_{t+1}^g \qquad \text{(IS curve/aggregate demand function)}$$

To analyze the problem of determination and stability, it is useful to start from the system described by equations 2 and 3 to which an additional interest rate rule equation is added: $(4)\ i_t =$

[11] Calvo (2016).

[12] The mathematics follow the methodology of Blanchard and Khan (1980). See also Di Pietro (2011) & Duffy (2007).

$\theta_\pi \pi_t^g + \theta_y y_t^g$ to make the model determinate (θ_π and θ_y represent the elasticities of the nominal interest rate as a result of variations in inflation and output gaps).[13]

More generally, the system of equations 2,3, and 4 is a state space system and can be generalized to a system with n equations in first order expectational differences such as,

$$(5) EX_{t+1} = AX_t + BU_t$$

By substituting Eq. (4) in (3) and with some algebraic manipulation, we can express the expected rate of inflation and level of output at time t+1 ($E_t\pi_{t+1}$; $E_t y_{t+1}$) as a function of the parameters of Eqs (2, 3 and 4) and of the inflation rate and level of output at time t (π_t; y_t). That is,

$$(6) \begin{bmatrix} E_t\pi_{t+1} \\ Ey_{t+1} \end{bmatrix} = \begin{bmatrix} \frac{1}{\mu} & -\frac{\alpha}{\mu} \\ \varphi\theta_\pi - \frac{\varphi}{\mu} & 1 + \varphi\theta_y + \frac{\varphi\alpha}{\mu} \end{bmatrix} \begin{bmatrix} \pi_t \\ y_t \end{bmatrix}$$

The system (6) has two control variables π_t y y_t^g, which means that two roots outside the unit circle are required for the system to have a unique solution. This in turn involves evaluating the system's characteristic polynomial $(p(\lambda) = \lambda^2 - \lambda Tr(A) + Det(A))$ for $\lambda = 1$ y $\lambda = -1$[14] which yields the following results,

$$(7)\ p(1) = \theta_y\varphi \left(\frac{1-\mu}{\mu}\right) + \frac{\alpha\varphi}{\mu}(\theta_\pi - 1) > 0.$$

$$p(-1) = 2 + \theta_y\varphi + \frac{\alpha\theta_\pi\varphi}{\mu} + \frac{\alpha\varphi}{\mu} + \frac{1}{\mu} + \frac{\theta_y\varphi}{\mu} + \frac{1}{\mu} > 0$$

From Eq. (7) it can be easily seen that the characteristic root that corresponds to $p(-1)$ is outside the unit circle. For the system to be determined (i.e., for there to be a single equilibrium solution) it is also necessary that the second characteristic root (the one that corresponds to $p(1)$) is also outside the unit circle.

This requires that the following interest rate rule condition be met: θ_π>1 in Eq. (7). In other words, the necessary and sufficient condition for the determinacy of equilibrium in an inflation targeting regime for a closed economy is that in the face of increases in the inflation rate, (π_t) or in the expected inflation rate $(E\pi_{t+1})$, the authorities react by raising the monetary policy interest rate (i_t) above the increase in the inflation rate (π_t) in such a way as to increase the real interest rate (i.e., $i_t - E\pi_{t+1}$). This is the Taylor principle.

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[13] The Taylor Rule can also be derived from an optimum monetary rule. See for example Svensson (1997) and Woodford (2003). Kapinos and Hanson (2011) follow a similar approach to ours.

[14] See de la Fuente (2000: 480-484).

Thus, for example starting from an equilibrium situation where the inflation rate is equal to its the target ($\pi_t = \pi^T \Leftrightarrow \pi_t^g = 0$) and where output is equal to its natural level ($y_t = y_t^n \Leftrightarrow y_t^g = 0$) assume that an increase in one of the components of output (either as a result of exogenous factors or from a deliberate economic policy decision) will lead to an increase in y_t above its natural level (i.e.,$y_t > y_t^n$). According to equation (3) this will result in an increase in the rate of inflation π_t and the expected inflation rate $E(\pi_{t+1})$ above the target inflation rate (π^T). Under this scenario a more than proportional increase in the interest rate of monetary policy (i_t) relative to the rate of inflation will mitigate inflationary pressures in such a way that $\pi_t \rightarrow \pi^T$ and, at the same time, will make it possible to reduce output so that it approaches its natural level (i.e, $y_t \rightarrow y_t^n$) (Eq. 4 above).

Table 4

Calibration exercise for the canonical inflation targeting model

With and without interest rate equation (IRE)	**Parameters**						**Characteristics roots**		**Number and type of variable**		**Solution**	
	$\boldsymbol{\mu}$	$\boldsymbol{\alpha}$	$\boldsymbol{\varphi}$	$\boldsymbol{\theta}$	$\boldsymbol{\theta_y}$	$\boldsymbol{\theta_\pi}$	$\boldsymbol{\lambda_1}$	$\boldsymbol{\lambda_1}$	**Predetermined**	**Control**	**Determinate or Indeterminate**	**Stability or instability**
1. With IRE	**1.0**	**1.0**	**1.0**		**0.5**	**1.5**	**1.50**	**2.0**	**0**	**2**	**Determinate**	**Stable**
2. With IRE	1.0	1.0	1.0		0.5	**0.5**	0.72	2.78	0	2	Indeterminate	
3. Without IRE	0.99	0.34	0.5		…	…	0.66	1.5	0	2	Indeterminate	
4. Without IRE	0.99	0.5	0.5		…	…	0.60	1.6	0	2	Indeterminate	
5. Without IRE	1.0	1.0	1.0		…	…	0.38	2.6	0	2	Indeterminate	

Source: Own elaboration based on Matlab with Dynare.

The determinacy and stability of the model can be illustrated didactically by calibrating the model including the interest rate equation (IRE) assuming θ_π>1 y θ_π<1 and with/without the interest rate equation (IRE). The chosen values of the parameters correspond to the standard values and ranges used in the inflation targeting literature. For analytical purposes and without loss of generalization it is assumed that $\pi^T = 0$ (i.e., the inflation target is equal to 0), an assumption that will be maintained throughout the rest of the calibration exercises. Based on these parameters, we computed the characteristic polynomial and obtianed the characteristic roots (See Table 4).[15]

As shown in Table 4, the canonical inflation targeting model (model with IRE and with θ_π>1) has two unit-roots outside the unit circle and therefore the model has a unique solution and is stable. Table 4 also illustrates the importance of the assumption, θ_π>1, since when θ_π<1, as assumed in the second calibration exercise, the model has one root inside the unit circle and another outside the unit circle and is therefore indeterminate. Obviously, without an interest rate rule, there is no possibility of determinacy or stability as evidenced by the last three calibration exercises.

Determinacy and stability permit the derivation of the fundamental properties of inflation targeting frameworks on which its alleged superiority rests *vis-à-vis* other monetary policy regimes, namely the coexistence of price stability with a tendency towards the full employment of resources.[16]

Extending the canonical inflation-targeting model to an open economy

The canonical closed economy model can be extended to the case of an open economy by introducing the nominal exchange rate into the inflation equation, and the real exchange rate into aggregate demand function.[17]

The real exchange rate (q_t) enters the model in the same way as output (y_t) and the inflation rate (π_t), that is, as an expectational or control variable. The real exchange rate is specified as a function of the expected future real exchange rate (q_{t+1}), of the domestic (r_t) and external (r_t^e) real interest rate differential and as a function of an exchange rate risk premium (z_t). Formally,

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[15] The procedure was performed with MATLAB. Version 7.

[16] This is another way to express the so-called 'divine coincidence' (Blanchard and Gali, 2005).

[17] Usually, much of the analysis specifies a canonical model under this hypothesis, the influence of the exchange rate is not included as an argument in the objective function of the central bank. Rather, it affects the target function through its direct impact on inflation and/or output gaps $(\pi_t - \pi^T \; and \; y_a - y_n)$. This presupposes, that monetary authorities, act only when the effect of exchange rate variations is manifested in changes in these gaps (De Gregorio, Tokman Valdés, 2005). This view is supported by the fact that the central bank should be concerned with the exchange rate, *per se*, only when its variation affects price stability. In addition, including the exchange rate in the objective function of the central bank can pose inconsistencies in the management of monetary policy both insofar as it entails, even implicitly, the presupposition that the monetary authority has two nominal anchors (the price level and the exchange rate). (Soikkeli, 2002; Stephens 2006). See Caputo (2009) for a discussion on the inclusion of the exchange rate in inflation targeting models.

$$(8) q_t = \phi E_t q_{t+1} - \varrho(r_t^* - r_t) + \sigma z_t \Leftrightarrow$$

$$q_t = \phi E_t q_{t+1} - \varrho[(i_t^* - E_t \pi_{t+1}^*) - (i_t - E_t \pi_{t+1}) + \sigma z_t$$

Where:

$i_t = nominal\ domestic\ interest\ rate.$
$i_t^* = nominal\ external\ interest\ rate.$
$\pi_t^* = external\ inflation\ rate.$

$\phi, \sigma > 0, \ \ \varrho < 0.$

The specification of the real exchange rate is derived from the portfolio approach to the exchange rate. It postulates that arbitrage in asset markets adjusts the exchange rate. According to this approach, the exchange rate behaves, no longer as the price of a good, as in the more traditional purchasing power parity theory (PPP), but as that of an asset. That is, it responds to potential capital gains or losses in future markets. In this approach, the future exchange rate (e_t^f) is equal to the current nominal exchange rate plus its expected variation (appreciation or depreciation) (i.e., $e_t^f = e_t + \Delta e_t^e$). Arbitrage in asset market ensures that the equilibrium condition, $e_t(1 + i_t) = e_t^f(1 + i_t^*)\ is\ met.$ From this it follows that, $e_t = \frac{\Delta e_t^f}{(i_t - i_t^*)}$ giving way to the interest rate parity theorem in its two variants (covered and uncovered interest parity).[18]

The first variant (covered interest parity) refers to the possibility of 'hedging' against future variations in the exchange rate and thus avoids incurring in losses and can, with due qualifications, be applicable to developed financial and futures markets. In the case of the uncovered interest parity, changes in the exchange rate can only be 'hedged' by variations in the interest rate differential. Thus, the interest differential varies when expected variations in the exchange rate occur.

Starting from the strongest variant interest rate parity theorem vriant, the uncovered interest rate parity, the differential between the nominal domestic and external interest rates $(i_t - i_t^*)$ is equal to the difference between the expected future and current spot nominal exchange rate $(E_t e_{t+1} - e_t)$. That is,

$$(9) i_t - i_t^* = E_t e_{t+1} - e_t$$

[18] See Taylor & Eatwell (2000)

This implies that interest rates (rates of return) in different financial centers can be the same even if they were not covered by a futures contract. If the covered interest parity condition is added to the uncovered parity theorem, then the equation indicates that the exchange rate established in the futures market is equal to the expected exchange rate ($E_t e_{t+1} = f e_{t+1}$).

However, there is no reason for this condition to be fulfilled even under the assumption of perfect mobility of financial flows. In fact, perfect mobility of financial flows does not imply perfect substitution of financial assets. As Smithin (2003, p. 166) explains:

> "In practice, even in conditions in which financial capital is completely mobile in a technical sense, this condition can only hold up to the inclusion of what is usually called a 'currency risk premium' (Frankel, 1992), which is required by foreign investors if they are to hold assets denominated in the domestic currency. Even if financial capital can cross borders electronically 'at the push of a button', it must still be the case that assets denominated in different currencies, and whose exchange rates are liable to change, are still not perfect substitutes. Even given 'perfect capital mobility' there need not be 'perfect asset substitutability'. It continues to matter, in other words, precisely whose promises to pay the investor holds at any given moment (US dollars, Canadian dollars, Mexican pesos, Euros or yen)".

Following this reasoning equation 9 can be modified to include a foreign exchange risk premium (z_t) such that,

$$(10) i_t - i_t^* = E_t e_{t+1} - e_t + z_t$$

From (10) the equation for the nominal exchange rate is obtained,

$$(11) e_t = E_t e_{t+1} - (i_t - i_t^*) + z_t$$

And expressing Eq. (11) in real terms yields the following expression for the real exchange rate (q_t),

$$(12) q_t = \phi E_t q_{t+1} - \varrho(r_t - r_t^*) + \sigma z_t$$

Equation (12) indicates that the real exchange rate increases (depreciates) in the face of increases in the external real interest rate. (r_t^*), the foreign exchange risk premium (z_t) and of decreases in the domestic real interest rate (r_t). It also shows that real domestic interest rates can deviate from external interest rates by a proportion equivalent to the appreciation of the real exchange rate (i.e., $r_t - r_t^* = E_t q_{t+1} - q_t \Rightarrow r_t > r_t^* = q_t < E_t q_{t+1}$).

Determinacy and stability in an open economy

According to the above, the inflation targeting model for an open economy consists of the following equations,

$$(2')\pi_t = \mu E_t\pi_{t+1} + \alpha(y_a - y_n) + \omega\Delta e_t + \varepsilon_{1t}$$

$$(3')y_t^g = -\varphi\,(i_t - E\pi_{t+1}) + Ey_{t+1}^g + \delta q_t + \varepsilon_{2t}$$

$$(4)i_t = \theta_\pi\pi_t^g + \theta_y y_t^g$$

$$(12')q_t = \phi E_t q_{t+1} - \varrho(r_t - r_t^e) + \sigma z_t + \varepsilon_{3t}$$

We further assume that the real interest rate r_t is expressed in Fisherian terms as the difference between the nominal interest rate (i_t) minus the expected rate of inflation ($E_t\pi_{t+1}$). That is,

$$(13)r_t = i_t - E_t\pi_{t+1}$$

On the other hand, the nominal exchange rate (e_t) can be expressed as the difference between the real exchange rate (q_t) and the difference between the domestic (P_t) and external price level (P_t^e),

$$(14)e_t = q_t + P_t - P_t^e$$

Expressing the model as a system of first-order expectational differences we have,

$$\begin{bmatrix} 1 & \varphi & 0 \\ 0 & \mu & 0 \\ 0 & \varrho & \phi \end{bmatrix}\begin{bmatrix} E_t y_{t+1} \\ E_t\pi_{t+1} \\ E_t q_{t+1} \end{bmatrix} = \begin{bmatrix} (1-\varphi\theta_y) & \varphi\theta_\pi & -\delta \\ -\alpha & (1+\omega) & \omega \\ \varrho\theta_y & \lambda\theta_\pi & 1 \end{bmatrix}\begin{bmatrix} y_t^g \\ \pi_t \\ q_t \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 \\ 0 & -\omega & 0 \\ -\varrho & 0 & -\sigma \end{bmatrix}\begin{bmatrix} r_t^e \\ q_{t-1} + \pi_t^e \\ z_t \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix}$$

Establishing the determinacy/indeterminacy and stability/instability of this system requires analyzing the properties of the matrix which contains the relevant parameters,

$$A = \begin{bmatrix} (1-\varphi\theta_y & \varphi\theta_\pi & -\delta \\ -\alpha & (1+\omega) & \omega \\ \varrho\theta_y & \lambda\theta_\pi & 1 \end{bmatrix}\begin{bmatrix} 1 & \varphi & 0 \\ 0 & \mu & 0 \\ 0 & \varrho & \phi \end{bmatrix}^{-1} =$$

$$
= \begin{bmatrix} \theta_y\varphi + \dfrac{\alpha\varphi}{\mu+1} & \theta_\pi\varphi - \dfrac{\varphi(\omega+1)}{\mu} & -\delta - \dfrac{\omega\varphi}{\mu} \\ \dfrac{-\alpha}{\mu} & \dfrac{\omega+1}{\mu} & \dfrac{\omega}{\mu} \\ \dfrac{\varrho\theta_y}{\phi} + \dfrac{\alpha\varrho}{\mu\phi} & \dfrac{\varrho(\omega+1)}{\mu\phi} + \dfrac{\varrho\theta_\pi}{\phi} & \dfrac{1}{\phi} - \dfrac{\varrho\omega}{\mu\phi} \end{bmatrix}
$$

Following Brooks (2004), the necessary and sufficient conditions for the determination of a 3x3 square matrix are:[19]

$$|D(A)|>1$$

$$|T(A) + D(A)| > M(A) + 1$$

$$|D^2(A) + T(A)D(A) + M(A)| > 1$$

Where, D = determinant, T = trace and M = the sum of the principal minors of order 2 of the matrix A. For our particular case the determinant (D), trace (T) and the minor main order 2 and its determinant are:

$$D(A) = \frac{\omega + \theta_\pi(\alpha\varphi + -\varrho\omega + \omega\varphi + \alpha\varrho\delta) + \theta_y(\varphi + \varrho\delta + \omega\varphi + \varrho\omega\delta) + 1}{\mu\phi}$$

$$T(A) = \theta_y\varphi + \frac{1}{\phi} + \frac{(\omega + 1 + \alpha\varphi)}{\mu} - \frac{\varrho\omega}{\mu\phi} + 1$$

$$M(A) = \frac{\omega + \theta_y\varphi(1+\omega) + \alpha\varphi\theta_\pi + 1}{\mu}$$

Due to the complexity involved in obtaining an analytical solution, we proceeded to analyze the determination and stability of the system by calibrating the model according to two general scenarios.

[19] See also Ascari and Ropelle (2009).

Table 5
Calibration exercise for the inflation targeting model in open economies (determination and stability analysis)

Parameters for the closed economy model					Parameters associated with the exchange rate				Variables		D	T+D	M+1	$D^2 + TD + M1$	λ_i
μ	α	φ	θ_y	θ_π	ω	δ	ϕ	ϱ	Predetermined	Control					
Quasi-closed economy															
1	0.34	0.5	0.5	1.5	0.02	0.02	0.02	0.02	0	3	102.0	154.8	3.0	1.57+e04	1.50 1.35 49.97
Open economy															
1	0.34	0.5	0.5	1.5	0.6	0.6	0.6	0.6	0	3	4.7	9.2	3.9	46.7	1.49$\pm$0.94i 1.53+0.00i r=1.75 y 1.53

Source: Own elaboration based on Matlab with Dynare.

The first scenario contemplates the case in which open economy conditions are not relevant to the trajectory and determination of equilibrium (Quasi-Closed Economy Scenario). According to this scenario, on the one hand, the parameters corresponding to the case of a closed economy are maintained at values similar to those in Table 4: $\mu = 1;, \alpha = 0.34, y\ \varphi = 0.5;\ \theta_y = 0.5\ y\ \theta_\pi = 1.5$. On the other hand, the parameters for an open economy are set at very small, insignificant, values. For analytical purposes $\omega, \varrho, \phi\ y\ \delta$ are equal 0.02.[20]

The second scenario includes an open economy context explicitly and consists of assuming that the prevailing conditions in the external sector are as important as those of the domestic economy (Open Economy Scenario). In this scenario r, $\mu = 1;, \alpha = 0.34, y\ \varphi = 0.5;\ \theta_y = 0.5\ and\ \theta_\pi = 1.5$; and $\omega, \varrho, \phi, \delta = 0.6$.

In both scenarios, as shown in Table 5, the conditions to establish the determinacy of the system are met. In addition, to complement the analysis, the characteristic vectors corresponding to the characteristic polynomial of the matrix containing the parameters were computed. The solutions when both real and complex roots are considered show that the system is stable.[21]

Once the conditions required for determinacy and stability were met, the dynamics of the open economy were analyzed by simulating its behavior through standard exogenous shocks. $(\varepsilon_{1t}, \varepsilon_{2t,} \varepsilon_{3t}/z_t)$ in the inflation equation (π_t), real exchange rate (q_t) and nominal interest rate (i_t). The exercise also contemplates shocks to the real exchange rate. The shocks are specified as,

(15)

$$\varepsilon_{1t} = \rho_{1t}\varepsilon_{1t-1} + u_{1t}$$
$$\varepsilon_{2t} = \rho_{2t}\varepsilon_{2t-1} + u_{2t}$$
$$\varepsilon_{3t}/z_t = \rho_{3t}\varepsilon_{3t-1} + u_{3t}$$

Where, $u_{it-n} \sim N(0,1)\ and\ 0 \leq \rho_{it-n} < 1$

In all simulations shocks were assumed to change by one standard deviation. All the simulations were carried out with the Dynare program. In the quasi-closed economy scenario, the

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[20] The parameter $\alpha = 0.34$ it is derived from Neoclassical microeconomic foundations. See Sienknecht (2011).

[21] In the case of real solutions for all cases considered there are three characteristic vectors greater than one corresponding to the three control variables $(E_t\pi_{t+1}, E_t y_{t+1}, E_t q_{t+1})$. In the case of complex roots, the determination of stability conditions first requires the transformation of Cartesian coordinates to polar coordinates which allows to transform any complex number into Cartesian form (i.e., $\alpha \pm i\theta$) to an equivalent trigonometric form $(r(\cos w \pm isen\omega))$. According to this method the stability condition is given by the modulus of the complex number $(r = +(\alpha^2 + \theta^2)^{\frac{1}{2}}$ and requires that $r > 1$.

parameters (ρ_{it}) associated with the inflation and the interest rate ($\varepsilon_{1t}, \varepsilon_{2t}$) take on a value equal to 1, while in the case of the exchange rate, the parameter associated with the shock in the exchange rate (ε_{3t}) has a value of 0.2. In line with the logic of the model the shocks ($\varepsilon_{1t}, \varepsilon_{2t,}\varepsilon_{3t}/z_t$) are uncorrelated.

In the open economy scenario, the parameters associated (ρ_{it}) with inflation and the interest rate ($\varepsilon_{1t}, \varepsilon_{2t}$) take on a value equal to 1, while in the case of the exchange rate, the associated parameter with the shock in the exchange rate (ε_{3t}) takes on a value of 1.5. In other words, in the second case, the conditions of the external sector have a greater weight in the economy than those associated with domestic conditions.

The results of the simulations for both scenarios are summarized in the two correlation matrices (Tables 6 and 7) which show the responses of inflation, output and the interest rate to the respective shocks. Since, following the logic of inflation targeting models (dynamic stochastic general equilibrium models) the responses of the variables of inflation, output, and the short-term interest rate to shocks are modeled in terms of deviations from their natural levels, equilibrium is characterized by the fact that $y_t^g = 0 \iff y_t = y_n\ (natural\ level\ of\ output)$; $\pi_t = 0$ (since it is assumed in this analysis that the inflation target, $\pi^T = 0$); and $q_t = 0 \Leftrightarrow q_t = q_n$ (natural level of the real exchange rate).

As expected, the shocks in the inflation rate and interest rate ($\varepsilon_{1t}, \varepsilon_{2t}$) have a negative correlation with the product gap (y^g). In the same way the inflation rate and the interest rate (π_t, i_t) have a negative correlation with the product gap (y^g) which obviously implies that the interest rate and inflation (in terms of deviations) move in the same direction. Thus, an increase in the inflation rate causes an increase in the nominal interest rate higher than the inflation rate (i.e., the real interest rate increases due to the stability condition mentioned above), $\theta_\pi > 1$) which generates a contraction in the product.

However, a shock to the the real exchange rate equation yields ambiguous results. A associated, say, with an increase in the exchange rate risk premium (as proposed in the exchange rate specification (ε_{3t}/z_t)) is positively correlated with inflation and the interest rate. At the same time, the real exchange rate shock has a positive effect on output, despite the rise in the interest rates.

Table 6: Correlation matrix for quasi-closed economy
$\mu = 1;, \alpha = 0.34, y\ \varphi = 0.5;\ \theta_y = 0.5;\ \theta_\pi = 1.5;\ \omega, \varrho, \phi, \delta = 0.6; \rho_{it-n}$=0.6;

	y^g	π_t	i_t	rer_t	ε_{1t}	ε_{2t}	ε_{3t}/z_t
q_t^g	0.83	-0.96	-0.77	1.0	…	…	…
ε_{1t}	-0.97	0.83	0.94	-0.92	1.0	…	…
ε_{2t}	-0.22	-0.55	0.23	0.35	0.00	1.0	…
ε_{3t}/z_t	0.05	0.06	0.22	0.11	0.00	0.00	1.0

Source: Own elaboration based on Matlab with Dynare.

Table 7: Correlation matrix for open economy
$\mu = 1;, \alpha = 0.34, y\ \varphi = 0.5;\ \theta_y = 0.5;\ \theta_\pi = 1.5;\ \omega, \varrho, \phi, \delta = 0.6;$

	y^g	π_t	i_t	rer_t	ε_{1t}	ε_{2t}	ε_{3t}/z_t
q_t^g	0.81	-0.42	0.24	1.0	…	…	…
ε_{1t}	-0.92	0.77	0.50	-0.71	1.0	…	…
ε_{2t}	-0.21	-0.51	0.12	0.27	0.0	1.0	…
ε_{3t}/z_t	0.32	0.40	0.86	0.65	0.0	0.0	1.0

Source: Own elaboration on Matlab with Dynare.

The same phenomenon occurs with an increase in the real exchange gap which (q_t^g) is positively correlated with the product gap (y^g) indicating that a depreciation (appreciation) leads to an increase in output above (below) its natural level. At the same time, the real exchange rate is positively correlated with the interest rate. In this case as in the case of the shock (ε_{3t}/z_t) to the real exchange rate eqaution, the product increases (decreases) in the face of a depreciation (appreciation) despite the increase in the interest rate.

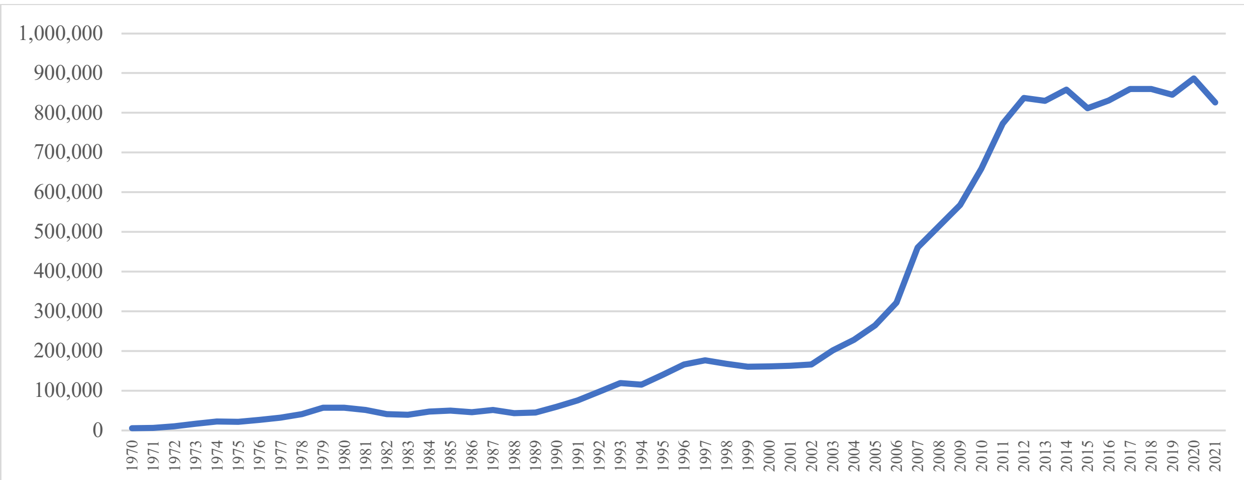
If the shock ceases to be transitory, unless the real exchange rate is stabilized, there will be a situation of divergence of the product with respect to its natural level. In this case, stability produces de facto unstable results.

The above analysis shows that in an open economy, the canonical inflation targeting model has a single (determined) solution and that this solution is stable. However, even if it is determined and stable, the model produces, in the case of an open economy with a flexible exchange rate, contradictory and incoherent results that call into question its core properties. These include, among the most important, that the output gap is both positive and negative, that variations in the nominal and real interest rate do not impact on the output gap and that the interest rate may be inoperative as an instrument to stabilize aggregate demand.

Open economy dynamics and regulation

The empirical analysis shows that the dynamics of an open economy questions the well behaved, properties of inflation targeting frameworks. The open economy context puts in doubt countercyclicality and, also, the possibility of achieving (in the best of worlds) full employment with price stability. The analysis underscores the need to control for movements in external variables such as the exchange rate premium and in the exchange rate itself which are obviously tied to internal conditions but also, and to a great extent, to external financial conditions.

Figure 4
Latin America and the Caribbean. International Reserves (including Gold)
1970-2021. In millions of US$ dollars



Source: World Bank (2022)

In the case of Latin America and the Caribbean, as in other parts of the developing world, the use of capital controls, has been rendered extremely difficult, if not impossible, to implement due to the existing web of trade and investment agreements. As an alternative option, countries have, in general, opted to increase international reserves as the main external buffer mechanism and to a lesser degree have relied on exchange rate interventions. Between 2000 and 2021, the stock of international reserves for the Latin American and Caribben region expanded from US$ 163 to 826 billion dollars (Figure 4).

The open economy inflation targeting model used in this paper exemplifies only a part of the complications introduced by the external sector. The focus has been placed on the relationship between the exchange rate premium, the real exchange rate and output, the interest policy rate, and the rate of inflation. But obviously for countries, such as those of Latin America and the Caribbean, which have a high degree of trade and financial openness, there are further effects and ramifications for the rest of the sectors including the government, the financial, and the non-financial corporate sector.

The exchange rate is a key variable in the transmission of impulses that emanate from the rest of the world, especially the developed world, and to which developing countries in cluding Latin American ones, are highly vulnerable due to the growing dependence of the government, the financial and the non-financial corporate sectors on international capital markets and thus on external debt for finance. Variations in the nominal exchange rate (which is directly affected by the exchange rate premium) have a statistically significant correlation coefficient with country risk: exchange rate depreciations are accompanied by increased sovereign risk. This increases the cost of external indebtedness while, at the same time, narrows the policy space to expand aggregate demand.

Exchange rate depreciations also have negative effects on the balance sheets of financial institutions and of non-financial corporate sector by increasing liabilities. These effects are compounded when collaterals are denominated in local currency and, also, by the fact that these sectors operate with currency mismatches (See, Borio, 2019; Chui et al. 2016, 2018). In addition, the empirical evidence shows that in the case of the non-financial corporate sector, leverage and investment exhibit a negative relationship beyond a certain threshold (Vernengo and Pérez Caldentey, 2020; Pérez Caldentey and Vernengo, 2021). Finally, exchange rates are distributive variables, and depreciation affects the real wage, and has important impacts on economic growth (Pérez Caldentey and Vernengo, 2017) and inflation.

These transmission mechanisms can lead to a context of financial fragility creating significant challenges for the management of monetary policy through inflation trageting. The existing consensus in mainstream economics recommends complementing the use of the short-term rate of interest with 'macroprudential regulatory tools' to address the existence of financial vulnerabilities.

However, in practical terms, macroprudential regulation consists in a series of measures not necessarily interconnected or articulated, which focus mostly on the banking system, to limit credit expansion, improve solvency, decrease interconnectedness, and avoid excessive leverage. As explained by Shin (2010) the main objective of macroprudential regulation is to ensure that the financial system conforms to its traditional intermediary function, by severing the link between voluntary savings and investment and avoiding disruptions in the chain of causation running from savings to investment. Thus the ultimate objective of macroprudential regulation is simply to facilitate the convergence of the market to the natural rate of interest. In this sense, it merely reinforces the logic of the inflation targeting model which, when applied to an open economy, leads to incoherent and contradictory results as shown in this paper.

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