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Inflation targeting when devaluations are contractionary

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In the New Consensus model, when monetary policy is sufficiently sensitive to changes in the rate of inflation, a standard Taylor rule can effectively pin down inflationary expectations and stabilize the economy at practically no output cost. It is often believed that assuming an open or a closed economy does not matter. This view is incorrect, and the result depends critically on the nature of devaluations. When devaluations are contractionary, standard Taylor rules do not work. This result holds in a standard New Consensus model and in an amended version of it. We suggest that a successful inflation-targeting regime for an open economy cannot rely only on the manipulation of a short-term interest rate.

Keywords: *inflation targeting, rational expectations, contractionary devaluation, Phillips curve, monetary policy rules*

JEL codes: *E31, E52, E58*

1 INTRODUCTION

Inflation targeting has become the poster-child for macroeconomic regimes, both in developed and non-developed economies. It is often argued that if monetary policy is sufficiently sensitive to changes in the rate of inflation, a Taylor rule can effectively pin down inflationary expectations and stabilize the economy at practically no output cost.

In an open economy set-up, it is usually prescribed that the exchange rate should be allowed to float as freely as possible, except when non-fundamental shocks hit the economy. Capital controls are thus discouraged, and reserve accumulation limited to the minimum necessary to curtail excessive volatility.

Implicit in this view is the presumption that exchange-rate movements are stabilizing, which implies that devaluations are short-run expansionary. But this is often not the case. The phenomenon of contractionary devaluations is certainly not uncommon in the Latin American context, including the most recent period during which several central banks adopted inflation targeting (the best examples are Brazil, Chile, Colombia, Mexico, and Peru).

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For example, in the recent Brazilian case, when the real exchange rate depreciated,[1] inflation accelerated, while output was stagnant, both during 2002–2003, and more recently, in 2014–2016 (see Serrano and Summa 2016). Although factors such as fiscal policy and terms of trade were probably at play, the possibility of contractionary effects of devaluations in modern Brazil should not be dismissed *a priori*.

Argentina represents another interesting example. During 2016 the economy contracted by about 3 percent due to a large exchange-rate depreciation in December 2015. The Central Bank of Argentina is currently moving towards the adoption of an inflation-targeting framework.[2] It thus make sense to ask: what are the implications of contractionary devaluations when inflation targeting is operative? Are Taylor rules a reliable approach to achieve macroeconomic stability?

This paper argues that the answer to both questions is more likely to be 'no.' Consider for example an appreciation of the nominal exchange rate that translates into a real appreciation. If demand depends negatively on the real exchange rate (the most likely case if devaluations are contractionary), then the appreciation generates further demand pressures, in a clearly destabilizing fashion. Now let us assume that the central bank targets inflation using a short-term interest rate. When a shock increases inflation, the central bank attempts to control inflation by increasing the real interest rate, but then the exchange rate appreciates, and demand increases, so the system is not stabilized.

The relation between contractionary devaluations and monetary policy rules *à la* Taylor is of particular interest for post-Keynesian monetary theory. Indeed, post-Keynesian theorists have always been very suspicious of the idea of fine-tuning the economy by relying mainly on the manipulation of a short-term interest rate. There are at least two points of view, identified as the 'activist' and the 'parking-it' approaches (Rochon 2007; Rochon and Setterfield 2007). While the 'parking-it' view argues that the nominal interest should be kept fixed as much as possible, the 'activist' approach considers it a possible tool to fine-tune the economy, albeit probably less effectively than fiscal and income policies.[3] Almost all post-Keynesians would agree that monetary policy by itself is a very limited instrument, but the proposers of the 'activist' view would not discard it as a counter-cyclical tool, provided that it is used in combination with other policies.

This paper vindicates both post-Keynesian positions. Although some of the modeling assumptions adopted here are clearly at odds with the post-Keynesian tradition, the analysis of a standard model shows that monetary policy based on a standard Taylor rule does not imply the determinacy of the equilibrium path when devaluations are contractionary, and hence inflation expectations are not well anchored by the monetary policy. Moreover, we show that adopting a rule where the nominal interest is kept fixed, consistent with the 'parking-it' view, will uniquely define the equilibrium path.[4]

1. In this paper we follow the Latin-American convention. We define the nominal exchange rate, e, as the number of units of the domestic currency that are needed to buy a unit of the foreign currency. A depreciation means that e goes up, and so on. Because the original literature on contractionary devaluations was developed for a world of fixed or semi-fixed exchange rates, the term 'devaluation' was more appropriate. Here we use 'depreciations' ('appreciations') and 'devaluations' ('revaluations') interchangeably.
2. All the data for Argentina were obtained from the revision of Article IV at the IMF during 2016.
3. From the second group, some have even suggested that inflation targeting is compatible with post-Keynesian economics, provided that the appropriate policy mix of policies is adopted. See Tadeu Lima and Setterfield (2008), as well as Mota dos Santos (2011).
4. These results will hold using a forward-looking perfect foresight model. Using different assumptions, the implications are similar: a standard Taylor rule may imply instability, while a 'parking-it' approach will produce stability.

To summarize, the main findings of this paper can be described as follows. When devaluations are contractionary and inflation is forward-looking the equilibrium path is not unique. This result holds under a large number of different scenarios, including monetary policy that features lags, with inflation and output-gap targets, core vs full CPI target, as well as when the output gap is endogenous. When inflation is backward-looking and the output gap is endogenous, instability is possible even if devaluations are not contractionary. Finally, a simpler policy rule where the nominal rate is fixed forever will stabilize the economy.

This paper is structured as follow. Section 2 presents a brief literature review. Section 3 develops a model of a small open economy that uses inflation targeting, assuming that prices are set in a forward-looking manner and that devaluations have contractionary effects on output. Section 4 extends the previous section model to make it more post-Keynesian-friendly, by adding 'sticky-inflation' and an endogenous output gap. Finally, Section 5 concludes.

2 REVIEW OF THE RELATED LITERATURE

This paper combines insights from two main theoretical bodies. The first is the contractionary devaluation hypothesis, and the second is the so-called 'New Consensus' macroeconomic model. We overview the contributions from both bodies, to illuminate the version of the model that we present in Sections 3 and 4. This literature review is not exhaustive, but we will cover the main points.

In the Structuralist literature, it is often assumed that devaluations have contractionary effects, at least in the short-run (Díaz-Alejandro 1965; Krugman and Taylor 1978). At the empirical level, the findings are mixed. For instance, Bebczuk et al. (2006) finds that devaluations are contractionary on highly dollarized economies, but expansionary otherwise, while other studies suggest that devaluations are expansionary when the span of time considered is long enough (see for example Edwards 1986).[5]

The few works that assume that devaluations are contractionary usually fail to grasp the implications for stability and for the dynamics of inflation. An exception is perhaps a relatively less well-known paper by Calvo (1983b) that analyses the implications of the contractionary devaluation hypothesis for a system of predetermined exchange rates (the rate of devaluation is given, but not necessarily equal to zero).[6] Using a rational expectations model where firms set their prices in a forward-looking fashion, Calvo finds that the equilibrium path is not uniquely determined: there are an infinite number of dynamic paths that converge to equilibrium. Under such conditions the level of the endogenous variables is not well defined in the short run and there is no 'anchor' for the variables of the system.

The contractionary devaluation hypothesis was developed during a period when fixed or semi-fixed exchange rates were the norm. Nowadays exchange-rate regimes display higher degrees of flexibility, and the adoption of flexible exchange rates with small doses of intervention in the foreign exchange market plus inflation targeting seems to be a common approach.

The contractionary effects of devaluations could still be present even if the exchange rate is allowed to float more or less freely. For example, a relatively recent work by

5. See Bahmani-Oskooee and Mitez (2003) for a literature review.
6. Taylor, L. (2004, ch. 9) also discussed a small model where contractionary devaluation generates a small cycle around the equilibrium point, also assuming a predetermined rate of devaluation.

Galindo and Ros (2008) uses VAR analysis and finds that devaluations have weak contractionary effects on output for the Mexican economy in the recent period, at least in the short run.

During recent years a consensus regarding how to manage monetary policy has emerged. This consensus agrees that a short-term interest rate, and not some monetary aggregate, should be the main tool for conducting an active monetary policy. We loosely refer to this consensus as the 'New Consensus.' It includes contributions from different theoretical approaches, including general equilibrium theory and post-Keynesianism.

It was challenging to rewrite general equilibrium theory under the premise that monetary aggregates do not play a role, but Woodford (2003, chs 2, 3, and 4) shows that is possible to create microfounded macro models when the central bank sets short-term interest rates. Furthermore, there is no real need to model money supply and demand, as these models often are of the 'cash-less' type, and on empirical grounds excluding money seem to do little harm (ibid., ch. 2).

Perhaps the most remarkable result of this new literature is the idea that the equilibrium path is uniquely determined if the short-term interest rate is sufficiently sensible with respect to changes in inflation (or, more precisely, with respect to deviations from a target). This is known as the 'Taylor principle' (Taylor, J. 1993).

Not so long ago, it was common to believe that interest-rate-based monetary policy rules promote instability or non-uniqueness of the equilibrium path (Sargent and Wallace 1975), but the implicit assumption was that the nominal interest rate was kept fixed. When the Taylor principle holds, inflationary expectations are 'anchored' if the central bank's policies are fully credible. Moreover, stabilizing inflation is equivalent to stabilizing output, if real frictions are absent. This is known as the 'Divine Coincidence' (Blanchard and Gali 2007).

These results are nowadays part of the core of large-scale dynamic stochastic general equilibrium (DSGE) models, but also of the small '3 equations model' presented in textbooks (Blanchard and Johnson 2013; Carlin and Soskice 2005). The 3 equations model is the modern reincarnation of the aggregate-demand–aggregate-supply framework, and it includes an intertemporal IS curve, a Phillips curve, and a Taylor rule.

The version of the 3 equations model that is best known includes an expectations augmented Phillips curve, where expected inflation is equal to past inflation. Thus, in this version of the model, inflation is a predetermined variable. However, to remain closer to the spirit of DSGE models, it is more natural to assume a pricing technology that looks into the future, for example using 'Calvo pricing' (see Calvo 1983a). This is far from being a minor assumption, because inflation becomes a non-predetermined variable.

To illustrate the difference, consider the expectations augmented Phillips curve defined by the expression $\pi = \pi^e + \text{Other Factors}$, where π and π^e are inflation and expected inflation, and where other factors that drive inflation can include supply-side shocks, the output gap, and so on. When inflation is forward-looking, then $\pi^e = \pi_{+1}$, so expected inflation is equal to inflation 'tomorrow,' while when inflation is 'backward-looking,' $\pi^e = \pi_{-1}$, so inflation is tied by its past evolution. But then notice that if we write the rate of change of inflation as $\frac{d\pi}{dt} \approx \pi_{+1} - \pi$, then the change in inflation is negatively related to the output gap, while if we write it as $\frac{d\pi}{dt} \approx \pi - \pi_{-1}$, then the change in inflation is positively related to the output gap.[7]

7. To see this, substitute each expression in the Phillips curve and solve for the rate of change of inflation. Appendix 1 provides the formalization proposed by Calvo (1983a).

Moreover, in forward-looking models the rate of inflation is a non-predetermined variable, while in backward-looking models inflation becomes a predetermined variable. The difference is far from trivial. Consider a policy experiment that involves a credible reduction of the inflation target. In the simpler model without forward-looking pricing, the rate of inflation is predetermined, so the central bank should raise interest rates to reduce demand, until inflation eventually falls. In a forward-looking set-up, if the central bank's policies are fully credible, the announcement is enough to bring down the rate of inflation immediately, and at no output cost.

Furthermore, the local stability conditions for a system where variables look into the future is strikingly different from a system tied to the past. More precisely, in a forward-looking system, a transversality condition is invoked to rule out explosive non-convergent paths, but then the appropriate initial conditions should be chosen. Systems of this kind often fail to produce a unique equilibrium path. Following Blanchard and Khan (1980),[8] a 'determined' system requires as many non-predetermined variables as positive roots. Systems with more non-predetermined variables than positive roots are 'non-determined.' Finally, systems with less non-predetermined roots than positive roots are unstable.

For models that aim to represent how inflation targeting works, determinacy is a desirable property of a good policy, and that is often achieved by imposing the Taylor principle. It basically implies that the central bank is able to 'anchor' expected inflation.

The literature that relies on rational expectations has discussed how appropriate it is to rule out the explosive non-convergent paths in monetary models. As argued by Cochrane (2011), is not always enough to choose the equilibrium path by invoking a transversality condition, as is done in the famous Ramsey model (see for instance Romer 2011, ch. 2). The reason is that it is correct to invoke a 'non-Ponzi' condition for a 'real' model, but for monetary models unstable paths that do not violate such conditions (that is, hyperinflations) are possible. It is hard to rule out these types of equilibrium paths without restricting the utility function in an arbitrary way, or assuming for example that the government backs up the money supply with a real commodity such as gold (Obstfeld and Rogoff 1983; 1986).

More importantly, when there are credibility problems, it is not possible to rule out any trajectory in which there is a regime switch. As shown by Calvo (2007), if central-bank policies are not credible, the inflation target may not be achieved, and in general it is not possible to rule out other self-fulfilling paths.[9]

However, even if credibility problems are ignored, and assuming we can safely impose a non-Ponzi condition, a Taylor rule with standard parameters may not be enough.[10] In a

8. In fact these authors explore discrete time models, but the logic is the same for continuous time models.
9. To illustrate the problem, it is easier to consider a similar model used to analyse stabilization programs with a fixed exchange rate (Calvo and Végh 1993; 1999). Suppose the economy is on a steady state with a positive rate of inflation and a positive rate of devaluation. If the stabilization program is credible, the rate of devaluation and inflation fall on impact, without changes in the real exchange rate or other real effects. But if the policy is not credible (so the private sector expects a policy change in the near future), tradable consumption becomes cheaper today, so the trade balance worsens and the real exchange rate appreciates. Precisely because the policy is not credible, an external deficit emerges and the stabilization attempt is eventually abandoned. The example illustrates that it is possible to generate an infinite number of equilibrium paths, indexed by the time when the program is aborted.
10. By 'standard,' the literature means that the nominal interest rate moves more than the rate of inflation, and possibly that it moves when the output gap is non-zero. In both cases, it is assumed that the reaction function calls for an increase in the nominal interest rate when the inflation gap and the output gap are positive.

closed economy set-up, the zero lower bound on nominal interest, and liquidity or real balance effects on aggregate supply, may drastically affect the results. As shown by Calvo (2016, chs 2–6), non-uniqueness of the equilibrium path cannot be ruled out.

Complications aside, it is often believed that monetary policy rules also work well in an open economy set-up. As in the closed economy counterpart, the determinacy of the equilibrium path is achieved if the Taylor principle is satisfied (see for example Calvo 2007), but the literature assumes that devaluations are expansionary (as in Galí and Monacelli 2005).

We believe it is an innovation to show that contractionary devaluations create a problem for standard Taylor rules. It is possible that this is the reason why some countries that use inflation targeting do not let the exchange rate float freely. In fact, in our recent experience, intervention in the foreign exchange market seems to be the norm, even for countries that are currently using inflation targeting (see Chang 2008 for an analysis of Latin America). Intervention in the foreign exchange market has been subject to scrutiny and criticism. Some authors suggest that a monetary policy compatible with inflation targeting requires a clean float of the exchange rate, but others accept that some small doses of intervention may be needed to achieve the target (see Ball 1999; Edwards 2006). However, this literature ignores the possibility of contractionary devaluations.

Post-Keynesians have also embraced the 3 equations model, both to discuss their policy implications and to amend the model by adding, most remarkably, an endogenous output gap. The post-Keynesian view largely agrees that the main tool of monetary policy is a short-term interest rate. In their early works, Kaldor, Minsky, and Robinson rejected the monetarist view based on an 'exogenous' money supply (Rochon and Vernengo 2001). However, according to post-Keynesians, using only a short-term interest rate to fine-tune the economy is a bad idea. There are two main views: the nominal interest rate should be either kept fixed (and preferably at a low level) or used as a counter-cyclical tool in conjunction with other policies. These views are identified as the 'parking-it' approach and the 'activist' view (for which is which, see Rochon 2007).

Authors from the post-Keynesian tradition, most remarkably those who seem to embrace the 'activist' view, have analysed the inflation targeting regime in a closed-economy set-up, and they show that full employment and price stability can be achieved combining the Taylor rule with an additional instrument (Mota dos Santos 2011; Tadeu-Lima and Setterfield 2008). Furthermore, Lavoie (2006) shows that a simple model that captures the main aspects of inflation targeting can be amended to incorporate hysteresis, and thus money is not neutral in the long run.

Very few models from the post-Keynesian camp have analysed the combination of inflation targeting and an open-economy set-up. Exceptions are Drumond and De Jesus (2016), Drumond and Porcile (2012), Porcile et al. (2011), and Vera (2014). These papers present open economy models to analyse the effect of monetary policy on stability, among other things,[11] but they all assume that devaluations are expansionary.

The next sections present a simple dependent economy model where inflation targeting is operative and a Taylor rule is the main stabilization tool. The goal is to illustrate the implications of contractionary devaluations, assuming both a forward-looking set-up where there are no credibility problems, and a model with backward-looking inflation and an endogenous output gap, as in the post-Keynesian tradition.

11. These authors follow the post-Keynesians and assume that the domestic conditions determine the price of the domestic good which is also exportable. The models developed in Sections 3 and 4 assume that the domestic economy is the price-taker in world markets.

3 A MODEL WITH FORWARD-LOOKING PRICES

This section presents a simple open-economy model where prices are set in a forward-looking manner, and the monetary policy is conducted using a Taylor rule. Before presenting the model, let us illustrate the main intuition. Consider what happens if the exchange rate goes up, while non-tradable prices lag behind. If demand and employment fall (as in the contractionary devaluation case), then domestic prices will tend to fall even more, but this effect tends to reinforce the contractionary pressures. This is the essential problem of contractionary devaluations.

Let us say that non-tradable inflation is some function of the level of the real exchange rate, or $\pi_N = \pi_N(Q)$. Now if $\pi_N{}' < 0$ (devaluations are contractionary) it follows that the change in the real exchange rate induces a change in the rate of change of the real exchange rate in the same direction. More precisely, assuming a constant rate of international inflation, the rate of change of the real exchange rate is given by the difference between the rate of devaluation and non-tradable inflation, or $\hat{Q} = E - \pi_N$. Hence, we are dealing with a differential equation of the form $\frac{\partial Q}{\partial t} = F(Q)$ with $F' > 0$, where Q is the real exchange rate (the relative price of tradables to non-tradables).[12]

As noted by Calvo (1983b), this is clearly an unstable system. When the real exchange rate falls, demand for non-tradable goods increases, so non-tradable inflationary pressures reinforce the original appreciation and the systems does not settle down at the equilibrium levels of the endogenous variables. Is the adoption of inflation targeting enough to tame such instability? We show that the answer is no.

We adopt the Calvo pricing assumption as the baseline case, because is a simple continuous time generalization of the staggered price setting (see Taylor, J. 1979). The model developed in the current section is designed to be as close as possible to the New Consensus model in its more rational and forward-looking incarnation. Models that feature more realistic assumptions compatible with the post-Keynesian tradition, namely backward-looking pricing and an endogenous output gap, are explored in Section 4.

As we will show, the assumptions regarding prices do not affect the destabilizing effects that contractionary devaluations impose on an otherwise standard model, although they may change the interpretation of the dynamics. In this section we will show that when devaluations are contractionary, a Taylor rule is not enough to anchor inflationary expectations, and there is no way for the private sector to pick among the infinite number of equilibrium paths that converge to equilibrium. This suggests that conducting monetary policy based solely on a Taylor rule is not the best strategy, at least when devaluations are contractionary.

Forward-looking prices are not necessarily the most appealing option for modeling price decisions, but they are common for the literature on inflation targeting that emphasizes expectations and central-bank credibility. They are also a straightforward way to introduce forward-looking behavior. Furthermore, if the central bank announces an inflation target, these credibility issues are considered a central aspect of the policy regime, so it is worth considering Calvo pricing as the benchmark case. However, we rule out credibility problems and we assume that central-bank policies are fully credible. Our purpose is to show that even when lack of credibility is not an issue, there are other problems with a standard Taylor rule.

12. The notation for derivatives is as follows. By F' we mean the derivative of the function F with respect to its only argument, and by F_a the derivative of the function F with respect to the variable a. We write $\frac{\partial Q}{\partial t}$ to denote the partial of Q with respect to time.

We assume that non-tradable prices are sticky but forward-looking, while tradable prices are fully flexible. When non-tradable prices are set *à la* Calvo (1983a; 1983b) the change in non-tradable inflation π_N is a *negative*[13] function of the output gap $Y_N - \overline{Y}$:

$$\frac{\partial \pi_N}{\partial t} = -\eta[Y_N(Q, i - \pi_N) - \overline{Y}], \tag{1}$$

where $\overline{Y}$ is full employment non-tradable output, and η is a parameter that depends on how sensitive prices are to demand, and on the degree of price stickiness. Non-tradable demand Y_N is a function of the real exchange rate Q (the relative price of tradables, e, to non-tradables P_N) and the real interest rate in terms of non-tradables, which is equal to the nominal interest rate minus non-tradable inflation $i - \pi_N$. As shown by Dornbusch (1983), this is the relevant real interest rate for determining the optimal amount of spending in non-tradable goods.[14]

For simplicity, we assume the following linear functional form $Y_N = \omega Q - \sigma(i - \pi_N)$. We also assume that $\sigma > 0$, but $\omega \gtrless 0$, depending on whether devaluations are expansionary ($\omega > 0$) or contractionary ($\omega < 0$). None of the following results depends on linearity. The real exchange rate evolves over time according to the following specification:

$$\frac{\partial Q}{\partial t} = E - \pi_N. \tag{2}$$

The previous equation follows from the definition of the real exchange rate as a relative price $Q = \frac{e}{P_N}$. Thus, E and π_N are the growth rates of the price of tradables and non-tradables, so $\frac{\partial Q}{\partial t}$ is the rate of growth of the real exchange rate. Taking logs of both sides of $Q = \frac{e}{P_N}$ and differentiation with respect to time, noticing that the international rate of inflation is zero and the law of one price holds for tradables, yields equation (2).[15]

So far, both the rate of devaluation and the nominal interest rate, E and i, were assumed to be given. It is known that the rate of devaluation and the domestic interest rate are related. The simplest specification involves assuming that the uncovered interest parity (UIP) condition holds.

$$i = E + i^*, \tag{3}$$

where the new term is the international nominal interest rate i^*. It is often recognized that in practice (3) does not hold. A more precise definition involves an endogenous risk premium, to account for barriers to capital mobility, imperfect substitutability

13. An anti-intuitive specification such as (1) deserves some comments. When there is excess demand, the Calvo model assumes that a lot of firms change their prices optimally, and that the number of firms that adjust prices in the future periods falls gradually towards zero. Section A1.1 in Appendix 1 presents the derivation of the rate of change of inflation as a function of excess demand, following Calvo (1983a).
14. The results will slightly change if we use total inflation rather than non-tradable inflation, but the main points will still hold.
15. Notice that in order to avoid writing $\frac{\partial Q}{\partial t} = Q(E - \pi_N)$, we define all the variables in logs (except for interest rates), so in fact $\frac{\partial Q}{\partial t} = \hat{Q}$.

between domestic and foreign assets, and last but not least, irrational behavior and mistakes by the private sector. However, the adoption of the UIP is a reasonable benchmark to capture a large degree of capital mobility, which seems to represent the current condition of most inflation targeting regimes.[16]

If the UIP condition holds, there are two ways to 'close' the model. If the rate of devaluation is predetermined, our system will determine the rate of interest endogenously. This corresponds to a system of fixed or semi-fixed exchange rates. To analyse an inflation targeting regime, we should assume that the exchange rate is allowed to float, and the interest rate is determined somewhere else. More precisely, we assume that the domestic interest rate is set according to the following Taylor rule:

$$i = \pi_N + a(\pi_N - \pi^T) + r^*, \tag{4}$$

where as before i is the nominal interest rate, π_N is non-tradable inflation, and the new terms π^T and r^* are the target inflation and the so-called natural rate of interest.[17] Which is a Taylor rule ignoring for the moment the output gap, and assuming that the central bank targets the 'sticky' component of the price index, in our set-up the non-tradable part. Notice that in equilibrium the domestic real rate $i - \pi_N$ is equal to the natural rate of interest r^*, which in our case is equal to the international nominal interest rate (because international inflation is assumed to be equal to zero). The parameter a is assumed to be positive, so the Taylor principle is satisfied, because the nominal interest rate changes by more than non-tradable inflation when $\pi_N \neq \pi^T$ (or in our case, $\pi_N \neq 0$).

Let us further simplify the model and assume that the international nominal rate is also zero, $i^* = 0$. Because there is no international inflation, then the international real rate is also equal to zero, $r^* = 0$. In this context, it is probably wise for the central bank to set $\pi^T = 0$ to avoid real exchange-rate complications. If $\pi^T \neq 0$ then $\pi_N \neq 0$ so the exchange rate is not constant in the long run because otherwise Q will continue to change. Thus, we also assume that the inflation target is zero.

Assuming that the UIP condition holds, then we can use the Taylor rule to substitute into the system of equations. More precisely, using (3) and (4) into (1) and (2), the 2×2 system becomes:

$$\frac{\partial \pi_N}{\partial t} = -\eta[\omega Q - \sigma(a\pi_N) - \overline{Y}] \tag{5}$$

$$\frac{\partial Q}{\partial t} = a\pi_N. \tag{6}$$

16. We do not discuss more realistic formulations because that involves specifying differential equations for the rate of accumulation of the stocks of different assets, and that complicates the math. However, some of the models presented in Appendix 1 come close to assuming that the UIP does not hold instantaneously. What really matters for our purposes is that the domestic interest rate is connected somehow to the rate of devaluation. For our purposes, assuming that in equilibrium the rate of devaluation is an increasing function of the interest-rate differential, for example $E = F(i - i^*)$ with $F' > 0$, is all that matters.
17. The natural rate coincides with the international real interest rate for an open economy, otherwise there is an additional complication introduced into the model, namely that if domestic inflation and international inflation are equal, then the nominal interest rate differential is not equal to zero and the rate of devaluation is non-zero, and the real exchange rate is not constant.

Stability conditions (both local and global because we assume a linear system) can be analysed looking at the Jacobian of (5) and (6). It is given by:

$$J = \begin{vmatrix} \eta\sigma a & -\eta\omega \\ a & 0 \end{vmatrix}.$$

The trace is positive and the determinant is negative if devaluations are contractionary. The main result can be stated as follows: the standard Taylor rule is not able to anchor inflationary expectations, and other types of policies may be needed to avoid speculative bubbles. This proof is as follows. From the Calvo pricing assumption π_N is non-predetermined, and because the nominal exchange rate is not fixed, neither is Q. Although non-tradable prices are 'sticky' (but notice their rate of change is not predetermined), thanks to the Taylor rule the domestic interest rate and the exchange rate are non-predetermined, so both π_N and Q are free to take any value at any time (unlike predetermined variables).

What happens if the economy is out of equilibrium? The private sector has no way to figure out how to set its prices, so any non-tradable inflation rate is compatible with an equilibrium path. If the non-tradable rate of inflation is too high, the real exchange rate is also too high, and the economy suddenly contracts, but on the equilibrium path it expands accompanied with falling inflation and a real appreciation. Likewise, if the non-tradable rate of inflation is too low, the real exchange rate is also too low, and the economy booms, but on the equilibrium path it contracts back, accompanied with increasing inflation and real depreciation.[18]

For example, if a 'sunspot' dictates a large depreciation of the exchange rate, non-tradable prices and non-tradable inflation may increase, even if monetary policy follows a Taylor rule that satisfies the Taylor principle. Figure 1 shows the phase diagram and helps to explain the problem. The locus of constant real exchange rate and constant inflation are depicted, as well as the unique (negatively sloped) saddle path that converges to the equilibrium point B.

Notice that since both Q and π_N are non-predetermined, the initial conditions are not given, and thus the economy may be placed initially on any point on the saddle path: for example it could be on B, but also on A and C. This is the meaning of 'indeterminacy': all the paths that start from any point on the saddle path and converge to B are valid equilibrium paths.

An interesting implication of the model presented so far is that a policy rule that involves a constant nominal interest rate $\bar{\imath}$ (as proposed by the 'parking-it' approach) will uniquely determine the equilibrium path. Indeed, the Jacobian assuming that $i = \bar{\imath}$ is given by:

$$J = \begin{vmatrix} \eta & -\eta\omega \\ -1 & 0 \end{vmatrix}.$$

When devaluations are contractionary, the determinant is equal to $-\eta\omega$, and because $\omega < 0$ its sign is positive. The trace is also positive, so the system has two roots

18. Notice that because of the Taylor rule, a high non-tradable rate of inflation means a high real interest rate in terms of non-tradables. So when both the non-tradable inflation rate and the real exchange rate are high, the economy faces a recession. The opposite is true when non-tradable inflation is low. In other words, the saddle path is negatively sloped (see Figure 1).

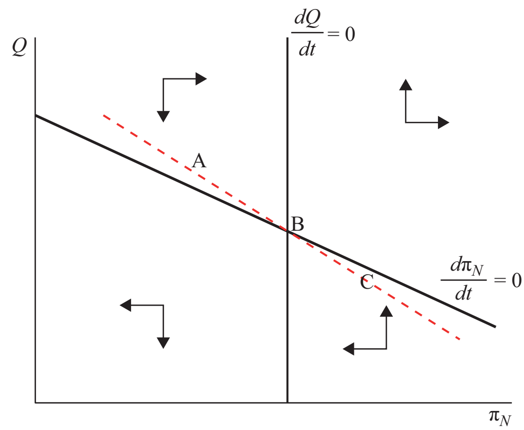

Figure 1 Phase diagram

with positive real parts, so there is a unique equilibrium path where the system jumps immediately into the equilibrium after an unexpected shock.

The results presented so far may depend on how we specify the Taylor rule, or more in general on the policy framework. But Sections A1.2 and A1.3 in Appendix 1 explore alternative specifications for the Taylor rule and other extensions, and show that contractionary devaluations imply indeterminacy of the equilibrium path under several reasonable specifications of the monetary policy rule, including the output gap, using full inflation targeting (rather than 'core inflation' only), assuming that the UIP does not hold continuously, and adding some lags to monetary policy. The next section explores the backward-looking version of the model, as well as an extension that includes an endogenous output gap.

4 BACKWARD-LOOKING INFLATION

The previous section discussed a forward-looking inflation model. We showed that a standard Taylor rule will produce a multiplicity of equilibrium dynamic paths. However, the forward-looking approach has some weaknesses, and the previous model may be questioned on empirical and theoretical grounds. For example, forward-looking pricing behavior is usually not consistent with the evidence on the behavior of prices after different shocks. More precisely, a negative relation between the output gap and the change in inflation is clearly at odds with common sense and the data (see Woodford 2003, ch. 3). Moreover, the forward-looking specification suggests that any credible announcement that implies a reduction in the steady state of inflation comes at no output cost.

This section analyses the case when inflation is backward-looking. Later on we follow the post-Keynesian tradition and we analyse the effects of an endogenous potential output. Although indexation and backward-looking behavior are usually associated with high rates of inflation, the forward-looking model performs poorly vis-à-vis a backward-looking model even when inflation is relatively low. Backward-looking models provide a more reasonable description of the dynamics and a much clearer way to distinguish stable from unstable systems. In practical terms, a model that relies on past inflation usually outperforms a model that just assumes that the firms set prices by forecasting future output gaps, either on empirical estimations and under reasonable calibrations of the standard New Keynesian model that uses pricing *à la* Calvo. Moreover, the best way to tell a consistent and realistic story that involves some adjustment of output and prices is to introduce backward-looking inflation.[19]

Let us assume that the change in non-tradable inflation is governed by:

$$\frac{\partial \pi_N}{\partial t} = \epsilon_1[\omega Q - \sigma(i - \pi_N) - \overline{Y}] + \epsilon_2(E - \pi_N). \tag{7}$$

Now non-tradable inflation increases when demand for non-tradables increases above the full employment level of output. The change in non-tradable demand depends negatively on the real interest rate and positively on the real exchange rate. On the other hand, non-tradable inflation tends to increase when the rate of devaluation exceeds non-tradable inflation, and to decrease in the opposite case.[20]

An equation like (7) is used in open-economy textbooks such as Vegh (2013, ch. 13, for example equation (13.21)) and Dornbusch (2002, ch. 31), but no formal derivation is provided. It is possible to obtain (7) from a standard pricing equation, and we will show that the specification is consistent with the post-Keynesian tradition (see Taylor, L. 1991, ch. 2).

Following Krugman and Taylor (1978), we keep the structure of the tradable sector as simple as possible. Tradable output is fixed and that sector does not employ any labor (not a bad assumption for Latin American countries). Prices are formed using a mark-up rule on domestic (wages) and foreign costs (imported intermediate inputs). However, they assume that perfect competition will not change the dynamics as long as the mark-up is kept fixed.

The key assumption is that there is a target rate of non-tradable inflation that firms want to set, and that the target inflation is just a weighted average of wage and foreign input costs. The fact that firms do not attain their target inflation rate instantaneously is what adds some stickiness to the rate of inflation.[21] More precisely, desired non-tradable prices P_N^T in period are given by:

$$P_N^T = (1 + \mu)\left(\frac{W}{A} + \frac{P_T}{B}\right), \tag{8}$$

19. Most well-known textbooks seems to praise the rational expectations approach, but they nevertheless use backward-looking equations. Examples include the standard macro textbooks such as Blanchard and Johnson (2013) or Carlin and Soskice (2005). Similarly, Woodford (2003, ch. 3, sec. 3), admits that the standard 3 equation forward-looking model should be modified to include some inertia.
20. The exposition can be more consistent with a fully optimizing framework if we let demand depend on the difference between the 'actual' real rate of interest in terms of non-tradable $i - \pi_N$ and the 'natural rate' r^*, but since the former is usually kept constant and we set it equal to zero, there is no harm in omitting it altogether from equation (10). It is also important to keep in mind that equation (10) is not totally consistent with the actual behavior of inflation after devaluations in semi-industrialized economies. It is often the case that a once-and-for-all devaluation of the exchange rate tends to accelerate inflation and to contract output. Such outcome is possible if non-tradable inflation accelerates, for example if wage earners claim for a higher growth of the nominal wage, despite a reduction in the level of employment. Thus, a different specification will add a separate effect to capture this. This can create stability, because non-tradable inflation can return to the target, but the output gap may not be stabilized.
21. Alternatively, we could assume that firms attain their target immediately, while workers obtain their target wage increases with a lag.

where A and B are the productivity of labor and of the imported intermediate inputs; they will be normalized to simplify the assumption that both are constant and equal to one. The variables W, μ, and P^T are the nominal wage, the mark-up, and the price of tradable goods. Logarithmic differentiation of equation (8) yields:

$$\pi_N^T = \varphi\hat{W} + (1-\varphi)E. \tag{9}$$

We assume that A and B are constant, and φ and $(1-\varphi)$ represent the share of domestic and foreign costs in total costs. The terms $\hat{W}$ and E are rates of growth of nominal wage costs and rates of change of international prices (as before, because international inflation is assumed to be zero). The new term π_N^T is 'desired' or 'target' non-tradable inflation. Once again we set international inflation to zero to reduce the number of symbols and to simplify the notation.

Let us assume that the total rate of inflation for the basket of goods that the workers consume is a weighted average of tradable and non-tradable inflation, in other words total inflation is $\pi = (1-b)\pi_N + bE$. As in a standard Phillips curve set-up, let the growth of nominal wages depend on the level of employment N in relation to some equilibrium rate of employment $\overline{N}$, via the function f, and on expected inflation (which we will assume to be equal to actual inflation π). In other words, we set $\hat{W} = \pi + f(N-\overline{N})$, then using the expression for inflation we obtain:

$$\hat{W} = (1-b)\pi_N + bE + f(N-\overline{N}). \tag{10}$$

According to (10), if employment increases, wages will grow faster than total inflation, and if employment decreases, wages will grow slower than total inflation. Then inserting (10) into (9) we obtain:

$$\pi_N^T = \varphi[(1-b)\pi_N + bE + f(N-\overline{N})] + (1-\varphi)E. \tag{11}$$

Finally, to introduce inertia, let the rate of change of non-tradable inflation depend on the difference between target non-tradable inflation and actual non-tradable inflation:

$$\frac{\partial\pi_N}{\partial t} = \rho(\pi_N^T - \pi_N), \tag{12}$$

where ρ captures the speed of adjustment. Since this parameter will not do anything important, in this section we will assume that is just a constant that multiplies the arguments, and that $\rho = 1$. Putting everything together by inserting π_N^T into (12):

$$\frac{\partial\pi_N}{\partial t} = \varphi[(1-b)\pi_N + bE + f(N-\overline{N})] + (1-\varphi)E - \pi_N. \tag{13}$$

It is possible to do some arrangements to equation (13). In particular, notice that:

$$\varphi[(1-b)\pi_N + bE] + (1-\varphi)E - \pi_N = c(E-\pi_N), \tag{14}$$

where $c = b\varphi + 1 - \varphi$. Hence let us write (14) as follows:

$$\frac{\partial\pi_N}{\partial t} = \varphi f(N-\overline{N}) + c(E-\pi_N). \tag{15}$$

The final step is to assume that employment depends positively on non-tradable demand. It is possible to justify this assuming that the non-tradable sector is the only source of employment, so the tradable sector does not employ any labor, but this is not required. All we need is that there is a particular relation between relative prices and employment, for example that a higher Q raises non-tradable demand and more labor is hired (that is, devaluations are expansionary). Other shocks that change employment (such as fiscal policy or terms of trade) can easily be inserted by plugging extra terms into the first part of the equation, but no harm is done by ignoring them to keep the equations simple. Then (15) reduces to equation (7).

More precisely, we assume that labor demand is equal to non-tradable output, because constant returns to scale prevail, labor is the only input, and labor productivity is set equal to one.

$$N = Y_N \tag{16}$$

As before, Y_N is non-tradable output. The tradable sector employs no labor, and it is assumed that its output is given in the short run. This assumption implies that the tradable sector output does not play any role in the following analysis because the economy is a price-taker in world markets. That means that employment depends on non-tradable demand only, which in turn is given by our linear specification $Y_N = \omega Q - \sigma(i - \pi_N)$. In turn, the full employment level of employment $\overline{N}$ is equal to non-tradable full employment output $\overline{Y}$, due to the assumptions adopted (constant returns to scale and a labor productivity equal to one).

On the other hand, the real exchange rate evolves according to our equation (2), repeated below:

$$\frac{\partial Q}{\partial t} = E - \pi_N. \tag{2}$$

If we introduce the Taylor rule into equations (7) and (2), we obtain a 2×2 dynamic system on π_N and Q. The Jacobian of the system is given by:

$$J = \begin{vmatrix} a(\epsilon_2 - \epsilon_1\sigma) & \epsilon_1\omega \\ a & 0 \end{vmatrix}.$$

Notice that $TRJ = a(\epsilon_2 - \epsilon_1\sigma)$, so its sign will depend on the strength of real interest rate and real exchange rate effects on demand. But the sign of the determinant does not change, and it is still determined by the nature of devaluation. If devaluations are expansionary, so $\omega > 0$, then the determinant becomes negative, while if devaluations are contractionary, then $\omega < 0$, and then the determinant becomes positive.

There are some noteworthy implications from the analysis of the Jacobian. The existence of a unique equilibrium path does not depend on the strength of different effects on demand. Let us keep in mind that the system features a predetermined variable (non-tradable inflation) and a non-predetermined variable (the real exchange rate), so a negative determinant is the critical condition to pin down both the level of inflation and the real exchange rate in the short run. Thus, even if the trace is positive, expansionary effects from devaluations ($\omega > 0$) will pin down the equilibrium path.

As in the previous section, contractionary devaluations create complications. When $\omega < 0$ there are two cases, depending on the sign of the trace. If the trace is negative ($\epsilon_1\sigma > \epsilon_2$) both roots are real with a negative sign, and the system will converge to equilibrium but the path depends on the initial conditions. If the trace is positive ($\epsilon_1\sigma < \epsilon_2$), then the system will never converge to equilibrium. For Latin America, the interest elasticity of demand seems to be much lower than the effects of exchange rates. Put differently, $\epsilon_2 > \epsilon_1\sigma$ unless $\frac{\epsilon_1}{\epsilon_2}$ is very large.[22] Thus, instability is the most likely outcome.

Finally, it is also possible to show that if the interest rate is kept fixed, the equilibrium is saddle-path stable when devaluations are contractionary. In that case the Jacobian becomes:

$$J = \begin{vmatrix} \epsilon_1\sigma - \epsilon_2 & \epsilon_1\omega \\ -1 & 0 \end{vmatrix}.$$

And regardless of the sign of the trace, the determinant is negative and the system displays saddle-path stability. Because there is one non-predetermined variable (Q), the equilibrium path is uniquely defined by the initial conditions. Once again, a simple 'parking-it' approach dominates the Taylor rule when devaluations are contractionary.

4.1 Adding an endogenous output gap

Post-Keynesians have presented convincing arguments to support the idea that potential output is not exogenous, but that it depends on the evolution of effective demand. This section shows that the presence of hysteresis in the evolution of capacity does not affect the main plot: when devaluations are contractionary, Taylor rules are not a good policy.

A simple way to introduce hysteresis is to add a third equation to the model of the following form:

$$\dot{\overline{Y}} = \gamma[\omega Q - \sigma(i - \pi_N) - \overline{Y}], \qquad (17)$$

where $\gamma > 0$, and equation (24) says that potential output increases when demand is above potential output, and decreases otherwise. A similar specification was proposed by Lavoie (2006), albeit using growth rates instead of levels. Together with equations (7) and (2), and after inserting the Taylor rule, the Jacobean of the linearized system becomes:

$$J = \begin{vmatrix} a(\epsilon_2 - \epsilon_1\sigma) & \epsilon_1\omega & -\epsilon_1 \\ a & 0 & 0 \\ -a\sigma\gamma & \gamma\omega & -\gamma \end{vmatrix}.$$

The trace is $TR = a(\epsilon_2 - \epsilon_1\sigma) - \gamma$, and the determinant is $DET = 0$ (as expected because systems with hysteresis have a zero root). It also known that the following condition holds:[23]

$$\lambda_1\lambda_2 + \lambda_1\lambda_3 + \lambda_3\lambda_2 = -a(\gamma\epsilon_2 + \epsilon_1\omega).$$

22. See Frenkel (2008) and García Lázaro and Perrotini (2014) for a discussion.
23. See Gantmacher (1959). The condition states that the sum of the product of the different combinations of the roots should be equal to the sum of the minors of the Jacobian (obtained removing the ith row and column one by one).

But because one of the roots is zero, let us say $\lambda_3 = 0$, then the sign of the previous expression is equal to the product of the non-zero roots, $\lambda_1\lambda_2$. When devaluations are expansionary the roots will have opposite signs unambiguously, because $\lambda_1\lambda_2 < 0$. Because the system has one non-predetermined variable, the real exchange rate (Q), which is free to take any value in the present, there is no way to uniquely pin down the equilibrium path; associated with each level of the real exchange rate are some initial conditions and a unique convergent trajectory.

If devaluations are contractionary and the effects are strong enough, $\gamma\epsilon_2 + \epsilon_1\omega < 0$ and then $\lambda_1\lambda_2 > 0$. Both roots will be either negative (if the trace is negative) and the system will display indeterminacy, or positive (if the trace is positive) and the system will be completely unstable. Notice that this former case is more likely, unless the speed of adjustment of potential output is very large; otherwise the contractionary effect of devaluations on demand dominates and both roots will be real and positive. Hence, adding an endogenous output gap does not get rid of the problems associated with contractionary effects from devaluations.

5 CONCLUSIONS

This paper has explored the implications of contractionary devaluations for the stability of an economy that targets inflation using a Taylor rule. We showed that the contractionary nature of devaluations creates instability or indeterminacy of the dynamic path.

These results hold under very different number scenarios, including full CPI target vs core inflation, Taylor rules with and without the output gap, slower exchange-rate dynamics, and interest-rate smoothing. The only way to restore determinacy or stability is to dramatically change the Taylor principle, so the interest rate should react less when non-tradable inflation changes, or by sticking to a rule that kept the nominal interest rate fixed.

The policy implications that can be derived from this paper are as follows: when devaluations are contractionary, the standard inflation targeting framework is probably not enough to stabilize the economy and to anchor inflationary expectations. Policies that aim to prevent exchange-rate stability (such as capital controls or interventions in the FX market) or to make devaluations expansionary are probably needed. Thus, other frameworks, or inflation targeting plus policies that prevent large exchange-rate fluctuations or that make devaluations expansionary may be needed.

Interestingly, an empirical assessment of the recent experience, for example in Latin America, suggests that almost all the central banks from the group of inflation targeting countries intervened heavily in the foreign exchange market (Chang 2008), and that they even introduced some regulations on capital mobility (see the new data by Fernandez et al. 2015). Furthermore, there is evidence of a counter-cyclical stance for fiscal policy during the 2009 crisis and the widespread utilization of income policies (for the case of Brazil, see Serrano and Summa 2016). Overall this suggests that really existing inflation targeting regimes hardly ever rely on a Taylor rule as the only tool. Thus, the 'New Consensus' 3 equation model provides an incomplete picture.

The models presented in this paper, as well as the recent experience, seem to support the two popular post-Keynesian views on monetary policy. More precisely, the inability of standard Taylor rules to anchor inflationary expectations suggest that pegging the interest rate or relying on additional policy instruments is a reasonable idea. Both positions are advocated by different strands of post-Keynesianism.

A shortcoming of the specification used in this paper is that contractionary devaluations are often also inflationary. Adding the inflationary effects of contractionary devaluations would require a slightly different specification that complicates the model. Intuitively, an economy where devaluations are contractionary and inflationary can be shown to be stable (the Jacobian will feature a negative trace and a positive determinant when prices are backward-looking), but stabilizing inflation will not imply the stabilization of output.

REFERENCES

Bahmani-Oskooee, M. and I. Mitez (2003), ‘Are devaluations expansionary or contractionary?’ *Economic Issues*, 8(2), 1–28.

Ball, L. (1999), ‘Policy rules for open economies,’ in J. Taylor (ed.), *Monetary Policy Rules*, Cambridge, MA: National Bureau of Economic Research, pp. 127–156.

Bebczuk, R., J. Galindo, and U. Panizza (2006), ‘An evaluation of the contractionary devaluation hypothesis,’ IDB Working Paper No 486.

Blanchard, O. and D. Johnson (2013), *Macroeconomics*, 6th edn, Upper Saddle River, NJ: Pearson.

Blanchard, O. and C. Khan (1980), ‘The solution of linear difference models under rational expectations,’ *Econometrica*, 48(5), 1305–1312.

Blanchard, O. and J. Gali (2007), ‘Real wage rigidites and the New Keynesian model,’ *Journal of Money, Credit, and Banking*, 39(1), 35–65.

Calvo, G. (1983a), ‘Staggered prices in a utility-maximizing framework,’ *Journal of Monetary Economics*, 12(3), 383–398.

Calvo, G. (1983b), ‘Staggered contracts and exchange rate policy,’ in J. Frenkel (ed.), *Exchange Rates and International Macroeconomics*, Cambridge, MA: National Bureau of Economic Research, pp. 235–258.

Calvo, G. (2007), ‘Interest rate rules, inflation stabilization, and imperfect credibility: the small open economy case,’ NBER Working Papers 13177, National Bureau of Economic Research.

Calvo, G. (2016), *Macroeconomics in Times of Liquidity Crisis: Searching for Economic Essentials*, Cambridge, MA: MIT Press.

Calvo, G. and C. Végh (1993), ‘Exchange-rate-based stabilization under imperfect credibility,’ in G.A. Calvo (ed.), *Money, Exchange Rates, and Output*, Cambridge, MA: MIT Press, pp. 365–390.

Calvo, G. and C. Végh (1999), ‘Inflation stabilization and BOP crises in developing countries,’ in J. Taylor and M. Woodford (eds), *Handbook of Macroeconomics*, Amsterdam: North-Holland, pp. 1531–1614.

Carlin, W. and D. Soskice (2005), *Macroeconomics: Imperfections, Institutions, and Policies*, Oxford: Oxford University Press.

Chang, R. (2008), ‘Inflation targeting, reserves accumulation, and exchange rate management in Latin America,’ Borradores de Economía No 487, Banco de la República, Colombia.

Cochrane, J. (2011), ‘Determinacy and identification with Taylor rules,’ *Journal of Political Economy*, 19(3), 565–615.

Díaz-Alejandro, C. (1965), *Exchange Rate Devaluation in a Semi-Industrialized Country*, Cambridge, MA: MIT Press.

Dornbusch, R. (1983), ‘Real interest rates, home goods, and optimal external borrowing,’ *Journal of Political Economy*, 91, 141–153.

Dornbusch, R. (2002), *Keys to Prosperity: Free Markets, Sound Money, and a Bit of Luck*, Cambridge, MA: MIT Press.

Drumond, E. and C. De Jesus (2016), ‘Monetary and fiscal policy in a Post-Keynesian open economy model,’ *Journal of Post Keynesian Economics*, 39(2), 172–186.

Drumond, E. and G. Porcile (2012), ‘Inflation targeting in a developing economy: policy rules, growth, and stability,’ *Journal of Post Keynesian Economics*, 35(1), 137–162.

Edwards, S. (1986), ‘Are devaluations contractionary?’ *The Review of Economics and Statistics*, 68(3), 501–508.
Edwards, S. (2006), ‘The relationship between exchange rates and inflation targeting revisited,’ NBER Working Paper No 12163.
Fernández, A., M. Klein, A. Rebucci, M. Schindler, and M. Uribe (2015), ‘Capital controls measures: a new dataset,’ NBER Working Paper No 20970.
Frenkel, R. (2008), ‘The competitive real exchange-rate regime, inflation and monetary policy,’ *CEPAL Review*, 96, 191–201.
Galí, J. and T. Monacelli (2005), ‘Monetary policy and exchange rate volatility in a small open economy,’ *Review of Economic Studies*, 72(3), 707–734.
Galindo, L.M. and J. Ros (2008), ‘Alternatives to inflation targeting in Mexico,’ *International Review of Applied Economics*, 22(2), 201–214.
Gantmacher, F. (1959), *The Theory of Matrices*, New York: Chelsea.
García Lázaro, A. and I. Perrotini (2014), ‘The *Modus Operandi* of New Consensus macroeconomics in Brazil, Chile and Mexico,’ *Problemas del Desarrollo*, 45(179), 35–63.
Krugman, P. and L. Taylor (1978), ‘Contractionary effects of devaluation,’ *Journal of International Economics*, 8, 445–456.
Lavoie, M. (2006), ‘A Post-Keynesian amendment to the New Consensus on monetary policy,’ *Metroeconomica*, 57(2), 165–192.
Mota dos Santos, A. (2011), ‘Inflation targeting in a Post Keynesian economy,’ *Journal of Post Keynesian Economics*, 34(2), 295–318.
Obstfeld, M. and K. Rogoff (1983), ‘Speculative hyperinflations in maximizing models: can we rule them out?’ *Journal of Political Economy*, 91(4), 675–687.
Obstfeld, M. and K. Rogoff (1986), ‘Ruling out divergent speculative bubbles,’ *Journal of Monetary Economics*, 17(3), 349–362.
Porcile, G., A. Gomes de Souza, and R. Viana (2011), ‘External debt sustainability and policy rules in a small globalized economy,’ *Structural Change and Economic Dynamics*, 22, 269–276.
Rochon, L. (2007), ‘The state of Post Keynesian interest rate policy: where are we and where are we going?’ *Journal of Post Keynesian Economics*, 30(1), 3–11.
Rochon, L. and M. Setterfield (2007), ‘Interest rates, income distribution and monetary policy dominance: Post-Keynesians and the “fair rate” of interest,’ *Journal of Post Keynesian Economics*, 30(1), 13–41.
Rochon, L. and M. Vernengo (2001), ‘Kaldor and Robinson on money and growth,’ *European Journal of the History of Economic Thought*, 8(1), 75–103.
Romer, D. (2011), *Advanced Macroeconomics*, 4th edn, New York: McGraw-Hill.
Sargent, T. and N. Wallace (1975), ‘Rational expectations, the optimal monetary instrument, and the optimal money supply rule,’ *The Journal of Political Economy*, 83(2), 241–254.
Serrano, F. and R. Summa (2016), ‘Aggregate demand and the slowdown of Brazilian economic growth in 2011–2014,’ *Nova Economia*, 25, 803–833.
Tadeu Lima, G. and M. Setterfield (2008), ‘Inflation targeting and macroeconomic stability in a Post Keynesian economy,’ *Journal of Post Keynesian Economics*, 30(3), 435–461.
Taylor, J. (1979), ‘Staggered wage setting in a macro model,’ *American Economic Review, Papers and Proceedings*, 69(2), 108–113.
Taylor, J. (1993), ‘Discretion versus policy rules in practice,’ *Carnegie-Rochester Conference Series on Public Policy*, 39, 195–214.
Taylor, L. (1991), *Inflation, Income Distribution, and Growth*, Cambridge, MA: MIT Press.
Taylor, L. (2004), *Reconstructing Macroeconomics: Structuralist Proposals and Critiques of the Mainstream*, Cambridge, MA: Harvard University Press.
Vegh, C. (2013), *Open Economy Macroeconomics in Developing Countries*, Cambridge, MA: MIT Press.
Vera, L. (2014), ‘The simple Post-Keynesian monetary model: an open economy approach,’ *Review of Political Economy*, 26(4), 526–548.
Woodford, M. (2003), *Interest and Prices: Foundations of a Theory of Monetary Policy*, Cambridge, MA: MIT Press.

APPENDIX 1

A1.1 Forward-looking pricing

This section presents the full derivation of the dynamic of inflation when prices are set in forward-looking fashion. Following Calvo (1983a), imagine that there is a continuum of firms with a measure 1, and that each firm can only adjust its price if it receives a signal with a random probability $\varphi > 0$. The probability of receiving such a signal h periods in the future is $\varphi e^{-\varphi h}$. At time t a perfect-foresight firm will set its price optimally. Calvo proposed the following specification for the optimal price:

$$V_t = \varphi \int_t^\infty [P_s + \varepsilon ED_s] e^{-\varphi(t-s)} ds, \tag{A1}$$

where V_t is the log of the price quoted at time t, P is the log of the average price set by competitors, ED is excess demand, and ε is a positive parameter. Each firm wants to charge what other firms are charging plus a term that depends positively on excess demand. Notice that the optimal price is weighted by the probability of adjusting the price $\varphi e^{-\varphi(t-s)}$. The approximate log of the price level at t is given by:

$$P_t = \varphi \int_t^\infty V_s e^{-\varphi(t-s)} ds. \tag{A2}$$

Differentiating the previous two equations with respect to time:

$$\dot{V}_t = \varphi[V_t - P_t - \varepsilon ED_t] \tag{A3}$$

$$\dot{P}_t = \varphi[V_t - P_t]. \tag{A4}$$

Notice that inflation is the rate of change of the price level, so $\pi_t = \dot{P}_t$, and hence:

$$\dot{\pi}_t = \ddot{P}_t = \varphi[\dot{V}_t - \dot{P}_t] = -\varnothing ED_t, \tag{A5}$$

with $\varnothing = \varphi^2 \varepsilon > 0$. Thus, the change in the rate of inflation is a negative function of excess demand. In the paper it is assumed that $ED_t = ED_t(Q, i - \pi)$. The rate of inflation is a 'forward-looking' variable, so it can take discrete jumps up or down if future or present excess demand changes.

A1.2 Different Taylor rules (Calvo pricing)

Most central banks include the output gap in their monetary policy rule. To analyse the implications for stability when devaluations are contractionary, let us assume that the central bank includes such a variable. More precisely, the central bank uses the following Taylor rule:

$$i = \pi_N + a\pi_N + b(Y_N - \overline{Y}). \tag{A6}$$

Combining it with the expression for Y_N yields:

$$i = \frac{\pi_N + a\pi_N + b[\omega Q - \sigma\pi_N - \overline{Y}]}{(1 - b\sigma)}. \tag{A7}$$

Assuming that the UIP condition holds $i = E$, and noticing that $i - \pi_N = \frac{a\pi_N + b[\omega Q - \overline{Y}]}{(1 - b\sigma)}$, then we can replace it into the old system of equations to obtain:

$$\frac{\partial \pi_N}{\partial t} = -\eta\left[\omega Q - \sigma\left(\frac{a\pi_N + b\omega Q - b\overline{Y}}{(1 - b\sigma)}\right) - \overline{Y}\right] \tag{A8}$$

$$\frac{\partial Q}{\partial t} = \frac{a\pi_N + b[\omega Q - \overline{Y}]}{(1 - b\sigma)}. \tag{A9}$$

The Jacobean of the linearized system close to the equilibrium is given by:

$$J = \begin{vmatrix} \frac{\eta\sigma a}{(1 - b\sigma)} & \frac{-\eta\omega}{(1 - b\sigma)} \\ \frac{a}{(1 - b\sigma)} & \frac{b\omega}{(1 - b\sigma)} \end{vmatrix}.$$

Despite the sign of $1 - b\sigma$, notice that if devaluations are contractionary, then the determinant is unambiguously negative, so even after the inclusion of the output gap we still have indeterminacy as a result. Thus, adding the output gap does not change the main results obtained in the previous sub-section.

Next we explore the consequences of assuming an inflation target that focuses on the overall price index, and not just on the 'sticky' component or 'core' inflation (in our model, the non-tradable sector). Now consider a monetary policy rule that targets total inflation, or more precisely $\pi = \delta\pi_N + (1 - \delta)E$, where δ and $(1 - \delta)$ are the shares of non-tradables and trandables in the consumer price index. The monetary policy rule becomes:

$$i = (1 + a)[\delta\pi_N + (1 - \delta)E]. \tag{A10}$$

But noticing that $E = i$:

$$i = \frac{(1 + a)\delta\pi_N}{1 - (1 + a)(1 - \delta)}. \tag{A11}$$

Keep in mind that $i - \pi_N = \frac{(1+a)\delta\pi_N}{1 - (1+a)(1 - \delta)} - \pi_N = \frac{a\pi_N}{1 - (1+a)(1 - \delta)}$. Then the dynamic system becomes:

$$\frac{\partial \pi_N}{\partial t} = -\eta\left[\omega Q - \sigma\left(\frac{a\pi_N}{1 - (1 + a)(1 - \delta)}\right) - \overline{Y}\right] \tag{A12}$$

$$\frac{\partial Q}{\partial t} = \frac{a\pi_N}{1 - (1 + a)(1 - \delta)}. \tag{A13}$$

And thus the Jacobean matrix becomes:

$$J = \begin{vmatrix} \dfrac{\eta\sigma a}{1-(1+a)(1-\delta)} & -\eta\omega \\ \dfrac{a\pi_N}{1-(1+a)(1-\delta)} & 0 \end{vmatrix}.$$

The trace is positive, and the determinant is negative if devaluations are contractionary, but only if $1 > (1+a)(1-\delta)$, or more precisely if $\frac{\delta}{(1-\delta)} > a$. If the inequality is reversed then the trace is negative and the determinant is positive. In any case, the system has more non-predetermined variables than positive roots, so the dynamic path is indeterminate.

A1.3 Adding some sluggishness to the system

This section explores what happens if we introduce some sluggishness into the system by adding predetermined variables. More precisely, we show that if the rate of devaluation or the nominal interest rate display some inertia, it is still not possible to effectively pin down the equilibrium path. Suppose now that the rate of devaluation evolves slowly, according to:

$$\frac{\partial E}{\partial t} = \theta(E - i). \tag{A14}$$

The equation may reflect the presence of capital controls, reserve accumulation, or any friction that prevents abrupt jumps in the rate of devaluation. It is similar to a crawling-peg system. The central bank still targets inflation using (4) from the main text. This creates a new dynamic system on π_N, Q, and E. The other two equations (after substituting using the Taylor rule) are:

$$\frac{\partial \pi_N}{\partial t} = -\eta[\omega Q - \sigma(a\pi_N) - \overline{Y}] \tag{A15}$$

$$\frac{\partial Q}{\partial t} = E - \pi_N. \tag{A16}$$

The Jacobian of the system is given by:

$$J = \begin{vmatrix} \eta\sigma a & -\eta\omega & 0 \\ -1 & 0 & 1 \\ -\theta(1+a) & 0 & \theta \end{vmatrix}.$$

The trace is clearly positive, and the determinant is given by the expression $DET = \eta\omega a\theta$. It will be negative if devaluations are contractionary. A negative determinant and a positive trace means that one root has a negative real part and the other two have a positive real part. Due to the existence of equation (A14), the system has now two predetermined variables (E and Q) and one non-predetermined variable (π_N), so there is a continuum of paths that converge to equilibrium.

Most central banks do not let the interest rate adjust immediately, but they usually accommodate monetary policy to include lags. Let us consider what happens when this is the case. More precisely, consider now the following system:

$$\frac{\partial \pi_N}{\partial t} = -\eta[\omega Q - \sigma(i - \pi_N) - \overline{Y}] \tag{A17}$$

$$\frac{\partial Q}{\partial t} = i - \pi_N \tag{A18}$$

$$\frac{\partial i}{\partial t} = \kappa[\pi_N + a(\pi_N - \pi^T) - i], \tag{A19}$$

where equation (A19) follows from the fact that interest rates change as a function of the deviation of the actual level of the nominal interest rate from the 'optimal' level, given by the expression $\pi_N + a(\pi_N - \pi^T)$, and we substitute using $E = i$. The parameter κ is a positive speed of adjustment that captures lags in the implementation of the 'optimal' interest rate $i = \pi_N + a(\pi_N - \pi^T)$. The Jacobian of the linearized system is given by:

$$J = \begin{vmatrix} -\eta\sigma & -\eta\omega & \eta\sigma \\ -1 & 0 & 1 \\ \kappa(1+a) & 0 & -\kappa \end{vmatrix},$$

with a negative trace and a determinant given by $DET = -\eta\omega a\kappa$, which is positive if devaluations are contractionary. Positive trace and negative determinant imply two roots with a negative real part and one root with a positive real part. But notice that, unlike the previous model, now we have one predetermined variable (i), and two non-predetermined variables (π_N and Q).

Pegging the rate of devaluation effectively sets a path for the exchange rate, and because non-tradable prices are 'sticky' (that is, given at a point in time), Q becomes a predetermined variable. But pegging the interest rate does not avoid abrupt changes in the nominal exchange rate (for example if the foreign interest rate changes). To summarize, adding some sluggishness to the system is still not enough to fully determine a unique equilibrium path.