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EFFICIENT CPI-BASED TAYLOR RULES IN SMALL OPEN ECONOMIES*

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Abstract

In a standard New-Keynesian model for a small open economy, we derive the efficient CPI inflation-based Taylor rule. We conclude that the natural rate of interest, based on CPI inflation, must be directly linked to the foreign interest rate, as well as to domestic productivity shocks. In this way this rule ensures that the real ex-ante CPI interest rate moves in the face of domestic and foreign shocks so as to induce efficient movements in consumption. The empirical evidence, on the other hand, shows that inflation-targeting central banks respond to movements in the foreign interest rate (Fed funds rate), besides reacting to expected CPI inflation and to the domestic output gap.

Resumen

En un modelo Neo Keynesiano estándar para una pequeña economía abierta, derivamos una regla de Taylor eficiente basada en inflación del IPC. Concluimos que la tasa natural de interés, basada en inflación del IPC, tiene que estar directamente relacionada a la tasa de interés externa, así como a innovaciones de productividad doméstica. De esta forma, esta regla permite que la tasa de interés real ex-ante, basada en la inflación del IPC, se mueva ante shocks domésticos y externos, de modo de inducir movimientos eficientes en consumo. La evidencia empírica, por otro lado, muestra que los bancos centrales con metas de inflación responden a movimientos en la tasa externa (tasa de fondos del FED), además de reaccionar a la inflación del IPC esperada y a la brecha de producto doméstica.

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1 Introduction

There is vast theoretical literature that characterizes the behavior of inflation-targeting (IT) central banks. In a closed economy New Keynesian model, with sticky prices, the efficient allocation can be implemented if inflation is fully stabilized (see Clarida et al. (1999) and Galí (2008)).[1] As shown by Clarida et al. (2001), and Galí and Monacelli (2005), in the context of a small open economy the problem is isomorphic to the closed economy case: the efficient allocation is reached if *domestic* inflation is fully stabilized. This allocation can be implemented by following a simple Taylor rule in which the policy rate reacts only to domestic variables: domestic inflation, the output gap and the natural rate of interest (which depends only on exogenous productivity shocks). In this case, fluctuations in the exchange rate and in CPI inflation are efficient as long as domestic inflation remains on target. As a result, the efficient Taylor rule should not react to movements in foreign variables.

Now, there are some practical limitations that make it difficult for central banks to follow the domestic inflation-based Taylor rules prescribed by theory. First, exogenous productivity shocks are difficult to identify in practice, so estimating the natural rate of interest is elusive. Second, in general domestic inflation (or GDP deflator inflation) is not known with the frequency and opportunity required to implement monetary policy. Third, CPI-inflation is a much more widely known concept and more commonly used by the general public as a reference to gauge inflation trends or setting indexed contracts. It is in this context that most IT central banks in small open economies have adopted CPI inflation as the explicit policy target (see Table 1). The implementation of this regime is characterized by a flexible IT approach, in which the central bank attempts a gradual return to the policy target in the face of inflationary shocks (see Svensson (1999)). Furthermore, there is evidence that IT central banks lean against exchange rate movements. This reaction goes beyond the impact that the exchange rate has on CPI inflation and output, and it may reflect concerns on competitiveness or financial issues.[2]

In the light of the previous evidence, and considering the unprecedented expansionary policies followed by central banks in advanced economies in the aftermath of the 2008 financial crisis and

[1] In this setup, stabilizing inflation removes two distortions associated to sticky prices. First, it stabilizes average markups at their frictionless level, ensuring that employment and output are at their efficient level. Second, price stickiness induces relative prices to move in a way unwarranted by changes in preferences and technologies. This second distortion is also removed when inflation is fully stabilized.

[2] See Clarida et al. (1998) and Lubik and Schorfheide (2007) for evidence in developed economies and Mohanty and Klau (2004) and Aizenman et al. (2011) for evidence in emerging markets.

their spillovers into emerging market economies, this paper addresses two unsettled issues. First, in the simple sticky price model of Galí and Monacelli (2005) we derive a CPI inflation-based Taylor rule capable of implementing the flexible price allocation.[3] In this context, we show that the efficient domestic inflation-based Taylor rule is equivalent to a CPI inflation-based Taylor rule that includes the foreign interest rate among its determinants. To our knowledge, such an instrument rule has not been derived in the context of New Keynesian small open economy models. Hence, our paper contributes to the literature on optimal instrument rules in small open economies. Second, we empirically investigate the extent to which IT central banks react to movements in the foreign policy rate (Fed funds rate) even after controlling for CPI inflation and other, target and non-target, variables. This is an intuitive way of identifying the importance of external factors in the conduct of monetary policy, given the fact that the Fed funds rate is, as opposed to the exchange rate, an exogenous variable in small open economies.

There are a number of papers that, departing from the assumptions in Galí and Monacelli (2005), find that CPI inflation targeting is efficient. For instance De Paoli (2009) shows that the presence of an internal monopolistic distortion and a terms of trade externality drives optimal policy away from domestic inflation targeting. In particular, in some cases, it is efficient to partially stabilize both the real exchange rate and domestic prices, leading to a policy of CPI targeting. This policy is such that it maximizes a combination of the gains from terms of trade externality and domestic price stability. Campolmi (2012), on the other hand, shows that introducing sticky wages, in an otherwise standard small open economy model, rationalizes CPI inflation targeting. This policy smoothes inefficient fluctuations in real wages, reducing the volatility of both wages and domestic inflation. As a consequence, CPI inflation targeting reduces the inefficient wage dispersion caused by the wage staggering, and also indirectly reduces inefficient movements in domestic inflation. Finally, Engel (2011) shows that when there is pricing to market, the elimination of the staggered price distortion requires the policymaker to target CPI inflation, rather than producer price inflation. [4] In a different context, characterized by a two-country general equilibrium framework, Corsetti and Pesenti (2005) show that optimal monetary rules should stabilize a CPI-weighted average of the markups of all firms selling in the domestic market. The intuition behind this result is that policies aimed at internal stabilization

[3]Under some assumptions, the flexible price allocation is also the efficient one.

[4]See Corsetti et al. (2010) for an exhaustive review of deviations from the New-Keynesian standard setting, where the targeting rules characterizing the optimal policy are not only in domestic output gaps and inflation, but also in misalignments of the terms of trade and real exchange rates, and cross-country demand imbalances.

can raise the volatility of world demand and the exchange rate. Foreign exporting firms will attempt to reduce the volatility of their export revenues, derived from a more volatile exchange rate, by increasing the price in the domestic market.

Unlike the previous contributions, the focus of our paper is to derive the efficient CPI inflation-based instrument rule *given* the welfare criterion in the standard Galí and Monacelli (2005) model. In particular, we investigate the role of foreign elements in an efficient CPI inflation-based Taylor rule, when the flexible domestic price allocation is efficient.

Our conclusions are as follows. First, we show that, in the Galí and Monacelli (2005) model, a CPI inflation-based Taylor rule can implement the flexible price (and the efficient) allocation under some specific circumstances. In particular, for this rule to be efficient the natural rate of interest, based on CPI inflation, should be directly linked to the foreign interest rate, as well as to domestic productivity shocks. In this way this rule ensures that the real ex-ante interest rate, based on CPI inflation, reacts to domestic and foreign shocks so as to induce efficient movements in consumption. A corollary of our results is that the natural CPI interest rate depends on two exogenous variables: domestic productivity shocks and the foreign real interest rate. Second, based on Taylor rules estimations for a panel of 23 IT countries, we find that central banks respond to movements in the foreign interest rate (the Fed funds rate), besides reacting to expected CPI inflation and the domestic output gap. This result is robust to controlling for movements in the exchange rate, as well as other variables capturing the international business cycle. It is also robust across different groups of countries: developed and emerging economies.

This paper is organized as follows. In Section 2, we present the standard New-Keynesian model for a small open economy. Section 3 derives the efficient CPI inflation-based Taylor rule in the context of the Galí and Monacelli (2005) model, and assess the relevance of foreign rates in such a rule. In Section 4 we estimate simple forward-looking Taylor rules for a panel of 23 IT countries. Those rules are estimated using quarterly data for the period in which IT has been implemented in each country. In this section we also test some of the predictions derived from our theoretical specification. Finally, concluding remarks are presented in Section 5.

2 A New-Keynesian small open economy model

Our efficient CPI-inflation Taylor rule is derived from the the canonical version of the model developed by Galí and Monacelli (2005).[5] This is an open economy general equilibrium model with flexible wages, sticky prices and monopolistic competition.

In this economy, households maximize expected utility from consumption and leisure. From the first order conditions of this process, it is possible to obtain the Euler equation for consumption:

$$c_t = E_t\left(c_{t+1}\right) - \frac{1}{\sigma}\left(i_t - E_t\left(\pi_{t+1}\right) - \rho\right), \tag{2.1}$$

where c_t denotes the percentage deviation of consumption from steady state, i_t is the nominal policy rate and π_t represents the CPI inflation. The σ coefficient is the inverse of the elasticity of substitution and ρ is the logarithm of the discount factor, β.

In this open economy a proportion α of consumption is allocated to imported goods. In this context, it can be shown that CPI inflation, π_t, is a linear combination between domestic inflation, $\pi_{H,t}$, and foreign inflation, $\pi_{F,t}$:

$$\pi_t = (1-\alpha)\pi_{H,t} + \alpha\pi_{F,t}. \tag{2.2}$$

The output market clearing condition, on the other hand, is such that y_t depends on consumption, c_t, and the terms of trade, s_t, defined as the price of domestically produced goods relative to imported goods. In this way, output can be expressed as:

$$y_t = c_t + \frac{\alpha\omega}{\sigma}s_t, \tag{2.3}$$

where $\omega = \sigma\gamma + (1-\alpha)(\sigma\eta - 1)$. Parameter $\eta > 0$ measures the substitutability between domestic and foreign goods, from the viewpoint of the domestic consumer, while γ measures the substitutability between goods produced in different countries.

2.1 Equilibrium dynamics: a canonical representation

The linearized equilibrium dynamics for the small open economy has a representation in terms of the output gap, x_t, and domestic inflation, $\pi_{H,t}$. The variable x_t represents the difference

[5] For more detail see Appendix A or the original paper.

between the actual output level, y_t, and its flexible price level, $\overline{y}_t$. As in Galí and Monacelli (2005), we refer to this representation as the canonical one and it is given by the following equations:

$$x_t = E_t(x_{t+1}) - \frac{1}{\sigma_\alpha}\left(i_t - E_t(\pi_{H,t+1}) - \overline{r}_{H,t}\right) \tag{2.4}$$

$$\pi_{H,t} = \beta E_t\{\pi_{H,t+1}\} + \kappa_\alpha x_t \tag{2.5}$$

$$\overline{r}_{H,t} = \rho - \sigma_\alpha \Gamma(1-\rho_a)a_t + \alpha\sigma_\alpha\left((\omega-1)+\Psi\right)E_t(\Delta y^*_{t+1}) \tag{2.6}$$

Equation (2.4) is the dynamic IS equation in which the output gap depends on the real ex-ante interest rate. This equation is derived from the Euler equation for consumption, eq.(2.1), combined with the risk sharing condition, and the market clearing condition for output, eq.(2.3). Two important differences emerge when comparing this IS equation with the Euler equation for consumption in (2.1). First, the relevant real ex-ante interest rate in the dynamic IS equation is defined in terms of domestic inflation rather than CPI inflation. Second, given that $\sigma_\alpha = \frac{\sigma}{(1-\alpha)+\alpha\omega}$, the sensitivity of the dynamic IS equation to movements in the interest rate depends not only on the intertemporal elasticity of substitution, σ, but also on the degree of openness, α. In particular, if $\omega > 1$ (which is true for high values of η and γ), an increase in openness reduces σ_α, thus rising the sensitivity to interest rate movements.

Equation (2.5) is the New Keynesian Phillips curve for the small open economy. This equation reflects the optimal price-setting strategy of a representative firm that sets prices in a staggered way. In particular, it is assumed that firms reset prices with probability 1-θ. In this case, the slope of (2.5) is $\kappa_\alpha = (\sigma_\alpha + \varphi)\lambda$, where $\lambda = \frac{(1-\beta\theta)(1-\theta)}{\theta}$. As noted by Galí and Monacelli (2005), the degree of openness affects the dynamics of inflation only through its influence on the size of the slope of the Phillips curve. In particular, under the assumption that $\omega > 1$, an increase in openness reduces the impact of output gap movements on domestic inflation.

Equation (2.6) represents the real natural rate of interest derived under the assumption that output is at its natural level and $\pi_{H,t} = 0$. In general, the natural rate of interest will depend on expected foreign output growth, $E_t\left(\Delta y^*_{t+1}\right)$, in addition to productivity shocks, a_t.

Finally, to close the model, Galí and Monacelli (2005) assume the central bank follows an instrument rule in order to set its policy rate. In particular, they propose a domestic inflation-based Taylor rule:

$$i_t = \overline{r}_{H,t} + \phi_\pi \pi_{H,t} + \phi_y x_t \tag{2.7}$$

The system (2.4) to (2.7) has a unique RE equilibrium, in which the flexible price allocation is implemented (i.e $x_t = \pi_{H,t} = 0$), if the policy coefficients ϕ_π and ϕ_y are such that

$$\phi_\pi + \frac{\phi_y}{\kappa_\alpha}(1-\beta) > 1 \tag{2.8}$$

The previous condition, usually referred to as the Taylor principle, ensures that the central bank will respond with sufficient strength to deviations of inflation and output gap from their target levels. As noted by Galí (2008), to the extent it prevents the emergence of multiple equilibria, this condition is viewed as a desirable feature of any interest rate rule.

3 Can CPI inflation-based Taylor rules be efficient?

Prescriptions from the Galí and Monacelli (2005) model are clear. The flexible price allocation can be implemented if the central bank follows the simple rule in (2.7). Furthermore, under certain conditions, the allocation induced by this rule is also the efficient one. From a practical point of view, however, this rule has some limitations. First, most IT countries explicitly target CPI inflation. Second, the empirical evidence suggests that central banks react to expected inflation. Hence, the rule in (2.7) is of little use as a benchmark in those cases. To overcome such limitations, we explicitly derive the conditions under which a forward-looking CPI inflation-based Taylor rule will induce the flexible price allocation. In particular, in the context of Galí and Monacelli (2005)'s model, we investigate the properties of a rule like

$$i_t = \overline{r}_t + \phi_\pi^{CPI} E_t\left(\pi_{t+1}\right) + \phi_y^{CPI} x_t \tag{3.1}$$

We proceed in three steps. First, we derive the natural rate of interest based on CPI inflation, the variable $\overline{r}_t$ in (3.1). Second, we determine the conditions that the policy coefficients, ϕ_π^{CPI} and ϕ_y^{CPI} should satisfy in order to induce the flexible price allocation. Finally, we assess the dynamic response of the economy to different shocks, under this rule, in the particular case in which the flexible price allocation is also the efficient one.

3.1 CPI-based natural rate

From the identity for inflation, eq. (2.2), we can derive a relationship between the real ex-ante CPI inflation-based interest rate, r_t, and the domestic inflation-based real rate, $r_{H,t}$

$$r_t = r_{H,t} - \alpha E_t \left(\Delta s_{t+1} \right) \tag{3.2}$$

The above expression is also valid in the flexible price equilibrium, so

$$\overline{r}_t = \overline{r}_{H,t} - \alpha E_t \left(\Delta \overline{s}_{t+1} \right) \tag{3.3}$$

where $\overline{r}_t = i_t - E_t \left(\overline{\pi}_{t+1} \right)$ is the natural CPI inflation-based real rate. The flexible price level of CPI inflation is not necessarily equal to zero and its behavior will depend on the nature of the shock hitting the economy. As will be shown in appendix B, from the UIP condition and the identity in (3.3) we can establish the following relationship between the two natural rates

$$\overline{r}_t = (1-\alpha)\overline{r}_{H,t} + \alpha r_t^* \tag{3.4}$$

Hence, $\overline{r}_t$ is a linear combination between $\overline{r}_{H,t}$ and the ex-ante real foreign rate, r_t^*. As expected, as long as α converges to zero both natural rates tend to coincide. Now, combining the definition of $\overline{r}_{H,t}$ in (2.6) with (3.4), it can be shown that $\overline{r}_t$ depends on two exogenous and independent processes. In particular [6]

$$\overline{r}_t = (1-\lambda_\alpha)\overline{r}_t^{close} + \lambda_\alpha r_t^*, \tag{3.5}$$

where $\overline{r}^{close}$ is the natural rate that will prevail if the economy is closed, that is in the case in which $\alpha = 0$. This rate is given by $\overline{r}_t^{close} = \rho - \sigma \frac{1+\varphi}{\sigma+\varphi}(1-\rho_a)a_t$, so only productivity shocks will affect it. The CPI-based natural rate will also depend on the foreign real rate. The impact of this latter variable on $\overline{r}_t$ will crucially depend on λ_α. As shown in the appendix B, this coefficient is increasing on α and has the following form:

$$\lambda_\alpha = \frac{\alpha(\sigma+\varphi) + \alpha\Theta\varphi}{(\sigma+\varphi) + \alpha\Theta\varphi}.$$

In the previous expression, all coefficients are positive, except $\Theta = \omega - 1$ which has an ambiguous sign. If $\omega > 1$, then λ_α is positive and less than one.[7] Hence, in this case the CPI

[6] See appendix B for a derivation.

[7] The condition $\omega > 1$ is satisfied for high values of η and γ.

inflation-based natural rate is a linear combination between the closed economy natural rate and the foreign real rate. Thus, reductions in the foreign interest rate have a negative impact on $\overline{r}_t$.[8]

3.2 Determinacy conditions for forward-looking rules

We have shown that the natural real rate, based on CPI inflation, depends on both domestic productivity shocks and the real foreign rate. In the flexible price equilibrium, this should be the natural rate relevant in the Euler equation for consumption, eq.(2.1).

Now, to assess the extent to which a rule like (3.1) is able to implement the flexible price allocation, we proceed as follows. First, we derive the conditions that a forward-looking domestic inflation-based Taylor rule should satisfy for determinacy. Then, we transform this rule in order to get an expression analogous to (3.1).

We know that the flexible price equilibrium is characterized by $x_t = \pi_{H,t} = 0$ and $i_t = \overline{r}_{H,t}$. As noted by Galí and Monacelli (2005), the condition $i_t = \overline{r}_{H,t}$ cannot be interpreted as a rule the central bank should follow mechanically to implement the flexible price allocation, because such a rule will imply an indeterminate equilibrium, and hence, will not guarantee that the outcome of full domestic price stability will be attained.

The indeterminacy problem can be avoided, and the uniqueness of domestic price stability outcome restored, by having the central bank follow a rule that makes the interest rate respond with sufficient strength to *expected* domestic inflation and/or the output gap. This simple forward-looking Taylor rule takes the form

$$i_t = \overline{r}_{H,t} + \phi_\pi E_t\left(\pi_{H,t+1}\right) + \phi_y x_t \tag{3.6}$$

Following the methodology in Bullard and Mitra (2002), we derive the determinacy conditions associated to the rule in (3.6). These conditions are as follows [9]:

[8] If $\omega < 1$, the λ_α coefficient may become negative. However, from the net export equation (A.11), the fact that $\omega < 1$, under the assumption that $\sigma \geq 1$, implies that the response of net exports to movements in the real exchange rate (and in the terms of trade) is negative. This negative relationship, however, is not supported by the data (see Mendoza (1995)). More generally, if the correlation between terms of trade and net exports is to be positive (the so called Harberger-Laursen- Metzler) and if $\sigma \geq 1$, it necessarily implies that $\omega > 1$. In this case it should be true that $0 < \lambda_\alpha < 1$, so the response of the CPI inflation-based natural rate to foreign interest rate shocks is, unambiguously, positive.

[9] See derivation in Appendix C.

$$\phi_y \geq 0, \tag{3.7}$$

$$\kappa_\alpha(\phi_\pi - 1) - \phi_y(1+\beta) < 2(1+\beta)\sigma_\alpha \tag{3.8}$$

and

$$\phi_\pi + \frac{\phi_y}{\kappa_\alpha}(1-\beta) > 1 \tag{3.9}$$

The above conditions guarantee the uniqueness of the equilibrium, implying that $x_t = \pi_{H,t} = 0$ and $i_t = \overline{r}_{H,t}$. Hence, the Taylor rule (3.6), which implies strict domestic inflation targeting, induces the real and nominal variables in the model to behave like they would in the absence of nominal rigidities.

3.3 CPI inflation-based rule

Using (2.2) and (3.6) it is possible to derive a CPI inflation-based Taylor rule:

$$\begin{aligned} i_t &= \overline{r}_{H,t} + \phi_\pi E_t\left(\pi_{H,t+1}\right) + \phi_y x_t \\ &= \overline{r}_t + \phi_\pi E_t\left(\pi_{t+1}\right) + \phi_y x_t + \alpha(1-\phi_\pi) E_t\left(\Delta \overline{s}_{t+1}\right) \end{aligned}.$$

The above forward-looking rule contains an additional term, $\alpha(1-\phi_\pi)E_t\left(\Delta\overline{s}_{t+1}\right)$ which is not present in the simple Taylor rule in (3.1). This element can be excluded from the rule if we impose the condition that $\phi_\pi = 1$. By doing this, we obtain the following simple Taylor rule

$$i_t = \overline{r}_t + E_t\left(\pi_{t+1}\right) + \phi_y^{CPI} x_t \tag{3.10}$$

Now, in order to ensure determinacy the above rule should satisfy conditions (3.7) to (3.9). Hence, if we impose $\phi_\pi = 1$, these conditions collapse to $\phi_y > 2\sigma_\alpha$. As a consequence, a rule like (3.1), in which $\phi_\pi^{CPI} = 1$ and $\phi_y^{CPI} > 2\sigma_\alpha$, ensures both determinacy and the attainment of the flexible price equilibrium.

Clearly, the forward looking CPI inflation-based Taylor rule (3.10) is more restrictive than its domestic inflation counterpart. In particular, the response to output has always to be positive and greater than $2\sigma_\alpha$ to ensure determinacy. Also, the response to expected CPI inflation cannot be different from 1. As a consequence, this rule efficiently accommodates movements in CPI inflation.

3.4 Impulse Response Analysis

To understand the mechanisms behind the CPI inflation-based rule in (3.10), we assess the dynamic implications of different shocks when the flexible price equilibrium is also the efficient one. In particular, as in Galí and Monacelli (2005), we work with the special parameter configuration $\sigma = \eta = \gamma = 1$ (which implies $\omega = 1$). In this case, the employment subsidy that exactly offsets the combined effects of the two distortions that are present in the open economy -namely market power and terms of trade distortions- can be derived analytically. Hence, in this particular case, the flexible price allocation, characterized by $x_t = \pi_{H,t} = 0$, is also the efficient one.

When $\omega = 1$, the domestic inflation-based natural rate, $\overline{r}_{H,t}$, depends only on domestic productivity shocks, whereas the CPI inflation-based natural rate, $\overline{r}_t$, depends on productivity shocks as well as on shocks affecting the foreign interest rate. In this particular case, these rates can be expressed as follows:

$$\overline{r}_{H,t} = \rho - \sigma\Gamma(1 - \rho_a)a_t \tag{3.11}$$

$$\overline{r}_t = (1 - \alpha)(\rho - \sigma\Gamma(1 - \rho_a)a_t) + \alpha r_t^* \tag{3.12}$$

In order to compare the two natural rates, we present the path followed by the main macro variables under three different shocks. First we consider a positive domestic productivity shock, then a foreign productivity shock and finally a foreign supply shock. The model is solved under the efficient CPI inflation-based rule in (3.10). The policy coefficients are $\phi_\pi^{CPI} = 1$ and $\phi_y^{CPI} = 0.5$.[10]

A domestic productivity shock leads, in the flexible price equilibrium, to a persistent reduction in the nominal interest rate. As a consequence, the CPI natural rate, $\overline{r}_t$, declines in a proportion (α) of the decline in $\overline{r}_{H,t}$ (see Figure 1). The decline in $\overline{r}_t$ increases consumption to a level which is consistent with the flexible price allocation. On the other hand, the real exchange rate and the terms of trade increase, expanding exports to the rest of the world. Both the increase in consumption and exports are coherent with a higher natural output level.

Before analyzing the impact of a foreign shock, it is worth mentioning that the rest of the world is characterized by a model which is similar to the small open economy one, with the only exception that the degree of openness, α^*, is assumed to be close to zero. The preferences are

[10] For the rest of the coefficients, we use the same calibration as in Galí and Monacelli (2005).

the same, and the central bank of the rest of the world implements the efficient allocation by ensuring that foreign inflation and the foreign output gap are equal to zero.[11]

Positive foreign productivity shocks cause a reduction in the foreign real interest rate in order to stabilize foreign inflation and the output gap at zero. Now, this decline in the foreign rate induces a nominal appreciation, prompting a reduction in both the terms of trade and the price of consumption (CPI). The consumption basket is relatively cheaper, so domestic consumption should increase. This increase in consumption is induced by a decline in the real CPI inflation-based natural rate (see Figure 1). The decline in exports (which are relatively more expensive) compensates the increase in consumption (and imports), such that output and net exports remain unchanged at their natural level.

A foreign supply shock, on the other hand, generates a policy trade-off in the rest of the world. In particular, this shock leads to a contraction in the foreign output gap in order to fully stabilize foreign inflation. To induce this contraction, the real foreign interest rate increases. In the domestic economy this generates a nominal depreciation, which increases the terms of trade and the price of the consumption basket (CPI). The CPI inflation-based interest rate increases in order to induce an efficient reduction in domestic consumption. Exports increase in a way that the trade balance and the level of output are unchanged.

Overall, the natural rate based on CPI inflation, $\overline{r}_t$, is affected by foreign and domestic shocks. Its movements are intended to induce efficient changes in domestic consumption, and do not mimic the movements in the natural rate based on domestic inflation, $\overline{r}_{H,t}$. In terms of policy implementation, if for some reason, domestic inflation is not observable or the target is set in terms of CPI inflation, a central bank following a CPI inflation-based Taylor rule should properly consider the relevant natural rate. In particular, following a CPI inflation-based Taylor rule that incorporates $\overline{r}_{H,t}$ as the natural rate, instead of $\overline{r}_t$, will imply an inefficient allocation.

4 Are foreign rates relevant in IT countries? Empirical evidence

As discussed previously, theoretical papers (Galí and Monacelli (2005) and Clarida et al. (2001)) stress the relevance of a simple domestic inflation-based Taylor rule, because of its analytical convenience and because there are arguments justifying domestic inflation stability in the context of sticky prices. In contrast, most IT central banks set their targets in terms of CPI inflation.

[11]Notice that, by construction, the domestic output gap, domestic inflation and the net exports are at zero. As a consequence, the change in relative prices is induced by changes in the nominal rate.

As a consequence, the empirical literature on Taylor rules has used CPI inflation as one of the determinants of the policy rate (Clarida et al. (1998), Clarida et al. (2000), Mohanty and Klau (2004), Lubik and Schorfheide (2007) and Aizenman et al. (2011)). These papers also assess the relevance of foreign elements for the conduct of monetary policy in small open economies. In general, however, the main focus is on the relative importance of exchange rate movements (the exception being Clarida et al. (1998)), rather than assessing the relevance of foreign interest rates. The advantage of considering foreign rates is that they are exogenous to the economy, and may anticipate future movements in the exchange rate.

In order to assess the empirical relevance of the simple CPI inflation-based Taylor rule derived in the pervious section, and to determine the importance of foreign rates, we estimate, for a set of IT countries, an instrument rule of the form:

$$i_{i,t} = \mu_i + \rho i_{i,t-1} + \phi_\pi E_t \left(\pi_{i,t+1} - \pi^T_{i,t+1}\right) + \phi_y \left(y_{i,t} - \overline{y}_{i,t}\right) + \phi_{i^*} i^*_t + \delta X_{i,t} + \nu_{i,t} \tag{4.1}$$

The above is a forward-looking Taylor rule in which the policy rate, $i_{i,t}$, reacts to expected inflation deviations from target, $E_t \left(\pi_{i,t+1} - \pi^T_{i,t+1}\right)$, and to the output gap, $\left(y_{i,t} - \overline{y}_{i,t}\right)$. We also consider the foreign interest rate, i^*_t, as one of the determinants of the policy rate. Variables in $X_{i,t}$ may contain additional endogenous or exogenous variables: exchange rate fluctuations, the U.S. output gap, and so on.

This forward-looking specification is widely used in empirical research and, as noted by Clarida et al. (1998), it has several virtues. First, explicitly incorporating expected inflation in the reaction function makes it easier to disentangle the link between the estimated coefficients and central bank objectives. In fact, it is not clear from the simple contemporaneous Taylor specification whether the central bank responds to the output gap independently of concern about future inflation, or if the output gap is, *per se*, a target. Second, by having the central bank respond to forecasts of inflation, output and other contemporaneous variables, we incorporate a realistic feature of policy-making, namely that central banks consider a broad array of information.

Our specification, on the other hand, incorporates an inertial element in the rule. This is introduced in order to reflect the fact that monetary policy changes only gradually as new information becomes available. In this context, the coefficients in (4.1) can be interpreted as short-run policy responses.[12]

[12] Long-run coefficients can be obtained by dividing the estimates by $\frac{1}{1-\rho}$.

Following Aizenman et al. (2011), we estimate (4.1) using panel data techniques. Our approach, however, innovates in several dimensions. First, we consider a panel of developed and developing countries (and not just developing countries). Second, we use data only from the period in which IT has been formally in place. Third, we estimate a forward-looking version rather than a policy rule that reacts to contemporaneous values of inflation as in Aizenman et al. (2011) [13]. Finally, we do not incorporate countries in which an official IT regime has not been adopted.

4.1 Data

We consider a group of 7 developed and 16 developing countries (see Table 1). The data considered for each country starts in the quarter in which the respective central bank explicitly adopted IT and ends in the last quarter of 2010. The policy rate, on the other hand, is the rate that the central bank targets. This may differ across countries. For instance the policy rate in Switzerland is the 3-month Swiss Franc Libor rate, whereas in Norway the policy rate is the overnight deposit rate at the central bank. This distinction is relevant because the specification in (4.1) aims to capture the explicit monetary policy response to different variables.

The inflation rate is defined as the year-on-year variation of the relevant price index. The target is the one explicitly announced by each central bank and it can be time-varying. The output gap considered is the deviation of output from an HP filter, whereas the foreign rate is the nominal Fed funds rate, i_t^{US}. Some other variables considered are the U.S. output gap $(y_t^{US} - \overline{y}_t^{US})$, the multilateral devaluation rate (de_t), the percentage change in the WTI oil price $(dWTI_t^{US})$ and the OCDE inflation rate (π_t^{OCDE}).

Before estimating the Taylor rule, we check whether the series are stationary. As shown in Table 2, the hypothesis of common unit root can be rejected for the series considered, either using the DF or the PP test. If series are considered across groups of developed and developing countries, the unit root hypothesis is also rejected.

4.2 Estimation Approach

There are two problems that emerge when estimating a forward-looking Taylor rule like (4.1). The first one is that in a panel with a lagged dependent variable, estimations are biased when the

[13] Our results are robust to considering a Taylor rule that responds to contemporaneous inflation.

time dimension of the panel, T, is small.[14] The second problem is that the correlation between the error term in (4.1) and expected inflation deviation used as regressor, may generate biased and inconsistent estimates, independently of the size of T.

In order to correct the previous problems, we proceed as follows. We use a country fixed-effects least-squares estimation procedure (LSDV) to correct the bias generated by the presence of a lagged dependent variable.[15] As shown by Judson and Owen (1999), the LSDV estimator performs well in a panel with a large T. In particular, the LSDV estimator has a smaller bias than the Anderson-Hsiao and Arellano and Bond estimators when $T = 30$.[16]

Now, in order to correct the bias generated by the correlation between the error term and the explanatory variable, we estimate the LSDV using a GMM-IV approach as in Clarida et al. (1998) and Clarida et al. (2000). In particular, we remove the unobserved expected inflation deviation by rewriting the policy rule (4.1) in terms of realized variables, as follows:

$$i_{i,t} = \mu_i + \rho i_{i,t-1} + \phi_\pi \left(\pi_{i,t+1} - \pi^T_{i,t+1}\right) + \phi_y \left(y_{i,t} - \overline{y}_{i,t}\right) + \phi_{i^*} i^*_t + \delta X_{i,t} + \varepsilon_{i,t}, \qquad (4.2)$$

were the error term, $\varepsilon_{i,t}$, is a linear combination of the forecast errors of inflation and the exogenous disturbance, $\nu_{i,t}$. We define a vector of variables $\mathbf{u}_{i,t}$ within each central bank's information set, at the time each one chooses the interest rate, that is orthogonal to $\nu_{i,t}$. Hence, $E\left[\varepsilon_{i,t}|\mathbf{u}_{i,t}\right] = 0$. The previous condition, along with equation (4.2), implies the following set of orthogonality conditions we exploit for estimation:

$$E\left[i_{i,t} - \mu_i - \rho i_{i,t-1} - \phi_\pi \left(\pi_{i,t+1} - \pi^T_{i,t+1}\right) - \phi_y \left(y_{i,t} - \overline{y}_{i,t}\right) - \phi_{i^*} i^*_t - \delta X_{i,t}|\mathbf{u}_{i,t}\right] = 0 \qquad (4.3)$$

In order to estimate the parameters of interest, we use the generalized methods of moments (GMM), instrumenting expected inflation deviations as well as any other endogenous regressor.[17] The set of instruments, $\mathbf{u}_{i,t}$, we use includes lagged values of country specific output, inflation deviations, the policy rate, exchange rate changes, as well as contemporaneous and lagged values of common variables: the Fed funds rate and the percentage change in the WTI oil price.

[14] See Nickell (1981) and Aizenman et al. (2011).

[15] In equation (4.1) the country fixed effect is introduced through the μ_i coefficient.

[16] This is the reason why we consider only IT countries with at least 30 observations.

[17] The exchange rate is also endogenous; hence, when this variable is included, the error term $\varepsilon_{i,t}$ also incorporates forecast errors of the exchange rate. In other words, exchange rate movements are also instrumented.

4.3 Results

Results from estimating (4.1) are presented in Table 3. When all 23 countries are included (column (1)), we find a positive and significant policy response to the Fed funds rate. In particular, the long-run response to this variable is 0.945. This result holds even after controlling for other external factors like the U.S. output gap, the exchange rate and changes in the WTI oil price. In general, the empirical literature on Taylor rules does not assess the role of foreign rates in determining the monetary policy stance. As a consequence, it is difficult to compare our results to previous findings. To our knowledge only Clarida et al. (1998) assess the role of foreign rates in simple forward-looking Taylor rules, concluding that they play a role in determining the policy rate in the cases of the Bank of England, the Bank of France and the Bank of Italy in the period that goes from 1980 to 1990. Our results are in line with those findings, although we consider a completely different period and a larger set of countries. The response to nominal devaluation is negative (and significant) for developed economies and positive, although not statistically different from zero, in emerging economies.

We find a high degree of policy inertia, measured by the lagged interest rate coefficient. This value suggests that roughly 20% of the new information that central banks have within each quarter is reflected in the policy rate. This confirms the conventional wisdom that central banks move the policy instruments slowly as new information becomes available. On the other hand, the response to inflation deviations from target and to the output gap are positive and significant. The long-run response to inflation is slightly greater than 1.0, whereas the long-run response to output deviations is smaller (0.5). Qualitative results, namely a high degree of policy inertia combined with a comparatively larger response to inflation than to output are in line with previous findings for the U.S. (Clarida et al. (2000)), some developed economies (Clarida et al. (1998) and Lubik and Schorfheide (2007)) and emerging countries (Mohanty and Klau (2004) and Aizenman et al. (2011)).

4.4 Subsample analysis: Developing and developed countries

To assess the extent to which our results may differ across countries, we split the sample into two different groups: emerging economies (16 countries) and developed economies (7 countries). In the case of emerging economies, column (2) in Table 3, the policy response to the Fed funds rate is positive and significant, with a the long-run response of 1.2. On the other hand, the response to exchange rate movements and to changes in the WTI oil price are not statistically different from zero. This is an indication that, once the effects of these variables on expected CPI inflation are taken into account, the monetary authority does not react to them. The response to the U.S. output gap, on the other hand, is negative and significant. This may be an indication that, in emerging economies, the business cycle moves in different directions than in the U.S.. The policy response to expected inflation deviation is positive, significant and slightly greater than 1.0 in the long run. As before, the response to the domestic output gap is positive and significant and is, in the long run, smaller than the response to inflation.

For developed economies, column (3) in Table 3, we find a positive, and significant, policy response to the Fed funds rate. This response is smaller than the one found for emerging economies. In terms of other foreign variables, we find a negative response to changes in the WTI oil price. This suggests that, for this group of economies, movements in the oil price (after controlling for the impact they have on expected inflation) may be contractionary and hence may induce a monetary policy easing. In that respect, a WTI oil price increase could be interpreted as a negative supply shock in the case of developed economies. The policy response to exchange rate movements, on the other hand, is negative and statistically different from zero.

In the case of developed countries, the long-run response to inflation is positive and significant. The response to the U.S. output gap is positive and significant whereas the reaction to the domestic output gap is not statistically different from zero. This may be an indication of a strong synchronicity between business cycles in the U.S. and developed economies.[18] If we exclude the U.S. output gap from the regression, the domestic output gap coefficient becomes positive and statistically significant.

In the case of developed economies, the Hansen J-Test is close to zero in our initial specification (column (3) in Table (3)). This is an indication that the error term is correlated with the instruments. This can happen either because an instrument has been excluded or because an explanatory variable, not included in the regression, is included as an IV. We explore this latter alternative and include in the regression some of the instruments. We find that, in the case in which the lagged value of the Fed's policy rate is included in the regression, the Hansen J-Test rejects the hypothesis of correlation between the instruments and the error term (see column (4) in Table (3)). In this case, the lagged FED policy rate has a negative and significant impact on the policy rate. Overall, the long-run response to the FED fund rate does not change from the

[18]We find collinearity between the U.S. output gap and the domestic output gap for the group of developed economies.

previous specification. Finally, we test the extent to which central banks in developed countries react to expected inflation rather than to the expected inflation gap, given the fact that the inflation target is, in most cases, a constant (column (5) in Table 3). Under this specification, the validity of instruments is not rejected and all previous results hold.

4.5 Robustness Exercises

Our results indicate that IT central banks, both in developing and developed economies, move the policy instrument in response to movements in the Fed funds rate.[19] They also respond, in a systematic way, to expected inflation, the domestic output gap and, in some cases, to some other external variables.

So far we have used the Fed's nominal rate, and there are three reasons to consider alternative specifications. First, the nominal Fed funds rate reacts, among other things, to movements in U.S. inflation. If those movements are correlated with domestic inflation, they may explain the observed correlation between domestic and foreign policy rates. Second, there may be common elements, like a worldwide decline in inflation, to which both the Fed funds rate and the domestic rate may have reacted. If this is the case, the correlation between rates may be induced by a third common variable. Finally, as suggested by the theoretical specification in (3.10), in a forward-looking CPI inflation based rule, is it efficient to react to the foreign real rate in order to stabilize domestic inflation.

To address the previous issues, we first replace the Fed's nominal policy rate by the ex-ante real rate, r_t^{US}. Data on this variable is based on the real rate constructed by the Fed.[20] We estimate the forward-looking specification using the Fed's real rate for all countries (see column (1) in Table 4). Results show that, even in this case, the policy response to the foreign rate is positive and statistically different from zero.[21] Now, to test the hypothesis that domestic and foreign rates are reacting to a common (global) variable, we introduce in the regression a measure of global inflation. This is the average inflation rate in OECD countries. As shown in column (2) in Table (4), the policy response to this common variable is positive and significant.

[19] We test whether there is a response to the ECB interest rate and found that specifications containing the Fed's policy rate are preferred (i.e. the response to the ECB policy rate is not significant).

[20] We use the information on real rates based on inflation expectations one year ahead. This series is published by the Cleveland FED. This, in turn, is constructed using the methodology developed in Haubrich et al. (2011).

[21] In addition to the Fed's real rate, we also introduce U.S. inflation. The results are virtually unchanged: the domestic policy rate reacts to the Fed's real rate. Results are not presented, but are available upon request.

In this case, the response to the real ex-ante foreign rate is still positive, although its long-run value declines importantly. The rest of the coefficients have the same sing as before, but smaller long-run values. Based on the previous results, we conclude that global inflation is an element to which central banks have reacted but, even when this element is taken into account, central banks still react to movements in the real foreign rate.

Finally, there may be other common elements, besides global inflation, which may explain the observed correlation between domestic and foreign rates. We introduce a linear trend in order to control for this additional (non observed) common element. As shown in column (3) in Table (4), once this linear trend is included the response to the real foreign rate is still positive and statistically different from zero. The rest of the coefficients do not change significantly, although the response to global inflation is not different from zero. This latter result suggests a certain degree of collinearity between our measure of global inflation and the linear trend.

4.6 Testable Implications

The simple forward-looking Taylor rule in (3.10) provides three testable implications. First, central banks should respond to the *real* ex-ante foreign rate. Second, this response is increasing in the relative importance that foreign goods have on the consumption basket (the α coefficient representing the degree of openness in the economy). Third, the response to expected inflation should be 1.

To test the previous implications, we estimate (4.1), but instead of using the nominal Fed funds rate, we use the real ex-ante version of it, r_t^{US}. The results, presented in Table 5, indicate that IT countries react to r^{US}, besides responding to expected inflation and to the output gap. The long-run elasticity to the foreign real rate is larger for emerging economies than for developed countries. The rest of the coefficients are similar to the findings reported in the baseline estimates in Table 3.

Now, to test the extent to which the response to the real foreign rate is increasing in the degree of openness, we proceed as follows. First, we estimate (4.1) using the real Fed's fund rate for emerging and developed countries. In each case, we allow for a country-specific response to the foreign real rate. Then we compare this country-specific elasticity, ϕ_{i,r^*}, to a proxy variable for openness. This latter variable corresponds to the exchange rate to CPI inflation pass-through coefficient reported by Devereux and Yetman (2010). This variable is computed at a country-specific level and shows the impact that changes in the nominal exchange rate have on CPI inflation. As shown in Figure (2) there is a positive and statistically significant correlation between ϕ_{i,r^*} and the pass-through coefficient. If we exclude outlier countries with either large pass-through coefficient (Peru) or negative ϕ_{i,r^*} coefficient (Hungary and Brazil), the qualitative results do no change: there is a positive and significant correlation between ϕ_{i,r^*} and the pass-through coefficient (Figure (3)).

Finally, we test the hypothesis that the long-run policy response to expected inflation, $\frac{\phi_\pi}{1-\rho}$, is equal to 1. As shown in Table 6, the null hypothesis cannot be rejected for the complete set of countries nor for emerging and developed economies considered separately.

Overall, we find that IT central banks react to the ex-ante real Fed funds rate and that this reaction is increasing in the degree of exchange rate pass-through. Furthermore, the policy response to expected inflation is not statistically different from 1. These findings are consistent with the efficient forward-looking CPI inflation rule in (3.10).

5 Conclusions

This paper addresses two unsettled issues. First, in the simple sticky price model of Galí and Monacelli (2005) we derive a CPI inflation-based Taylor rule capable of implementing the flexible price allocation. Second, we empirically investigate the extent to which IT central banks react to movements in the foreign policy rate (the Fed funds rate) even after controlling for CPI inflation and other, target and non-target, variables.

We show that a CPI inflation based Taylor rule can implement the efficient allocation under some specific circumstances. In particular, for this rule to be efficient, the natural rate of interest must be directly linked to the real foreign interest rate, as well as to domestic productivity shocks. The policy response to CPI inflation, on the other hand, is such that it accommodates, to some extent, movements in CPI inflation whereas the response to output gap movements should be positive. In this way, this rule ensures that the real ex-ante interest rate, based on CPI inflation, moves in the face of domestic and foreign shocks so as to induce efficient movements in consumption. This is in sharp contrast with the natural rate relevant for domestic inflation Taylor rules, which depends only on productivity shocks.

The empirical evidence we provide in this paper, based on Taylor rules estimates for a panel of 23 IT countries, shows that central banks respond to movements in the foreign interest rate (the Fed funds rate), besides reacting to expected CPI inflation and the domestic output gap.

This result is robust to controlling for movements in the exchange rate, as well as other variables capturing the international business cycle. It is also robust across different groups of countries: developed and emerging economies. Moreover, the policy reaction to foreign interest rates is increasing in the degree of openness, which is in line with our theoretical results.

Overall, our results provide a rationale for the systematic policy response to movements in the foreign interest rate we observe in practice. In this context, we show that this response to foreign rates is coherent with a central bank that tries to stabilize domestic inflation and output in a context in which CPI inflation is the explicit policy target.

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APPENDIX

A Galí and Monacelli (2005) Model

A.1 Households

The representative household maximizes expected utility from consumption and leisure. Given the sequence of flow budget constraints of the household, the optimal allocation of consumption and labor is given by the following expressions:

$$c_t = E_t\left(c_{t+1}\right) - \frac{1}{\sigma}\left(i_t - E_t\left(\pi_{t+1}\right) - \rho\right) \tag{A.1}$$

$$w_t - p_t = \sigma c_t + \varphi n_t \tag{A.2}$$

Equation (A.1) is the conventional Euler equation in which consumption, c_t, depends on its future expected value and it is inversely related to the real ex-ante CPI-based interest rate, $i_t - E_t\left(\pi_{t+1}\right)$. The σ coefficient represents the inverse of the intertemporal elasticity of substitution. Equation (A.2), on the other hand, is the competitive labor supply schedule. This determines the quantity of labor supplied, n_t, as a function of the real wage, $w_t - p_t$, given the marginal utility of consumption, σc_t. The φ coefficient is the inverse of the labor supply elasticity. Finally, $\rho = log(\beta)$ where β is the discount factor.

A.1.1 Domestic inflation, CPI inflation, terms of trade and real exchange rate

In this open economy, a proportion α of consumption is allocated to imported goods. In this context it can be shown that the price of the consumption basket, p_t, is a linear combination between the price of domestically produced goods, $p_{H,t}$, and the price of imported goods, $p_{F,t}$:

$$p_t = (1-\alpha)p_{H,t} + \alpha p_{F,t}. \tag{A.3}$$

Hence, CPI inflation is a linear combination between domestic inflation, $\pi_{H,t}$, and foreign goods inflation, $\pi_{F,t}$, expressed in domestic currency:

$$\pi_t = (1-\alpha)\pi_{H,t} + \alpha \pi_{F,t}. \tag{A.4}$$

On the other hand, the terms of trade, s_t are defined as the log-difference between the prices of foreign and domestic goods

$$s_t = p_{F,t} - p_{H,t} \tag{A.5}$$

where $p_{F,t} = e_t + p_t^*$ if we assume that the law of one price holds for individual goods at all times. The variable e_t represents the nominal effective exchange rate and p_t^* is the world price index. Now, from (A.4) and (A.5) it follows that domestic inflation and the terms of trade are linked according to:

$$\pi_t = \pi_{H,t} + \alpha \Delta s_t. \tag{A.6}$$

Finally, using (A.3) and (A.5), it can be shown that the real exchange rate, defined as $q_t = e_t + p_t^* - p_t$, is proportional to the terms of trade:

$$q_t = (1 - \alpha) s_t. \tag{A.7}$$

A.1.2 International Risk Sharing and the UIP Condition

An Euler equation analogous to (A.1) holds also for the rest of the world. Under the assumption of complete markets for securities traded internationally, the stochastic discount factor for the domestic economy is also the relevant one for households in the rest of the world. In this context, it can be shown that:

$$\begin{aligned} c_t &= c_t^* + \frac{1}{\sigma} q_t \\ &= c_t^* + \left(\frac{1-\alpha}{\sigma} \right) s_t, \end{aligned} \tag{A.8}$$

which is a simple relationship linking domestic consumption with world consumption, c_t^* , and the real exchange rate (terms of trade). This relationship, which holds in many international RBC models (see Backus and Smith (1993)), states that domestic consumption should increase if the real exchange rate depreciates, that is, consumption should be relatively high in countries where it is relatively cheap.

Now, under the assumption of complete international financial markets, the equilibrium price of a riskless bond denominated in foreign currency can be combined with the price of a similar bond in domestic currency to obtain the familiar expression for the UIP condition:

$$i_t - i_t^* = E_t\left\{\Delta e_{t+1}\right\}. \tag{A.9}$$

A.2 Aggregate Demand

Goods market clearing in the small open economy requires that domestic output be consumed by domestic households and by the rest of the world. Now, taking into account the optimality conditions that determine the demand for output, both by domestic households and the rest of the world,[22] the output market clearing condition can be expressed as:

$$y_t = c_t + \frac{\alpha\omega}{\sigma} s_t, \tag{A.10}$$

where $\omega = \sigma\gamma + (1-\alpha)(\sigma\eta - 1)$. Parameter $\eta > 0$ measures the substitutability between domestic and foreign goods, from the viewpoint of the domestic consumer, while γ measures the substitutability between goods produced in different countries.

Finally, let $nx_t = \left(\frac{1}{Y}\right)\left(Y_t - \frac{P_t}{P_{H,t}} C_t\right)$ denote net exports in terms of domestic output expressed as a fraction of the steady-state output, Y. A first-order approximation yields $nx_t = y_t - c_t - \alpha s_t$, which combined with (A.10) implies a simple relation between net exports and terms of trade

$$nx_t = \alpha\left(\frac{\omega}{\sigma} - 1\right) s_t. \tag{A.11}$$

A.3 Firms

A representative firm in the home economy produces a differentiated good with a linear technology whose only input is labor:

$$y_t = a_t + n_t \tag{A.12}$$

where a_t is an AR(1) productivity process that evolves according to $a_t = \rho_a a_{t-1} + \epsilon_t$, where ϵ_t is an i.i.d productivity shock.

Given this production function, real marginal costs depend on the real wage, deflated by domestic prices, and productivity:

[22] For more details on optimality conditions, see Galí and Monacelli (2005).

$$mc_t = -v + w_t - p_{H,t} - a_t \tag{A.13}$$

where v=-log(1-τ), with τ representing an employment subsidy whose role is to remove the distortion associated to monopolistic competition.

Now, using (A.2), (A.8), (A.10), (A.12) and the fact that $c_t^* = y_t^*$, the real marginal costs can be expressed as:

$$mc_t = -v + (\sigma_\alpha + \varphi)y_t + (\sigma - \sigma_\alpha)y_t^* - (1 + \varphi)a_t, \tag{A.14}$$

where $\sigma_\alpha = \frac{\sigma}{(1-\alpha)+\alpha\omega} > 0$. Hence, as in the close economy, the marginal cost is increasing in domestic output and decreasing in technology. World output, on the other hand, has a positive impact on domestic marginal costs as long as $\sigma > \sigma_\alpha$.

Firms are assumed to set prices in a staggered fashion, as in Calvo (1983). In particular, a measure 1-θ of randomly selected firms sets new prices each period. The firm's probability of re-optimizing in any given period is assumed to be independent of the time elapsed since it last reset its price. As shown by Galí and Monacelli (2005), the optimal price-setting strategy for a firm resetting its price in period t, gives rise to a forward-looking Phillips curve of the form:

$$\pi_{H,t} = \beta E_t \left\{\pi_{H,t+1}\right\} + \lambda\widehat{mc}_t \tag{A.15}$$

where β is the discount factor, $\lambda = \frac{(1-\beta\theta)(1-\theta)}{\theta}$ and $\widehat{mc}_t$ is the log deviation of the real marginal cost from its flexible price level. The intuition behind this Phillips curve is that if prices can be re-optimized only infrequently, price setters will incorporate the expected path of future marginal costs into their pricing decisions. In an open economy those marginal costs depend on both domestic and external variables.

In the absence of nominal rigidities, firms set prices such that the markup is constant, $mc_t = -\mu$, for all t. Imposing this latter condition on (A.14) and solving for domestic output gives an expression for the natural level of output, $\overline{y}_t$, defined as

$$\overline{y}_t = \Omega + \Gamma a_t + \alpha\Psi y_t^* \tag{A.16}$$

where $\Omega = \frac{v-\mu}{\sigma_\alpha+\varphi}$, $\Gamma = \frac{1+\varphi}{\sigma_\alpha+\varphi}$, and $\Psi = -\frac{(\omega-1)\sigma_\alpha}{\varphi}$. It follows, from (A.14), that the output gap, $x_t = y_t - \bar{y}_t$, is proportional to marginal costs:

$$\widehat{mc}_t = (\sigma_\alpha + \varphi)x_t. \tag{A.17}$$

B CPI Inflation-Based Natural Rate

From the UIP condition, equation (A.9), and (3.3) we can establish the following relationship between the the two natural rates

$$\overline{r}_t = (1-\alpha)\overline{r}_{H,t} + \alpha r_t^*. \tag{B.1}$$

Combining the above equation with the expression for $\overline{r}_{H,t}$ (equation (2.6)), and using the fact that in the rest of the world $E_t\left(\Delta y_t^*\right) = \frac{1}{\sigma^*} r_t^*$ gives

$$\overline{r}_t = (1-\alpha)\left[-\sigma_\alpha \Gamma_\alpha (1-\rho_a)\right] a_t + \left[\frac{(1-\alpha)\alpha\sigma_\alpha\left(\Theta+\Psi\right)}{\sigma^*} + \alpha\right] r_t^*$$

Now, considering that $\sigma_\alpha = \frac{\sigma}{(1-\alpha)+\alpha\omega}$, $\Gamma_\alpha = \frac{1+\varphi}{\sigma_\alpha+\varphi}$, $\Theta = \omega - 1$ and $\Psi = -\frac{\Theta\sigma_\alpha}{\sigma_\alpha+\varphi}$, the above expression can be simplified to

$$\begin{aligned}
\overline{r}_t &= (1-\alpha)\left(\frac{-\sigma(1+\varphi)(1-\rho_a)}{\sigma+\varphi-\alpha\varphi+\alpha\varphi\omega}\right) a_t + \left(\frac{\alpha(1-\alpha)\Theta\varphi}{\sigma+\varphi+\alpha\varphi\Theta} + \alpha\right) r_t^* \\
&= \left(\frac{(1-\alpha)(\sigma+\varphi)}{(\sigma+\varphi)+\alpha\varphi\Theta}\right)\left(\frac{-\sigma(1+\varphi)(1-\rho_a)}{\sigma+\varphi}\right) a_t + \left(\frac{\alpha(\sigma+\varphi)+\alpha\Theta\varphi}{(\sigma+\varphi)+\alpha\Theta\varphi}\right) r_t^* \\
&= (1-\lambda_\alpha)\left(\frac{-\sigma(1+\varphi)(1-\rho_a)}{\sigma+\varphi}\right) a_t + \lambda_\alpha r_t^* \\
&= (1-\lambda_\alpha)\,\overline{r}_t^{close} + \lambda_\alpha r_t^*
\end{aligned} \tag{B.2}$$

where $\lambda_\alpha = \left(\frac{\alpha(\sigma+\varphi)+\alpha\Theta\varphi}{(\sigma+\varphi)+\alpha\Theta\varphi}\right)$ and $\overline{r}_t^{close} = \left(\frac{-\sigma(1+\varphi)(1-\rho_a)}{\sigma+\varphi}\right) a_t$. Furthermore, $|\lambda_\alpha| < 1$. Now, in the particular case in which $\Theta = \omega - 1 \geq 0$, the condition $0 \leq \lambda_\alpha < 1$ is satisfied. Hence, in this case the CPI inflation based natural rate is a linear combination between the closed economy natural rate and the foreign real rate.

C Determinacy Conditions for a Forward-Looking Taylor Rule

The open economy model can be characterized by four equations. The IS (2.4), the New Keynesian Phillips Curve (2.5), the natural rate (2.6) and the forward-looking rule based on domestic inflation (3.6). Using this latter equation to eliminate i_t, we can write the system in the form

$$\begin{bmatrix} x_t \\ \pi_{H,t} \end{bmatrix} = A \begin{bmatrix} E_{t+1}(x_{t+1}) \\ E_{t+1}(\pi_{H,t+1}) \end{bmatrix} \tag{C.1}$$

where $A = \begin{pmatrix} \frac{\sigma_\alpha}{\sigma_\alpha+\phi_y} & \frac{(1-\phi_\pi)}{\sigma_\alpha+\phi_y} \\ \frac{\kappa_\alpha\sigma_\alpha}{\sigma_\alpha+\phi_y} & \frac{\kappa_\alpha(1-\phi_\pi)}{\sigma_\alpha+\phi_y} + \beta \end{pmatrix}$

The characteristic polynomial of A is given by $p(\lambda) = \lambda^2 + a_1\lambda + a_0$, where $a_0 = \frac{\beta\sigma_\alpha}{\sigma_\alpha+\phi_y}$ and $a_1 = -\left(\frac{\sigma_\alpha}{\sigma_\alpha+\phi_y} + \frac{\kappa_\alpha(1-\phi_\pi)}{\sigma_\alpha+\phi_y} + \beta\right)$. Since the variables x_t and $\pi_{H,t}$ are free, we need both eigenvalues of A to be inside the unit circle for uniqueness. The previous conditions are satisfied if:

$$|a_0| < 1 \tag{C.2}$$

$$|a_1| < 1 + a_0. \tag{C.3}$$

Condition (C.2) implies that $\phi_y > (\beta - 1)\sigma_\alpha$ and $\phi_y > \sigma_\alpha(1+\beta)$. Without loss of generality, both conditions are satisfied (when β tends to 1) if:

$$\phi_y \geq 0 \tag{C.4}$$

On the other hand, condition (C.3) implies that:

$$\kappa_\alpha(\phi_\pi - 1) - \phi_y(1+\beta) < 2(1+\beta)\sigma_\alpha \tag{C.5}$$

and

$$\kappa_\alpha(\phi_\pi - 1) + \phi_y(1-\beta) > 0 \tag{C.6}$$

Hence, the forward-looking Taylor rule implements the efficient equilibrium if conditions (C.4) to (C.6) are satisfied.

Table 1: List of Inflation-Targeting Countries

Country	Date of Implementation	Policy Rate	Target
Developed countries			
Australia	1994.q3	cash rate	CPI
Canada	1991.q1	o/n discount rate	CPI
Norway	2001.q1	o/n deposit rate at CB	CPI
New Zealand	1990.q1	cash rate	CPI
Sweden	1995.q1	repo	CPI
Switzerland	2000.q1	3-month CHF Libor	CPI
U.K.	1992.q1	Repo	CPI
Developing Countries			
Brazil	1999.q1	SELIC o/n	CPI
Chile	1991.q1	o/n discount	CPI
Colombia	1999.q3	TBS o/n rate	CPI
Czech Rep.	1998.q1	2-week repo	CPI
Hungary	2001.q1	2-week deposit	CPI
Iceland	2000.q1	7-day repo	CPI
Indonesia	2001.q1	1-month SBI	CPI
Israel	1992.q2	headline	CPI
Mexico	1999.q1	1-day bank funding 3	CPI
Peru	1994.q1	o/n deposit rate at CB	CPI
Philippines	2001.q1	reverse repo	CPI
Poland	1998.q1	28-day intervention	CPI
South Africa	2000.q1	repo	CPI
South Korea	1998.q1	o/n call	CPI
Thailand	2000.q1	14-day repo	Core CPI
Turkey	2002.q1	o/n borrowing	CPI

Source: official central bank information.

Table 2: Joint Unit-Root Tests

	Dickey-Fuller			Phillips-Perron		
Variable	Z	P	L	Z	P	L
i_t	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
$y_t - \overline{y}_t$	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
π_t	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
$\pi_t - \overline{\pi}_t$	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
de_t	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
$dWTI_t^{US}$	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
$y_t^{US} - \overline{y}_t^{US}$	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
i_t^{US}	0,0000	0,0007	0,0000	0,2955	0,8499	0,3178
r_t^{US}	0,0000	0,0001	0,0000	0,0031	0,1123	0,0078
π_t^{OCDE}	0,0097	0,2101	0,0195	0,0898	0,5843	0,1182

p-values for each statistic

Z: statistic based on a normal distribution

P: statistic based on a chi-squared distribution

L: statistic based on a logistic distribution

Figure 1: Responses to Different Shocks under the Efficient Rule

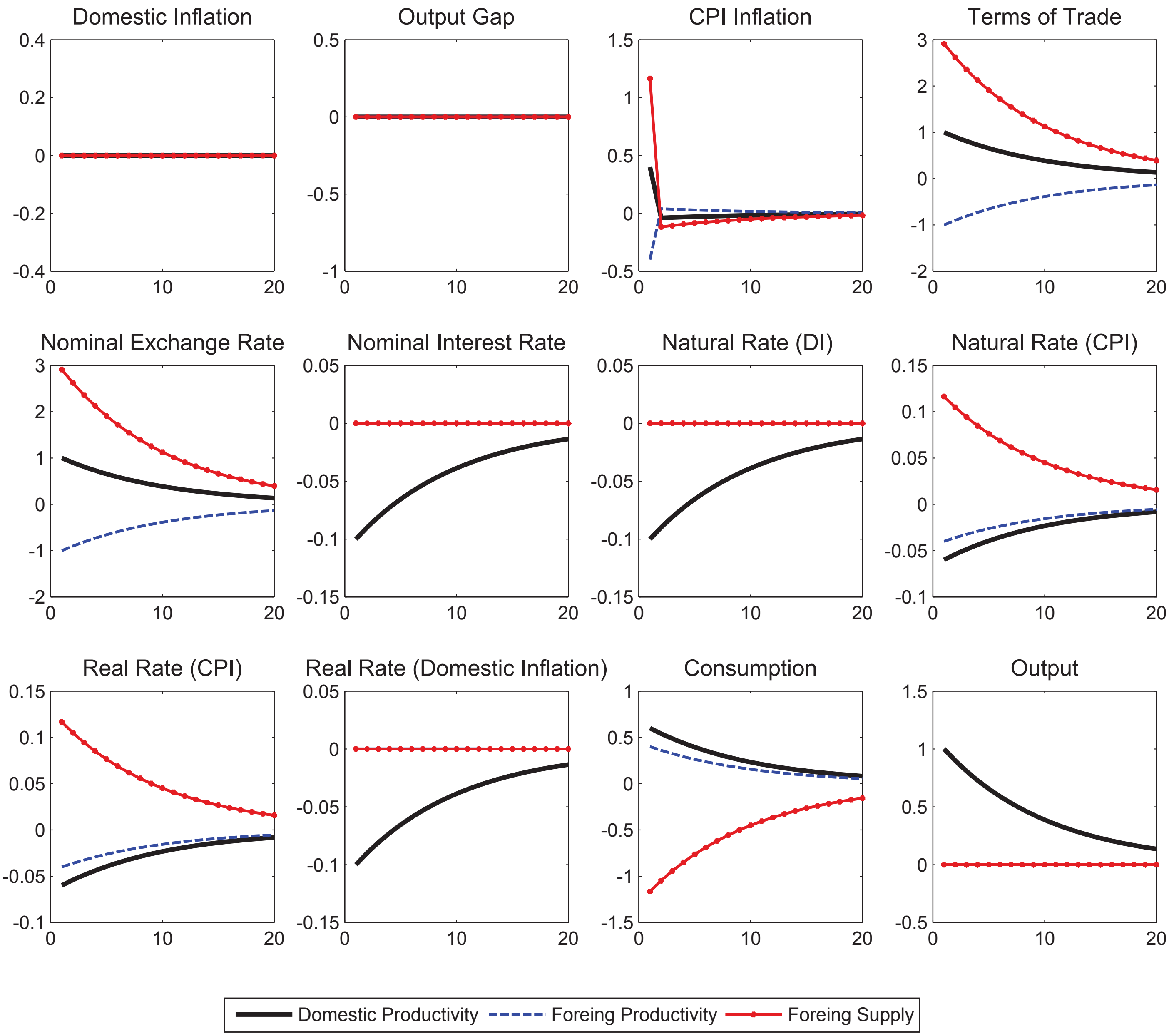

Figure 2: Correlation between ϕ_{r^*} and Passthrough Coefficient (All Countries)

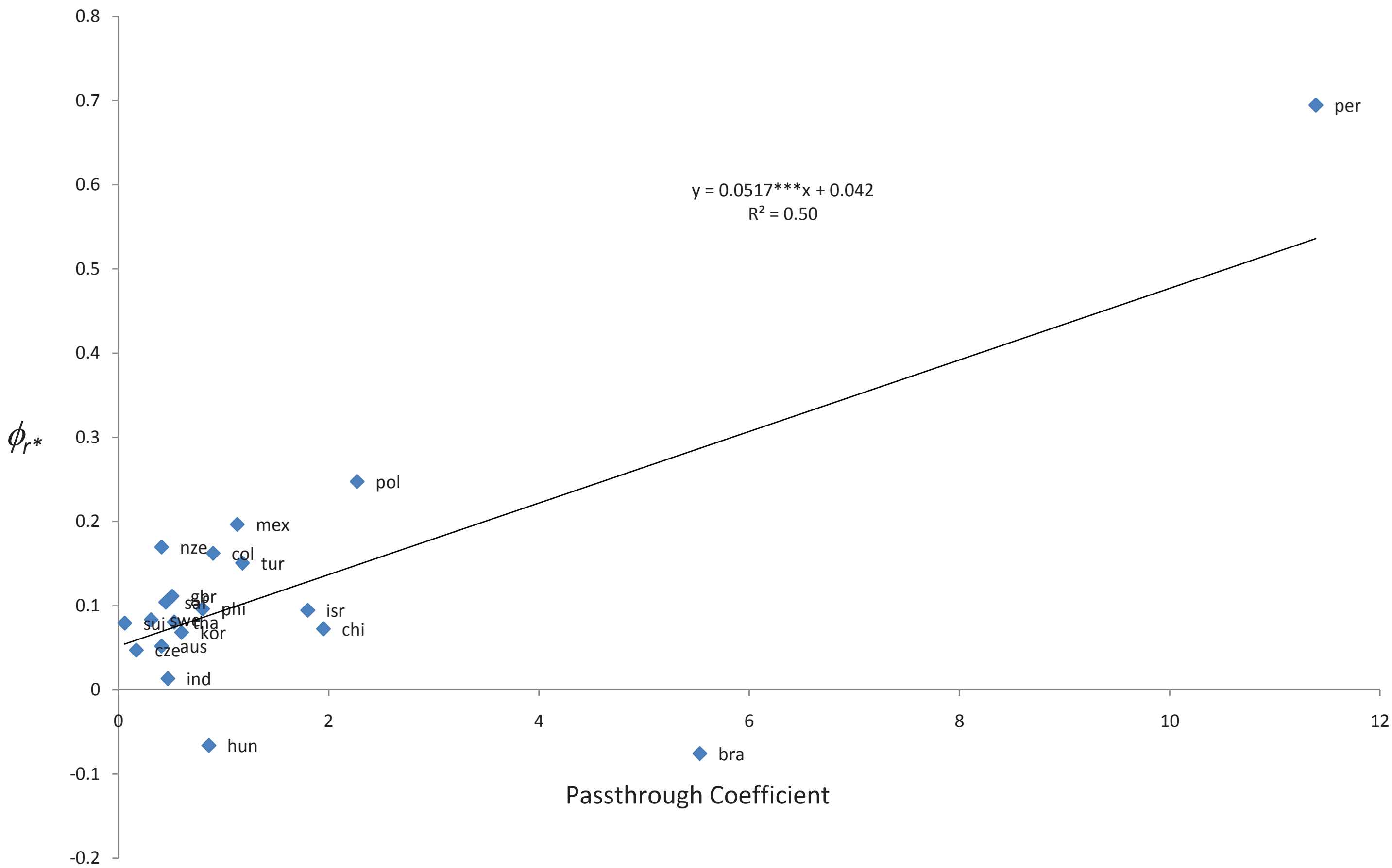

Figure 3: Correlation between ϕ_{r^*} and Passthrough Coefficient (Excluding Outliers)

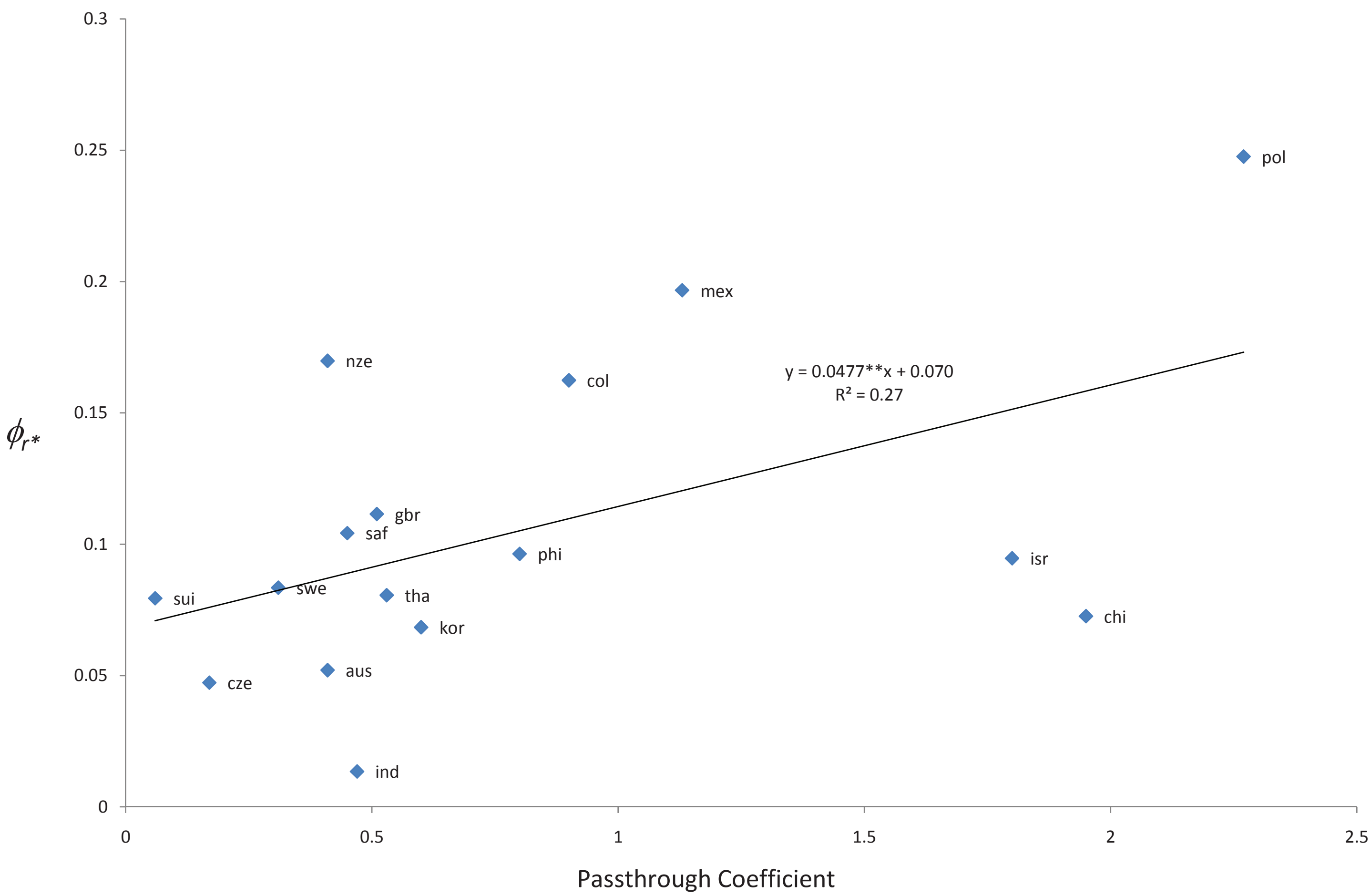

Table 3: Forward-Looking Taylor Rules Estimates (2-Step GMM with Country FE)

Explanatory Variables	**All Countries**	**Emerging**	**Developed**		
				(w/ lagged for.rate)	(w/o target)
	(1)	(2)	(3)	(4)	(5)
i_{t-1}	0,783***	0,782***	0,885***	0,911***	0,915***
	[0,0358]	[0,0409]	[0,0216]	[0,0215]	[0,0212]
$y_t - \overline{y}_t$	0,110***	0,143***	-0,0487		
	[0,0376]	[0,0448]	[0,0401]		
π_{t+1}					0,0688**
					[0,0319]
$\pi_{t+1} - \overline{\pi}_{t+1}$	0,236***	0,256***	0,0561*	0,0494*	
	[0,0486]	[0,0555]	[0,0319]	[0,0294]	
de_t	-0,129***	-0,0669	-0,120***	-0,102***	-0,106***
	[0,0275]	[0,0616]	[0,0182]	[0,0153]	[0,0157]
$de_t \times 1_{\{\text{Emerging}\}}$	0,0615				
	[0,0639]				
$dWTI_t^{US}$	-0,986*	-0,768	-0,894***	-0,855***	-0,899***
	[0,572]	[0,861]	[0,300]	[0,260]	[0,260]
$y_t^{US} - \overline{y}_t^{US}$	-0,127*	-0,295**	0,209***	0,185***	0,184***
	[0,0690]	[0,115]	[0,0493]	[0,0309]	[0,0310]
i_t^{US}	0,205***	0,267***	0,0980***	0,305***	0,326***
	[0,0404]	[0,0685]	[0,0196]	[0,0444]	[0,0453]
i_{t-1}^{US}				-0,238***	-0,255***
				[0,0507]	[0,0518]
LONG-RUN COEFFICIENTS					
$y - \overline{y}$	0,507	0,656	-0,423		
π					0,809
$\pi - \overline{\pi}$	1,088	1,174	0,488	0,555	
$y^{US} - \overline{y}^{US}$	-0,585	-1,353	1,817	2,079	2,165
i^{US}	0,945	1,225	0,852	0,753	0,835
No. Observations	1,106	677	422	422	429
No. Countries	23,00	16,00	7,00	7,00	7,00
Avg. Observations per Country	48,09	42,31	60,29	60,29	61,29
Adjusted R-Squared	0,81	0,81	0,88	0,90	0,90
RMSE	1,55	1,90	0,59	0,54	0,55
Log Likelihood	-2043,00	-1388,00	-375,20	-337,10	-346,00
Hansen J-Statistic p-Value	0,53	0,91	0,03	0,06	0,15
Underidentif. LM-Statistic p-Value	0,00	0,00	0,00	0,00	0,00

HAC Standard Errors in Brackets

***: Significative at 1%-level

**: Significative at 5%-level

*: Significative at 10%-level

Table 4: Robustness Check: Real Fed Funds Rate, World Inflation and Trend (2-Step GMM with Country FE)

Explanatory Variables	**Real US Rate**	**World Inflation**	**Trend**
	(1)	(2)	(3)
i_{t-1}	0,839***	0,760***	0,765***
	[0,0291]	[0,0377]	[0,0364]
$y_t - \overline{y}_t$	0,129***	0,0833**	0,0968***
	[0,0384]	[0,0374]	[0,0352]
$\pi_{t+1} - \overline{\pi}_{t+1}$	0,221***	0,215***	0,218***
	[0,0502]	[0,0493]	[0,0463]
de_t	-0,135***	-0,148***	-0,128***
	[0,0314]	[0,0273]	[0,0259]
$de_t \times 1_{\{\text{Emerging}\}}$	0,0311	0,0843	0,136**
	[0,0645]	[0,0580]	[0,0545]
$dWTI_t^{US}$	-1,205**	-0,67	-0,31
	[0,611]	[0,534]	[0,501]
$y_t^{US} - \overline{y}_t^{US}$	-0,0666	-0,0852	0,0374
	[0,0691]	[0,0685]	[0,0644]
r_t^{US}	0,163***	0,140***	0,0765**
	[0,0427]	[0,0397]	[0,0353]
π_t^{OECD}		0,282***	0,0487
		[0,0544]	[0,0648]
t			-0,0189***
			[0,00471]
LONG-RUN COEFFICIENTS			
$y - \overline{y}$	0,801	0,347	0,412
$\pi - \overline{\pi}$	1,373	0,896	0,928
$y^{US} - \overline{y}^{US}$	-0,414	-0,355	0,159
r^{US}	1,012	0,583	0,326
No. Observations	1106	1106	1106
No. Countries	0,801	0,821	0,836
Avg. Observations per Country	23	23	23
Adjusted R-Squared	48,09	48,09	48,09
RMSE	1,63	1,54	1,48
Log Likelihood	-2096	-2038	-1988
Hansen J-Statistic p-Value	0,213	0,975	0,871
Underidentif. LM-Statistic p-Value	-2,10E+03	-2,04E+03	-1,99E+03

HAC Standard Errors in Brackets

***: Significative at 1%-level

**: Significative at 5%-level

*: Significative at 10%-level

Table 5: Forward-Looking Taylor Rules Estimates using Real Fed Funds Rate (2-Step GMM with Country FE)

Explanatory Variables	**All Countries**	**Emerging**	**Developed** (w/ lagged for.rate)	**Developed** (w/o target)
	(1)	(2)	(3)	(4)
i_{t-1}	0,839***	0,825***	0,912***	0,913***
	[0,0291]	[0,0360]	[0,0184]	[0,0198]
$y_t - \overline{y}_t$	0,129***	0,161***		
	[0,0384]	[0,0470]		
π_{t+1}				0,0573*
				[0,0348]
$\pi_{t+1} - \overline{\pi}_{t+1}$	0,221***	0,242***	0,0503*	
	[0,0502]	[0,0576]	[0,0312]	
de_t	-0,135***	-0,1	-0,0940***	-0,106***
	[0,0314]	[0,0680]	[0,0164]	[0,0181]
$de_t \times 1_{\{\text{Emerging}\}}$	0,0311			
	[0,0645]			
$dWTI_t^{US}$	-1,205**	-1,145	-0,556**	-0,701**
	[0,611]	[0,968]	[0,263]	[0,279]
$y_t^{US} - \overline{y}_t^{US}$	-0,0666	-0,195*	0,190***	0,200***
	[0,0691]	[0,113]	[0,0340]	[0,0345]
r_t^{US}	0,163***	0,213***	0,231***	0,251***
	[0,0427]	[0,0733]	[0,0469]	[0,0505]
r_{t-1}^{US}			-0,164***	-0,179***
			[0,0514]	[0,0558]
		LONG-RUN COEFFICIENTS		
$y - \overline{y}$	0,801	0,920		
π				0,659
$\pi - \overline{\pi}$	1,373	1,383	0,572	
$y^{US} - \overline{y}^{US}$	-0,414	-1,114	2,159	2,299
r^{US}	1,012	1,217	0,761	0,828
No. Observations	1,106	677	429	431
No. Countries	23,00	16,00	7,00	7,00
Avg. Observations per Country	48,09	42,31	61,29	61,57
Adjusted R-Squared	0,80	0,79	0,90	0,89
RMSE	1,63	1,99	0,55	0,56
Log Likelihood	-2096,00	-1418,00	-345,90	-361,10
Hansen J-Statistic p-Value	0,21	0,39	0,03	0,05
Underidentif. LM-Statistic p-Value	0,00	0,00	0,00	0,00

HAC Standard Errors in Brackets

***: Significative at 1%-level

**: Significative at 5%-level

*: Significative at 10%-level

Table 6: Testing Long-Run Responses to CPI Inflation. $H_0 : \frac{\phi_\pi}{1-\rho} = 1$

Wald Test for specifications in Table (5)				
	All Countries	Emerging	Developed (w/ lagged for.rate)	Developed (w/o target)
	(1)	(2)	(3)	(4)
χ^2	2,040	1,870	1,400	0,740
$Prob > \chi^2$	0,153	0,171	0,236	0,389

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