BANCO CENTRAL DE RESERVA DEL PERÚ

How Does a Global Disinflation Drag Inflation in Small Open Economies?

Marco Vega* y Diego Winkelried**

*London School of Economics y Banco Central de Reserva del Perú.
**Cambridge University y Banco Central de Reserva del Perú

DT. N°. 2005-001
Serie de Documentos de Trabajo
Working Paper series
Enero 2005

How Does a Global Disinflation Drag Inflation in Small Open Economies?*

Marco Vega†
LSE and Central Bank of Peru

and

Diego Winkelried
Central Bank of Peru

July 2004

Abstract

This paper shows how persistent world inflation shocks hitting a small open economy can re-weight the importance of domestic and foreign factors in the determination of prices. In particular, we study why a global disinflation environment may imply a weakening of the channels whereby domestic shocks affect inflation. We derive a state-dependent Phillips curve based on translog preferences that make the elasticity of substitution of domestic goods sensitive to foreign prices. With this approach we are able to replicate this dragging effect of global disinflation on domestic inflation. We also provide empirical evidence from a wide panel of countries to support the significance of such an effect.

JEL Classification: E31, E52.

Keywords: Phillips Curve, Translog Aggregator, Competitiveness.

*We are indebted to Piti Disyatat, Charles Goodhart, Paul Castillo, Vicente Tuesta and Hugo Perea for valuable comments and suggestions. We also acknowledge participants at the Central Bank of Peru seminars series and the 2004 Latin American Meeting of the Econometric Society in Santiago-Chile.

†Corresponding author: m.a.vega@lse.ac.uk, mvegad@bcrp.gob.pe

1 Introduction

Compared to decades gone, many economies are nowadays characterized by low inflation environments. As pointed out by Andersen and Wascher (2000), Bowman (2003) and Rogoff (2003), there are several reasons behind this global disinflation scenario, for instance institutional factors such as increasing central bank independence, strong commitments to anti-inflationary policies, and the *increased competitiveness* hypothesis in price setting behavior. According to this hypothesis, both the rising globalization and deregulation witnessed worldwide in the 90s have contributed to the fall in the market power of price setting firms. As a result, inflation rates have reached unusual low levels (even below targets) and seem to remain very low, barely reacting to expansionary monetary policies. This fact has been remarkable in small open economies such as Latin American countries since the mid 90s[1].

There are at least two ways to tackle the *increased competitiveness* hypothesis. The first is related to the behavior of markups *vis-a-vis* inflation. A pioneering result offered in Rotemberg and Woodford (1991) for a close economy is that aggregate markups are counter-cyclical[2]. This contrasts the views in Taylor (2000) and Jonsson and Palmqvist (2003) for open economies, where lower inflation rates imply lower market power. In general, the markup debate is not conclusive.

A convenient alternative route of analysis is to leave aside the behavior of markups and note that the *increased competitiveness* hypothesis also relies on the rising number of good varieties faced by consumers due to globalization. The implication of this casual observation is that consumers are more prone to substitute away their consumption towards newer and cheaper goods[3]. As stated by Rogoff (2003, pg. 18), "(...) sharp reductions in [tradable goods] prices are bound to create spillover effects on other sectors. Many traded goods are intermediate goods or, to some degree, *substitutes for non-traded goods*" (the emphasis is ours).

The usual modeling tool for inflation dynamics is the well-known New Keynesian Phillips Curve[4]. Under this approach, it is common to assume that the demands for goods produced by monopolistic firms arise from Constant Elasticity of Substitution (CES) preferences, which seems to be an inappropriate assumption within the *increased competitiveness* context. The contribution of this paper hinges precisely on modeling a simple mechanism explaining the change in the substitutability between foreign and home goods and its implications for aggregate inflation dynamics. For this purpose we follow Bergin and Feenstra (2000, 2001) and rely on translog preferences leading to a state-dependent Phillips curve for a small open economy. The advantage of the translog specification over the widely used CES counterpart is that it allows the demands for goods to depend on the prices of other goods and thereby making the price elasticity of domestically produced goods dependent on price movements elsewhere.

In the light of this type of preferences, a global environment characterized by frequent disin-

[1]Country specific examples can be found in Rogoff (2003).

[2]This means that booms represent periods of falling market power whereas recessions picture episodes of rising market power. Bénabou (1992) and Banerjee and Rusell (2004) also find the negative relationship.

[3]See Kamada and Hirakata (2002) for an empirical overview of the increased competitiveness phenomenon for the Japanese economy. For the USA, Broda and Weinstein (2004) find that import prices have fallen faster than what official statistics suggest due to the increase in the imported goods varieties.

[4]See Clarida et al. (1999).

flation shocks[5], induces a strong strategic complementarity, namely, home producers having to optimally *follow up* the world (downward) inflation trend[6]. The identification of this *dragging* effect of world inflation results crucial for the understanding of the transmission mechanisms of monetary policy in small open economies. Once home inflation has been pushed down severely, monetary policy has a mixed blessing: on one hand, it can enjoy the benefit of low world inflation and on the other hand, it will soon find that pushing up inflation with its standard domestic interest rate instrument gets harder and harder. One obvious way to push up inflation in such circumstances is to use the one channel that gets stronger: the *pass-through* from the exchange rate to inflation, precisely the way central banks might less be willing to be heading for.

Before proceeding, it is important to have a better grasp of the differences between the *dragging* and the *pass-through* effects. For a small open economy, world inflation fluctuations quickly hit tradable goods prices which are then - albeit with lags - aggregated out to affect overall inflation. This is the well-known *pass-through* effect[7] which does not directly impact on non-tradable goods pricing. In contrast, if world inflation also affects non-tradable goods prices, due to a substitution effect, the consequences for overall inflation are stronger. We dub this impact as the *dragging* effect.

The rest of the paper is organized as follows. Section 2 develops partial-equilibrium Phillips curve derivations based on both the CES and the translog aggregator. Section 3 provides some empirical evidence to support the *increased competitiveness* hypothesis and the *dragging* effect using a wide panel of countries. In Section 4 we perform world disinflation experiments with a stylized general equilibrium model to study the effects on the variables of interest and on the power of monetary policy to affect inflation[8]. Section 5 contains our final remarks and suggests some lines of further research.

2 The state-dependence of the Phillips curve

The above discussion recalls the recurrent debate about the non-linearity of the Phillips curve. As pointed out by Dupasquier and Ricketts (1998), several models of price-setting behavior suggest that the parameters of the Phillips curve are functions of macroeconomic conditions[9] such as the level of inflation and, in an open economy, the real exchange rate[10]. These non-linearities may lessen the accuracy of the traditional CES-based New Keynesian Phillips curve as a sensible modeling tool, particularly in small economies with significant disinflation episodes.

[5]For example, the constant appearance of cheap foreign products competing with local ones or the constant innovation in information-based products.

[6]See Bakshi et al. (2003) for a discussion on strategic complementarities in the presence of trend inflation.

[7]See Goldfjan and Werlang (2000) for a review of the *pass-through* literature.

[8]The term *monetary policy power* does not refer to the power to affect aggregate demand but the power to affect inflation.

[9]Amongst the most popular explanations of such asymmetries are signal extraction or misperceptions, adjustment costs, downward nominal wage rigidities and the presence of monopolistically competitive markets. More details can be found in Ball et al. (1988) and King and Watson (1994).

[10]Another important condition for an open economy is studied in Lougani et al. (2001). They analyze why countries with greater restrictions on capital mobility tend to have steeper Phillips curves.

In this section we analyze the relationship between the relative price of tradables to non-tradables[11] and the importance of domestic factors to explain inflation. The goal is to provide a theoretical framework to endogenize the *dragging* effect. Throughout the document, lower cases of both real quantities and prices refer to the natural logarithms of the respective upper cases. Also, the h and w subscripts refer to home and world variables, respectively. Variables with no subscripts are aggregate figures. The details of the analytical derivations are outlined in the Appendix.

The framework set up here tries to be as simple as possible. The aim is to build a partial equilibrium model to derive microfounded inflation equations to be empirically tested in Section 3 and to be used for monetary policy analysis in Section 4. The emphasis is on aggregation features generated from two alternative assumptions about consumer preferences, with different implications concerning the substitutability among goods and in turn, different effects on the Phillips curve parameters. We work with two types of goods - a home, non-tradable good and a world, tradable good - which enter into the consumption basket according to either a CES (which will be treated as a benchmark) or translog aggregator.

The price of the world good obeys the law of one price. That is, if P_t^* denotes the international price of the world good and S_t is the nominal exchange rate, then the domestic currency price of this good is $P_{w,t} = S_t P_t^*$ and its inflation is $\pi_{w,t} = \Delta s_t + \pi_t^*$. World inflation is exogenous and follows a simple AR(1) process,

$$\pi_t^* = (1-\rho)\overline{\pi} + \rho\pi_{t-1}^* + \epsilon_t \text{ with } \epsilon_t \sim iid \tag{1}$$

where $|\rho| < 1$ and $\overline{\pi}$ is the steady-state world inflation rate.

On the other side, to model stickiness in home prices, we adopt the cost-of-changing-prices setup of Rotemberg (1982). This approach consists first in finding desired prices, as if having firms operating in a flexible price environment and then introducing costs of adjustment to move observed prices towards the optimal ones.

Two simplifying assumptions are made to derive analytically tractable inflation equations. The first one is the linearity of the home good production function. This assumption shuts off the direct demand effect on marginal costs and hence on prices[12]. Since this effect is virtually the same under both aggregators, the gains from working with the standard concave production function are negligible to our purpose. Moreover, provided that both preference assumptions do not qualitatively make difference in the sensitive parts of marginal costs, we assume a given labor demand. The second assumption is that we define real domestic wages in terms of the home price rather than the consumption price. This allows us to derive inflation equations that are easy to handle and interpret, without altering the main conclusions of our model.

2.1 Inflation dynamics with a CES aggregator

Under the CES consumption aggregator, the consumption of the home good $C_{h,t}$ depends negatively on its own price $P_{h,t}$ and positively on the aggregate consumption C_t. Specifically,

[11] This ratio is the theoretical counterpart of the real effective exchange rate used in the empirical section.

[12] In the standard New-Keynesian Phillips curve, price dynamics is affected by real marginal cost movements, which in turn, are affected by aggregate demand.

$$c_{h,t} = \ln(1-\alpha) - \eta(p_{h,t} - p_t) + c_t \tag{2}$$

where p_t is the log aggregate CPI. In this equation $\eta > 1$ measures the degree of substitutability between the two goods and $\alpha \in \langle 0, 1 \rangle$ is usually interpreted as the degree of openness.

It is easy to show that if the steady-state relative price P_h/P_w is equal to one, the consumer-based price inflation can be approximated by

$$\pi_t = (1-\alpha)\pi_{h,t} + \alpha\pi_{w,t} \tag{3}$$

Overall inflation does depend on α but not on η. Thus, under CES preferences, the degree of goods substitutability plays no fundamental role on aggregate dynamics.

2.1.1 Home firms and flexible price setting

The domestic good producer is endowed with monopolistic power and sets its price accordingly. Production $Y_{h,t}$ is made with a technology that exhibits constant returns on labor. So, for given nominal wages W_t, the total nominal costs are $\mathcal{C}_h(Y_{h,t}) = W_t Y_{h,t}$.

Every period, the domestic producer chooses its price $P_{h,t}$ to maximize profits,

$$\mathcal{B}(P_{h,t}) = P_{h,t} Y_{h,t}(P_{h,t}) - \mathcal{C}_h(Y_{h,t}(P_{h,t})) \tag{4}$$

subject to the equilibrium condition $Y_{h,t} = C_{h,t}$. The optimal price decision reduces to the standard markup pricing over marginal cost. If we take logs to the markup pricing equation we obtain the working expression $p_{h,t}^{ces} = \ln(\mu) + w_t$, where μ is the flexible-price markup $\mu = \frac{\eta}{\eta-1}$. As we note later, the differentiated expression for $p_{h,t}^{ces}$ is a key variable that feeds into the inflation processes and is simply defined as

$$\Delta p_{h,t}^{ces} = \Delta w_t \tag{5}$$

2.1.2 Introducing price rigidity

Now suppose that firms cannot set their desired optimal price due to the existence of adjustment costs. As Rotemberg (1982), we assume that the monopolistic firm maximizes profits net of the loss it incurs by inducing variability in its price path.

We perform a quadratic approximation of (4) around the flexible price equilibrium (the optimal price level in the absence of adjustment costs, $p_{h,t}^{ces}$). After introducing adjustment costs, the firm's problem can be reformulated as the following cost minimization program

$$\min_{p_{h,s}} E_t \left[\sum_{s=t}^{\infty} \beta^{s-t} \left\{ \left(p_{h,s} - p_{h,s}^{ces}\right)^2 + \frac{1}{2c}\left(p_{h,s} - p_{h,s-1}\right)^2 \right\} \right] \tag{6}$$

where $\beta \in \langle 0, 1 \rangle$ is the firm's discount factor, $c > 0$ and E_t is the expectation operator.

The optimal price plan obtained by solving (6)[13] implies the following inflation process

$$\pi_{h,t} = \left(\frac{\beta}{1+\beta}\right) E_t\left[\pi_{h,t+1}\right] + \left(\frac{1}{1+\beta}\right) \pi_{h,t-1} + \left(\frac{2c}{1+\beta}\right) \Delta\varpi_t + \xi_t \tag{7}$$

where $\Delta\varpi_t$ is the growth of real wages defined as $\varpi_t = w_t - p_{h,t}$. The term ξ_t is a combination of *iid* forecast errors and is treated as a shock.

2.1.3 Aggregate inflation

It is straightforward to plug (7) into the aggregator (3) to obtain

$$\begin{aligned} \pi_t \;\; &= \;\; a_0 E_t[\pi_{t+1}] + (1-a_0)\pi_{t-1} + a_{slope}\Delta\varpi_t + ... \\ &\qquad ... + \; \alpha[\pi_{w,t} - a_0 E_t[\pi_{w,t+1}] - (1-a_0)\pi_{w,t-1}] + a_2\xi_t \end{aligned} \tag{8}$$

where $a_0 = \beta\left[\frac{1}{1+\beta}\right]$, $a_{slope} = (1-\alpha)(2c)\left[\frac{1}{1+\beta}\right]$ and $a_2 = (1-\alpha)$.

The result is a standard hybrid Phillips curve with the following features: (i) it has a dynamic linear homogeneity property implying nominal neutrality in the long run; (ii) it depends on the real marginal cost defined by $\Delta\varpi_t$ and on the expectation shock ξ_t; and (iii) it depends on the world price inflation.

Consider now a world inflation shock ($\epsilon_0 = 1$). According to (8) and (1), if we abstract from nominal exchange rate or other endogenous movements, the response on impact[14] of aggregate inflation is α. In the absence of other perturbations the shock will be partially corrected in the subsequent periods as $\pi_{w,t}$ reverts to its long-run value, due to the presence of the term $-\alpha(1-a_0)\pi_{w,t-1}$. Further, it is useful to recall equation (7) and note that the shock *per se* does not affect home prices[15]. Thus, world inflation affects the aggregate inflation by a direct *pass-through* effect.

2.2 Inflation dynamics with a translog aggregator

With two consumption goods, the aggregate log price p_t is defined as

$$p_t = (1-\alpha)\, p_{h,t} + \alpha p_{w,t} - \frac{\gamma}{2}\left(p_{w,t} - p_{h,t}\right)^2 \tag{9}$$

In this aggregator, the parameters $\alpha \in \langle 0, 1\rangle$ and $\gamma > 0$ are such that both goods enter symmetrically in consumption preferences. Also, homogeneity in the demand functions is imposed. Since the translog can be understood as an augmented CES aggregator[16], the parameter α is the same as in (2).

[13] The solution of this type of dynamic problem has been neatly outlined in Sargent (1979) and applied to inflation dynamics by Batini et al. (2000).

[14] In the pre-shock period, $\pi_{-1} = \Delta\varpi_{-1} = \pi_{w,-1} = 0$. The shock implies that $\pi_{w,0} = 1 + \Delta s_0$. Then, the response on impact over inflation is $\pi_0 = a_0(1-\alpha)E_t[\pi_{h,1}] + \alpha E_t[\pi_{w,1}]) + \alpha(1 + \Delta s_0 - a_0 E_t[\pi_{w,1}]) = a_0(1-\alpha)E_t[\pi_{h,1}] + \alpha(1+\Delta s_0)$.

[15] In a general equilibrium setting, domestic inflation would respond to changes in $\Delta\varpi_t$ generated, for instance, by a policy reaction to the external shock.

[16] See Deaton and Muellbauer (1980).

The log of the compensated demand for the domestic good is then

$$c_{h,t} = \ln(1 - \alpha + \gamma q_t) - (p_{h,t} - p_t) + c_t \tag{10}$$

which differs from the demand under the CES specification in an important way: it depends on the relative price of the world good to the home good, $q_t = p_{w,t} - p_{h,t}$.

Differencing equation (9) leads to aggregate inflation

$$\pi_t = (1 - \alpha_t)\pi_{h,t} + \alpha_t \pi_{w,t} \tag{11}$$

This expression resembles equation (3) for the CES case. However, the weights are time-varying now. In this case $\alpha_t = \alpha - \frac{1}{2}\gamma(q_t + q_{t-1})$, so the inflation process is a changing weighted average of domestic and foreign inflation[17]. As the relative price of the world good falls, q_t turns negative and therefore, world inflation gradually becomes more important to the determination of overall inflation.

2.2.1 Home firms and flexible price setting

Under translog aggregation, the non-tradable firm takes into account the fact that the demand for its good depends on the world good price. Then, the expression for the change in prices under a flexible-price scenario becomes

$$\Delta p_{h,t}^{trans} = \frac{1}{2}\pi_{w,t} + \frac{1}{2}\Delta w_t \tag{12}$$

Namely, the optimal price change $\Delta p_{h,t}^{trans}$ is an average of world inflation and marginal costs growth. A key fact of this price rule is that to prevent consumers from substituting away the consumption of home goods, the home producer will find optimal to *follow up* the world trend, so a falling world inflation will *drag* home inflation[18].

2.2.2 Introducing price rigidity

In the presence of adjustment costs, the domestic inflation process is

$$\begin{aligned}\pi_{h,t} \quad = \quad & \left(\frac{\beta}{1+\beta+c}\right) E_t[\pi_{h,t+1}] + \left(\frac{1}{1+\beta+c}\right)\pi_{h,t-1} + ... \\ & ... + \left(\frac{c}{1+\beta+c}\right)\pi_{w,t} + \left(\frac{c}{1+\beta+c}\right)\Delta\varpi_t + \zeta_t \end{aligned} \tag{13}$$

where ζ_t is an *iid* shock.

This equation is quite different from that in the CES case in (7). Particularly, home inflation now depends positively on world inflation[19].

[17] For the shares of either home or world good expenditure to be bounded between zero and one, we require both γ and q_t not to be too large. Empirically and for practical purposes, these conditions always hold.

[18] In the opposite case, when the world price increases, it is on the interest of the profit-maximizing producer to rise its price against the backdrop of a higher demand for the non-tradable good.

[19] The degree of dependence is captured by the adjustment cost parameter c. When adjustments costs are high (c is small), the degree of dependence weakens and the situation is close to the CES case.

2.2.3 Aggregate inflation

To aggregate the inflation dynamics we plugged (13) into (11) to get

$$\begin{aligned} \pi_t &= a_0 E\left[\pi_{t+1}\right] + a_1 \pi_{t-1} + \left(1 - a_0 - a_1\right) \pi_{w,t} + a_{slope,t} \Delta \varpi_t + ... \\ &\quad ... + \ \alpha_t \left[\pi_{w,t} - a_0 E_t\left[\pi_{w,t+1}\right] - \left(1 - a_0\right) \pi_{w,t-1}\right] + a_{2,t} \zeta_t \end{aligned} \tag{14}$$

where $a_0 = \beta\left[\frac{1}{1+\beta+c}\right]$, $a_1 = \left[\frac{1}{1+\beta+c}\right]$, $a_{slope,t} = (1-\alpha_t)\, c\left[\frac{1}{1+\beta+c}\right]$ and $a_{2,t} = (1-\alpha_t)$.

The above Phillips curve not only has the basic properties of (8) but also exerts more interesting dynamics. The slope $a_{slope,t}$ depends negatively on α_t, the share of the imported good in the consumption basket, whereas the pass-through coefficient is directly related to α_t. Since α_t increases as the relative price q_t decreases, a drop of external prices (relative to home prices) causes the slope of the Phillips curve to fall and the pass-through coefficient to rise.

This result has an intuitive interpretation. In an open economy Phillips curve, the slope parameter could be roughly interpreted as a measure of the importance of domestic factors in the formation of prices. A fall in the price of tradables or a rise in the price of non-tradables leads to demand substitution, implying a higher share of tradable goods in domestic expenditure. Under such circumstances, foreign shocks disturbing tradable prices would become more important in equilibrium determination. As a result, the Phillips curve becomes more elastic (its slope falls). This is also consistent with the negative correlation between q_t and the pass-through[20].

Besides and perhaps more importantly, an external shock directly affects home price-setting, magnifying the response of aggregate inflation. Hence, in this case the *pass-through* effect of world price fluctuations is reinforced by the existence of the *dragging* effect.

3 The *dragging* effect in the world

One important result of the previous section is the state-dependence of the Phillips curve parameters in a context where a wider variety of goods become available for consumption. Particularly, the theoretical model suggests that movements in the real exchange rate are related to both the Phillips curve slope and the pass-through coefficient in opposite ways. In doing so, they continuously re-weight the contribution of domestic and foreign factors that determine inflation.

To provide some empirical basis for this point, in this section we perform Dynamic Panel Data estimations for inflation equations using a large set of countries. Next, we briefly describe our preferred econometric methodology and present empirical evidence that supports the existence of the *dragging* effect[21].

[20] This result is in line with empirical findings in Goldfjan and Werlang (2000).

[21] The econometric discussion below is referential and does not attempt to be comprehensive. The interested readers are referred to the articles that developed the estimators used in this document.

3.1 Specification and empirical hypothesis

Consider the inflation equation

$$\begin{aligned}\pi_{j,t} &= \phi_\pi \pi_{j,t-1} + \phi_x x_{j,t} + \phi_w \pi^w_{j,t} + ... \\ &\quad ... + \left(\varphi_q + \varphi_x x_{j,t} + \varphi_w \pi^w_{j,t}\right) \Delta q_{j,t} + (\eta_j + \varepsilon_{j,t}) \end{aligned} \tag{15}$$

where the subscripts j and t represent country and time period, respectively. The variable $\pi_{j,t}$ stands for inflation, $x_{j,t}$ is a measure of domestic real marginal costs, $\pi^w_{j,t}$ is foreign inflation expressed in domestic currency (external inflation plus nominal depreciation) and $\Delta q_{j,t}$ denotes real depreciation. The error term is comprised by an unobservable, time-invariant country specific effect η_j and a random perturbation $\varepsilon_{j,t}$ that is assumed to be serially uncorrelated.

Equation (15) is a flexible representation that tries to capture how inflation is determined among countries and especially to assess the importance of domestic factors (proxied by $x_{j,t}$) *vis-a-vis* external shocks (given by $\pi^w_{j,t}$). Furthermore, it allows us to investigate whether changes in the relative prices of goods ($\Delta q_{j,t}$) not only affect inflation but also introduce non-linearities in price setting.

In fact, the companion coefficient for $x_{j,t}$, $\phi_x + \varphi_x \Delta q_{j,t}$, can be interpret as the Phillips curve slope while $\phi_w + \varphi_w \Delta q_{j,t}$ captures the pass-through of foreign to domestic prices. It is clear that, by construction, both quantities are influenced by real exchange variations as long as $\varphi_x \neq 0$ and $\varphi_w \neq 0$, which is testable in a straightforward manner. Moreover, the theoretical section states that, in the presence of the *dragging* effect, it should happen that $\varphi_x > 0$ and $\varphi_w < 0$ which is the main empirical hypothesis of this study.

3.2 Methodological Issues

Let $X_{j,t} = [x_{j,t}\ \pi^w_{j,t}\ \Delta q_{j,t}\ x_{j,t}\Delta q_{j,t}\ \pi^w_{j,t}\Delta q_{j,t}]$ and $\theta' = [\phi_x\ \phi_w\ \varphi_q\ \varphi_x\ \varphi_w]$ so that equation (15) can be conveniently rewritten as

$$\pi_{j,t} = \phi_\pi \pi_{j,t-1} + \theta' X_{j,t} + (\eta_j + \varepsilon_{j,t}) \tag{16}$$

To drop out country specific effects, the regression equation is first-differenced so

$$\pi_{j,t} - \pi_{j,t-1} = \phi_\pi \left(\pi_{j,t-1} - \pi_{j,t-2}\right) + \theta' \left(X_{j,t} - X_{j,t-1}\right) + \left(\varepsilon_{j,t} - \varepsilon_{j,t-1}\right) \tag{17}$$

We require using instrumental variables to estimate (17) for two reasons. First, differencing (16) introduces a correlation between $(\pi_{j,t-1} - \pi_{j,t-2})$ and the new error term $(\varepsilon_{j,t} - \varepsilon_{j,t-1})$. Second, most of the variables contained in $X_{j,t}$ are very likely to be jointly determined with inflation (i.e. they are endogenous) so it is essential to allow for the possibility of simultaneity or reverse causality[22]. Taking advantage of the dynamic nature of the data, the relevant instruments consist of suitable lags of the levels of the explanatory and dependent variables. Then, the following moment conditions should hold

$$\begin{aligned} E[\pi_{j,t-s}(\varepsilon_{j,t} - \varepsilon_{j,t-1})] = 0 \\ E[X_{j,t-s}(\varepsilon_{j,t} - \varepsilon_{j,t-1})] = 0 \end{aligned} \tag{18}$$

[22]Foreign inflation can be considered as strictly exogenous for small open economies. However, since $\pi^w_{j,t}$ includes nominal exchange rate fluctuations, it must be treated as endogenous.

for $t = 3, ..., T$ and $s \geq 2$. The estimator that fulfills (18) is the well-known *GMM Difference Estimator* developed in Arellano and Bond (1991). Although it properly accounts for the endogeneity of regressors and is consistent, it has some statistical shortcomings. For instance, Arellano and Bover (1995) show that the lagged levels of the explanatory variables are often weak instruments (particularly in the presence of persistence) which could, in turn, lead to asymptotic inefficiency and biasness of the estimator.

To overcome such limitations, Arellano and Bover (1995) proposed an extended estimator, fully developed in Blundel and Bond (1998), aimed to increase efficiency. The idea is to jointly estimate the original equations in levels (16) and the system in differences (17). This refers to the *GMM System Estimator*, which should satisfy the following additional conditions[23],

$$\begin{aligned} E[(\pi_{j,t-1} - \pi_{j,t-2})(\eta_j + \varepsilon_{j,t})] = 0 \\ E[(X_{j,t} - X_{j,t-1})(\eta_j + \varepsilon_{j,t})] = 0 \end{aligned} \tag{19}$$

The instruments for the system in levels are lagged differences of the explanatory and dependent variables[24] [25].

The goodness of this GMM estimator depends on whether the selected instruments are valid. To address this issue, we perform two specifications tests as suggested in Arellano and Bond (1991), Arellano and Bover (1995) and Blundel and Bond (1998). To test for the overall validity of the instrument set, we first use a J test for overindentifying restrictions. Failure to reject the null hypothesis gives support to the model. The second test examines if the disturbances are serially correlated. The usual approach is to test whether the residuals for the differenced-system are serially correlated. The rejection of the null hypothesis of absence of serial correlation suggests a misspecification error to be solved by imposing different, more adequate moments conditions[26].

3.3 Data and samples

We used annual data from the International Financial Statistics database (IFS May 2004) for the 1980-2003 period and for 40 countries. Our panel is unbalanced mainly because of country discrepancies in new data releases (some missing values in year 2003), historical data (the

[23]These conditions arise from the stationarity properties $E[\pi_{j,t-p}\eta_j] = E[\pi_{j,t-k}\eta_j]$ and $E[X_{j,t-p}\eta_j] = E[X_{j,t-k}\eta_j]$ for all p and k. The assumption behind is that although is correlated with the levels of the explanatory variables, there is no correlation between the former and the differences of the explanatory variables.

[24]Provided that lag levels are used as instruments in the differenced system, the only non-redundant instrument for the levels system is the most recent difference. Details are in Blundel and Bond (1998).

[25]In the Dynamic Panel Data literature, the moment conditions are as exposed here and applied to each time period to ensure a flexible structure for their covariance matrix [Ahn and Schmidt (1995)]. The result is an instrument matrix whose width increases more than proportionally with T. In this study however, we work with instruments for each variable and lag distance for all periods (i.e. the width of the instrument matrix is independent of T) because the time-series dimension of our panel (T20) is considerably larger than what is standard in the literature (T5). This approach not only reduces the computational demand of the estimation, but also prevents the second-step estimates of the standard errors to be overfitted.

[26]The differenced error $(\varepsilon_{j,t} - \varepsilon_{j,t-1})$ is expected to be first-order autocorrelated even if $\varepsilon_{j,t}$ is uncorrelated (otherwise, $\varepsilon_{j,t}$ would follow a random walk). Second (or higher) order autocorrelation of the differenced residuals indicates that is serially correlated of at least first order.

80's) are unavailable for "new" countries such as the Czech Republic and, more importantly, we have constrained the sample dropping observations with annual inflation higher than 30 percent. We decide to exclude such observations because some countries in the sample presented hyperinflationary episodes that may bias the results[27]. Overall, the full panel consists of 833 observations (20.82 per country, on average).

The dependent variable in (15), $\pi_{j,t}$, is the CPI percent change (line 64) which is available for all countries. We then consider the growth in real GDP per worker as $x_{j,t}$, since it was the most homogenous approximation of real marginal cost available for all countries[28]. This is computed as the difference between GDP Volume (line 99b) and employment (line 67e)[29] growth rates. The real effective exchange rate (REER) as reported in the IFS (line 63) is available for almost every country[30] so $\Delta q_{j,t}$ is directly computed[31]. Finally, foreign inflation expressed in domestic currency, $\pi^w_{j,t}$, can be inferred from the REER and CPI data.

The countries included in the full sample are listed in Table 1. We also found convenient to estimate (15) using three different sub-samples (also listed in Table 1). First, since our theoretical analysis refers to economies subject to external shocks, we consider the most open economies in the sample. We ranked all countries according to the 1980-2003 average of the imports plus exports to GDP ratio (the so-called *openness ratio*, lines 98c, 90c and 99b). The median of this ratio over countries and time was roughly 60 percent, and we considered those countries that present a mean ratio higher that 55 percent. The second sub-sample corresponds to emerging market economies. This classification is useful since, according to Rogoff (2003), these economies have shown over the sample the deepest structural reforms related to deregulation and trade liberalization. Finally, we consider all the countries but constrain the time span to the 90's (and the 2000's), since it is the decade when globalization grew stronger and the global disinflation began.

3.4 Estimation results

Estimations are displayed in Table 1. For each sample we estimated two versions of the inflation equation (15). The first constrains the coefficients affected by the real depreciation to zero ($\varphi_q = \varphi_x = \varphi_w = 0$), while the second is unrestricted. The purpose for such strategy is to show the marginal effects of considering the influence of relative price fluctuations in the inflation equations.

[27]Although the decision is arbitrary, it responds to previous results in the inflation-output trade-off literature. For instance, Ball et al. (1988) find that a high inflation mean would tend to bias downwards the trade-off estimates. Additionally, Bakshi et al. (2003) and Ascari (2004) state that a Phillips curve-type inflation equation such as (15) is not a suitable way to model high-inflation dynamics.

[28]We tried other measures of real marginal costs such as GDP or GDP per worker gaps. The results were qualitatively similar than the one reported. However, they were not as statistically significant and appeared to be sensitive to the detrending method.

[29]There were some missing observations for the number of employees in the middle of the panel. In such cases, we filled them by applying the growth rate of the labor force (line 67d) or the population growth (line 99z) in few cases, when labor force data were not available.

[30]For Brazil, Greece, Mexico, Peru and Thailand REER data are taken from the *Economist Intelligence Unit* country database.

[31]The REER is measured as the ratio of the domestic currency price index of foreign goods to the domestic price index, so an increase in the REER implies a real depreciation.

With the full sample, it can be seen in the constrained inflation equation (column 1) that the coefficients ϕ_x and ϕ_w are both positive and statistically significant. When augmenting the model (column 2), there is some weak evidence of the *dragging* effect for all the countries in the sample. The parameter of the real exchange rate affecting the mean of inflation φ_q is negative and significant. However those affecting the Phillips curve parameters, albeit they have the expected sign, are imprecisely estimated. The estimation suggests a diffuse (positive) effect of depreciation on the Phillips curve slope and no statistical effect on the pass-through coefficient.

When considering sub-samples, evidence switches in favor of the *dragging* effect. The constrained inflation equation for the most open economies (column 3) presents some misspecification problems, namely serial autocorrelation of residuals. The introduction of the real depreciation and the other interaction terms (column 4) solves this issue while provides empirical support to our hypothesis $\varphi_x > 0$ and $\varphi_w < 0$. Similar results are found for only emerging markets data (columns 5 and 6), although the point estimate of ϕ_x is not significant while φ_x is statistically positive within a 90 percent confidence interval. Finally, the presence and importance of the *dragging* effect is strong in the estimations when including all the countries but constraining the time span since the beginning of the 90s (columns 7 and 8).

The above findings provide evidence of the real exchange as a determinant of the output-inflation tradeoff in small open economies. Moreover, they reveal that relative price fluctuations have played an important role in the global disinflation phenomenon of the 90s, by limiting the importance of domestic shocks and increasing the influence of foreign shocks[32].

4 Implications for monetary policy

Given that the fall in the slope of the Phillips curve originated from relative price fluctuations ends up weakening a channel whereby domestic shocks affect inflation, monetary policy may lose effectiveness. Regardless of the expectation or exchange rate transmission mechanisms implied in the Phillips curve, monetary policy also affects inflation through marginal costs, so the lower the slope is, the weaker the standard interest rate instrument becomes. In other words, the power of the interest rate instrument is inversely related to the *dragging* effect of world inflation[33].

We shall study this fact formally by including the two inflation equations derived in Section 2 into a stylized model. Then, we shock the system to study policy implications.

[32]These results are complementary to those of Lougani et al. (2001). They find that countries with greater restrictions on capital mobility have a steeper Phillips curve. A casual inspection of the data suggests that the countries with stricter capital control have suffered lower real depreciations in the sample period. However, a refined analysis would be needed to establish a more robust link between their results and ours.

[33]In an open economy, it is known that the degree of price stickiness is lower due to the presence of imported goods and nominal exchange rate fluctuations. Since real effects of monetary policy shocks occur mainly because of nominal rigidities, the decline of monetary policy effectiveness is a consequence of the decrease of overall price stickiness implied by the *dragging* effect.

4.1 A simple framework

The model consists of six equations. The first is the law of motion of world inflation defined in (1) while the second is a Phillips curve derived either for the CES (equation (8)) or the translog (equation (14)) preferences.

The third equation, (20) below, establishes the link between the monetary policy interest rate instrument i_t and the growth of real wages

$$\Delta\varpi_t = E_t\left[\Delta\varpi_{t+1}\right] - b_r(i_t - E_t\left[\pi_{t+1}\right] - r) + \epsilon_{\varpi,t} \tag{20}$$

where r is the equilibrium real interest rate (assumed fixed) and $b_r > 0$. Typically this equation is specified in terms of the output gap and is interpreted as an IS curve[34]. However, in the absence of demand effects due to the assumed linearity of the production function, marginal costs solely depend on the real wage rate. The important feature of equation (20) is the negative relation between the real interest rate (gap) and the indicator of marginal cost used in our setup.

Equation (21) describes a plausible monetary policy rule that incorporates a concern about deviations of future expected inflation rates from the target $\overline{\pi}$ and the measure $\Delta\varpi_t$

$$i = (r + \overline{\pi}) + f_p\left(E_t\left[\pi_{t+1}\right] - \overline{\pi}\right) + f_{\varpi}\Delta\varpi_t + \epsilon_{i,t} \tag{21}$$

where $f_p > 1$ and $f_{\varpi} > 0$.

Equation (22) is the definition of the relative price process

$$q_t = q_{t-1} + \frac{1}{4}\left(\pi_{w,t} - \pi_{h,t}\right) \tag{22}$$

Finally, exchange rate dynamics is embedded into the model in two alternative forms,

$$\begin{array}{ll} s_t = s_{t-1} - \chi q_{t-1} & \text{PPP Model} \\ s_t = E_t\left[s_{t+1}\right] - \frac{1}{4}\left(i_t - \left\{r + f_p^*\pi_t^* + (1 - f_p^*)\overline{\pi}\right\}\right) & \text{UIP Model} \end{array} \tag{23}$$

We choose these alternatives given the fact that there is no macroeconomic consensus about the correct nominal exchange rate model. However, despite our ignorance about how exchange rate dynamics actually evolves, we will show that the *dragging* effect is robust to exchange rate model uncertainty.

The two alternative specifications in (23) represent two extremes regarding the way the exchange rate adjusts to shocks. In the PPP model, the exchange rate moves only insofar as the real exchange rate is misaligned (i.e. whenever there are deviations from purchasing parity or disequilibria in the goods market). The parameter χ measures the speed of nominal exchange rate adjustments to real exchange rate deviations from its zero long-run steady-state value. Under this setting, the exchange rate shows smoother and somewhat persistent dynamics. Also there will be no response to shocks on impact, since s_t depends on lagged values of q_t.

In contrast, in the UIP case the spot exchange rate is a jump variable reacting to current and future expected values of the interest rate differential, so that the non-arbitrage condition

[34] See Clarida et al. (1999)

holds. To prevent for undue jumps in the spot exchange rate, we allow the world nominal interest rate to move in response to world inflation shocks. Insofar as domestic and world interest rates will tend to move in the same direction, the spot exchange rate jump will not be magnified. This means that a falling world inflation will decrease the world interest rate[35]. In addition, the UIP model renders a more volatile exchange rate than the PPP model, with a non-zero response on impact.

We assume arbitrary but reasonable values for the model coefficients. We consider a steady-state real interest rate r equal to 3 percent (which implies a value $\beta = 0.99$) and a yearly steady-state inflation rate $\overline{\pi}$ equal to 2.5 percent. For the world inflation process, we make the autoregressive parameter $\rho = 0.5$ which means that the effect of a shock dies away in about a year. With respect to the aggregators, for both the CES and translog cases the parameter that measures the degree of openness α is set to 0.35. For the translog case, $\gamma = 1$. Finally, the parameter c is set such that the slopes of both Phillips curves are equal in steady state[36].

On the other hand, in equation (20) we set $b_r = 0.2$. In the policy rule (21), we choose the values $f_p = 1.5$ and $f_{\varpi} = 0.5$. For the exchange rate PPP equation (23) we use $\chi = 0.36$ which implies a half-life of a misalignment of about a year. Finally, for the UIP model for exchange rate we set $f_p^* = f_p\rho = 0.75$ (see footnote 34).

4.2 The exercise

We perform two experiments regarding the way world disinflation may hit an economy initially resting on its steady state[37]. We first evaluate a one-period-only disinflation shock ϵ_0 that brings world inflation from $\overline{\pi} = 2.5$ to 1 percent on impact. This shock will illustrate the dynamics of the model. Second, we hit world inflation such that the level of world inflation remains at 1 percent for a year (4 quarters)[38] Through this type of persistent shock we try to replicate the global disinflation phenomenon. We then compare the responses of the model variables under the two specifications for the Phillips curve[39]. We perform this exercise with the PPP model and then repeat the procedure with the UIP model.

4.2.1 The PPP Model

The results for inflation are displayed in Figure 1 where the first row depicts the responses under the one-quarter shock and the second, under the persistent one-year shock. The responses are consistent with the reasoning laid out in the theoretical section above. The CES specification produces a moderate fall while the translog case generates a deeper drop in aggregate inflation.

[35]In fact, the term in braces in equation (23) states that the world interest rate is set by the policy rule $i_t^* = (r+\overline{\pi}) + f_p\left(E\left[\pi_{t+1}^*\right] - \overline{\pi}\right) = (r+\overline{\pi}) + f_p\rho\left(\pi_t^* - \overline{\pi}\right)$ so $f_p^* = f_p\rho$. With this, we are assuming that both the home and domestic policymakers have the same response to inflation deviations.

[36]This means that if we set c^{trans} in the translog case, then $c^{ces} = \frac{c^{trans}}{2}\left[\frac{1+\beta}{1+\beta+c^{trans}}\right]$.

[37]To solve for the rational expectations equilibrium, we use the algorithm outlined in Klein (2000).

[38]To do this we simulate the model subject to the following history of world inflation shocks: $\epsilon_0 = 1 - \overline{\pi}$, $\epsilon_1 = \epsilon_2 = \epsilon_3 = (1-\rho)\epsilon_0$ and $\epsilon_j = 0$ for $j > 3$.

[39]Additionally, we shocked the model considering different sizes and signs for the shocks in order to exploit the non-linearities in (14). Although we did find differences in the responses of the endogenous variables, none of them were sizeable enough to be reported.

The home inflation behavior provides a better insight. We observe that it remains basically unperturbed in the CES case while the translog home inflation reacts in the same direction as the world inflation shock. In this case the falling world inflation *drags* the home inflation down, a fact that becomes even more apparent under the persistent shock.

In Figure 2 we show the effect on other three key variables for monetary policy: the real wage growth rate, the nominal interest rate and the nominal depreciation. Under both types of shocks, the monetary policy rule calls for a stronger, expansionary response of the policy instrument in the more disinflationary environment, i.e the translog case. The stronger response of interest rates in turn implies a stronger effect upon the real wage growth. It is remarkable that although monetary policy performs in an unduly expansionary way, the effect on inflation is flimsy.

In Figure 3 we plot the reasons behind the weakening of monetary policy in the translog setting: the effect of the shocks on the slope of the Phillips curve $a_{slope,t}$ and the pass-through parameter α_t. Under both transitory and permanent shocks, the slope of the Phillips curve co-moves with the relative price whereas the pass-through moves in the opposite direction. Both, the reduction of the Phillips curve slope and the increase in pass-through reinforce the *dragging* effect *vis-a-vis* the reduction of monetary policy power.

These results are in line with the two key features observed in the empirical part: the positive correlation between the slope of the Phillips curve and the real exchange rate and the negative correlation between the pass-through and this relative price.

4.2.2 The UIP Model

In Figures 4, 5 and 6 we present the responses of the different variables under the UIP model. It is important to recall that the main difference relative to the previous results is originated in the response of the nominal exchange rate. As it can be seen, the shock causes a strong depreciation on impact, since a cut in the interest rate as a policy reaction is anticipated. The depreciation of the nominal exchange rate more than offsets the shock so that the world inflation in domestic currency raises. Under translog preferences, this leads to an increase in the domestic inflation and, finally, turns into a higher aggregate inflation.

Nonetheless, after the shock, the *dragging* effect operates and the results are qualitatively the same as the ones obtained in the PPP model. Note, however, that the depreciation on impact under the persistent shock calls for a subsequent appreciation that magnifies the *dragging* effect of the disinflation shock.

5 Final remarks

This paper provides a simple theoretical explanation of how world disinflation might drag down domestic inflation in small open economies. In particular, we empirically find such an effect in both open and emerging markets economies, especially during the last decade. We argue that globalization and the increasing availability of cheaper foreign goods make world prices ever more important to the price setting of domestic non-tradable goods. This is what we call the *dragging* effect.

The *dragging* effect causes the contribution of domestic factors on aggregate inflation to reduce due to demand substitution in favor of foreign goods. Since domestic expenditure in tradable goods increases relative to that of non-tradables, the usual demand (interest rate) channel of monetary policy also loses importance in the determination of prices. Thus, monetary policy suffers a loss of effectiveness to affect inflation.

We argue that translog preferences are able to capture the strategic complementarity that leads to the *dragging* effect. In our disinflation experiments, translog preferences fare better than the usual CES preferences, since the latter cannot replicate the *follow up* behavior in price setting. To *follow up* is the best action home price setters can do to avoid loosing market share in an increasingly competitive environment.

A natural extension of the paper is to move the model economy towards a more detailed general equilibrium framework to better understand the impact of the *dragging* effect. For instance, to have a better insight of the labor market and its relation to marginal costs. In this case, a shock that pushes down the relative price of tradables to non-tradables might expand the demand in the tradable sector and reduce that of the non-tradable sector. This could lower non-tradable sector real wages (relative to those of the tradable sector) and hence reduce home good prices, making the *dragging* effect even more pronounced than what is suggested here.

The existence of the *dragging* effect has important consequences for monetary policy in small open economies, since it can lead the economy to a low-inflation trap. In this circumstance, the direct interest channel is barely useful and the pass-through gains strength, so policy makers may find convenient to induce exchange rate depreciation as a way out of the trap.

Appendix

A Flexible price setting

A.1 The CES case

The consumption basket is given by

$$C_t = \left[(1-\alpha)^{\frac{1}{\eta}} C_{h,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{w,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{24}$$

where $C_{h,t}$ and $C_{w,t}$ denote the quantity of domestic and imported goods respectively. Standard intratemporal choice condition for the home good implies

$$C_{h,t} = (1-\alpha) \left(\frac{P_{h,t}}{P_t} \right)^{-\eta} C_t \tag{25}$$

which is the version in levels of (2) in the main text.

After imposing the condition $Y_{h,t} = C_{h,t}$ and replacing $\mathcal{C}_h = W_t Y_{h,t}$ and (25) in (4) we obtain the profit function

$$\mathcal{B}(P_{h,t}) = (1-\alpha)\left(P_{h,t} - W_t\right) \left(\frac{P_{h,t}}{P_t} \right)^{-\eta} C_t \tag{26}$$

which is maximized by the rule $P^{ces}_{h,t} = \left(\frac{\eta}{\eta-1}\right) W_t$, its percentage change being equation (5).

A.2 The translog case

We first define the log expenditure function as a sum of log aggregate consumption and log consumption-based price index, $g_t = p_t + c_t$. Given that we are treating a two-goods case, the price aggregator p_t is defined as equation (9), $p_t = (1-\alpha)\, p_{h,t} + \alpha p_{w,t} - \frac{\gamma}{2}\left(p_{w,t} - p_{h,t}\right)^2$.

The compensated demand for the domestic good can be easily determined using Shephard's Lemma

$$C_{h,t} = \frac{\partial G_t}{\partial P_{h,t}} = \frac{G_t}{P_{h,t}} \frac{\partial g_t}{\partial p_{h,t}} = \frac{G_t}{P_{h,t}} \left(1 - \alpha + \gamma q_t\right) \tag{27}$$

After replacing $G_t = P_t C_t$, we obtain the demand for the home good

$$C_{h,t} = \left(1 - \alpha + \gamma q_t\right) \left(\frac{P_{h,t}}{P_t}\right)^{-1} C_t \tag{28}$$

which is the version in levels of (10). In this case, the profit function is

$$\mathcal{B}(P_{h,t}) = \left(1 - \alpha + \gamma q_t\right) \left(P_{h,t} - W_t\right) \left(\frac{P_{h,t}}{P_t}\right)^{-1} C_t \tag{29}$$

The optimal price level solves the first order condition

$$P^{trans}_{h,t} = \left(1 - \frac{1 - \alpha + \gamma q_t}{\gamma}\right) W_t \tag{30}$$

Equation (30) cannot be solved explicitly for $P^{trans}_{h,t}$ since q_t depends on $p^{trans}_{h,t} = \ln(P^{trans}_{h,t})$. However we can approximate the optimal price by taking logs,

$$p^{trans}_{h,t} = \ln\left(1 - \frac{1 - \alpha + \gamma q_t}{\gamma}\right) + w_t \tag{31}$$

and using the fact that for a small number x, $\ln(1-x) \simeq x$, then

$$p^{trans}_{h,t} = \frac{1-\alpha}{2\gamma} + \frac{p_{w,t}}{2} + \frac{w_t}{2} \tag{32}$$

After differentiation of (32) we get equation (12) in the text.

B Price setting with adjustment costs

The quadratic approximation of the profit function (4) around its desired price level $P^*_{h,t}$ (either the CES or translog) is

$$\mathcal{B}\left(P^*_{h,t}\right) \simeq \mathcal{B}\left(P^*_{h,t}\right) + \mathcal{B}'\left(P^*_{h,t}\right)\left(P_{h,t} - P^*_{h,t}\right) + c_a \left(p_{h,t} - p^*_{h,t}\right)^2 \tag{33}$$

where $c_a = -\frac{1}{2}\mathcal{B}''\left(P^*_{h,t}\right)\left(P^*_{h,t}\right)^{-2} > 0$. The linear term disappears due to the optimality of $P^*_{h,t}$ while the constant term is irrelevant to the firms' decision-making.

On the other hand, the adjustment costs for price changes are given by $c_b\left(p_{h,t} - p_{h,t-1}\right)^2$. Therefore, in the presence of adjustment costs, the firm pricing problem can be reformulated as an overall minimization problem

$$\min_{\left\{p_{h,s}\right\}_{s=t\ldots\infty}} E_t\left[\sum_{s=t}^{\infty}\beta^{s-t}\left\{\left(p_{h,s} - p^*_{h,s}\right)^2 + \frac{1}{2c}\left(p_{h,s} - p_{h,s-1}\right)^2\right\}\right] \tag{34}$$

subject to the transversality condition

$$\lim_{s\to\infty}\beta^s\left[\left(E_t p_{h,s} - E_t p^*_{h,s}\right) + \frac{1}{2c}\left(E_t p_{h,s} - E_t p_{h,s-1}\right)\right] = 0 \tag{35}$$

where $\frac{1}{2c} = \frac{c_b}{c_a} > 0$.

To solve the firms problem, we consider the Euler equation in period t,

$$2c\left(E_t p_{h,t} - E_t p^*_{h,t}\right) + \left(E_t p_{h,t} - E_t p_{h,t-1}\right) - \beta\left(E_t p_{h,t+1} - E_t p_{h,t}\right) = 0 \tag{36}$$

The operator E_t is the expectation conditional on the information set accumulated up to time t when the pricing decision is made. Equation (36) describes the optimal price plan of the firm. On the basis of the information set, the lagged price level $p_{h,t-1}$ is a predetermined variable while the firm sets $p_{h,t} = E_t p_{h,t}$ which is actually observed. If we want to track the actual evolution of $p_{h,t}$ we need to set up the system of Euler equations as

$$2c\left(p_{h,s} - p^*_{h,s}\right) + \left(p_{h,s} - p_{h,s-1}\right) - \beta\left(E_s p_{h,s+1} - p_{h,s}\right) = 0 \tag{37}$$

for $s = t, t+1, \ldots$. Due to rational expectations, the next period price forecasting error based on this period information set is an iid sequence of random variable, $E_s p_{h,s+1} - p_{h,s+1} = \frac{2c}{\beta}\xi_{s+1}$. Replacing and reordering conveniently yields

$$\left[1 - \frac{(2c+1+\beta)}{\beta}L + \frac{1}{\beta}L^2\right]p_{h,t+1} = -\left(\frac{2c}{\beta}\right)\left(p^*_{h,t} + \xi_{t+1}\right) \tag{38}$$

where L denotes the lag operator, $L^j p_{h,t} = p_{h,t-j}$. Following Sargent (1979), the lag-polynomial in brackets can be factorized as

$$\left[1 - \frac{(2c+1+\beta)}{\beta}L + \frac{1}{\beta}L^2\right] = \left(1 - \lambda_1 L\right)\left(1 - \lambda_2 L\right) \tag{39}$$

where the equalities $\lambda_1 + \lambda_2 = \frac{(2c+1+\beta)}{\beta}$ and $\lambda_1\lambda_2 = \frac{1}{\beta}$ hold.

The solution for the roots of this polynomial are such that $0 < \lambda_1 < 1$ and $\lambda_2 > \frac{1}{\beta}$: one stable solution and the other explosive. Upon inspection of the above two equations in λ_1 and λ_2, it is easy to verify that:

$$\beta\lambda_1^2 + 1 - 2c\lambda_1 = (1+\beta)\lambda_1 \tag{40}$$

Replacing the factorized polynomial and multiplying by $(1-\lambda_2 L)^{-1}$ allows us to get

$$(1-\lambda_1 L)\, p_{h,t+1} = -\,(1-\lambda_2 L)^{-1} \left(\frac{2c}{\beta}\right) \left(p^*_{h,t} + \xi_{t+1}\right) \tag{41}$$

After expanding the inverse lag operator polynomial on the right hand side[40] the expression becomes

$$p_{h,t} = \lambda_1 p_{h,t-1} + \frac{2c}{\beta} E_t \left[\sum_{j=t}^{\infty} \left(\frac{1}{\lambda_2}\right)^{j-t+1} p^*_{h,j} \right] + d\,(\lambda_2)^t \tag{42}$$

The transversality condition makes $d = 0$, so we can express the price decision as

$$p_{h,t} = \lambda_1 p_{h,t-1} + \frac{2c}{\beta} E_t \left[\sum_{j=t}^{\infty} (\beta\lambda_1)^{j-t+1} p^*_{h,j} \right] \tag{43}$$

This is the key solution to the problem. To derive an inflation process, we forward (43) one period, take time t expectations and multiply by $\beta\lambda_1$,

$$\beta\lambda_1 E_t\left[p_{h,t+1}\right] = \beta\,(\lambda_1)^2\, p_{h,t} + \frac{2c}{\beta} E_t \left[\sum_{j=t+1}^{\infty} (\beta\lambda_1)^{j-t+1} p^*_{h,j} \right] \tag{44}$$

Then, taking (43) out of (44), rearranging and differentiating

$$\left(1+\beta\lambda_1^2\right) \pi_{h,t} = \beta\lambda_1 E_t \pi_{h,t+1} + \lambda_1 \pi_{h,t-1} + 2c\lambda_1 \Delta p^*_{h,t} + iid \tag{45}$$

The optimal price $p^*_{h,t}$ depends on the consumption aggregator assumed.

B.1 The CES case

According to equation (5), $\Delta p^*_{h,t} = \Delta p^{ces}_{h,t} = \Delta w_t = \Delta\varpi_t + \pi_{h,t}$, so that equation (45), after some trivial manipulation, becomes

$$\left[1+\beta\lambda_1^2 - 2c\lambda_1\right] \pi_{h,t} = \beta\lambda_1 E_t \pi_{h,t+1} + \lambda_1 \pi_{h,t-1} + 2c\lambda_1 \Delta\varpi_t + \beta\lambda_1 \varepsilon_t \tag{46}$$

Considering equation (40) allows us to obtain equation (7) in the main text that does not depend on λ_1 due to the assumed linearity of the production function. It is now straightforward to aggregate the inflation dynamics to get the overall inflation rate using the aggregator in (3).

[40] Note that since $\lambda_2 > 1$ the expansion is $(1-\lambda_2 L)^{-1} = -\frac{1}{\lambda_2}L^{-1} - \left(\frac{1}{\lambda_2}\right)^2 L^{-2} - \left(\frac{1}{\lambda_2}\right)^3 L^{-3} + \ldots$

B.2 The translog case

Now we replace $\Delta p^*_{h,t} = \Delta p^{trans}_{h,t} = \frac{1}{2}\pi_{w,t} + \frac{1}{2}\Delta w_t = \frac{1}{2}\pi_{w,t} + \frac{1}{2}\Delta\varpi_t + \frac{1}{2}\pi_{h,t}$ into equation (45) to obtain

$$\begin{aligned}\left[1 + \beta\lambda_1^2 - c\lambda_1\right]\pi_{h,t} = \beta\lambda_1 E_t\pi_{h,t+1} + \lambda_1\pi_{h,t-1} + c\lambda_1\pi_{w,t} + ... \\ ... + c\lambda_1\Delta\varpi_t + \beta\lambda_1\varepsilon_t\end{aligned} \tag{47}$$

Again, the equality (40) allows to simplify equation (47) into (13). Then, after aggregating with (11) we get the time-varying Phillips curve (14).

References

Andersen, P. and W. Wascher, 2000. Understanding the Recent Behaviour of Inflation: An Empirical Study of Wage and Price Developments in Eight Countries, BIS paper No. 3, 267-302.

Ahn, S. and P. Schmidt, 1995. Efficient Estimation of Models for Dynamic Panel Data, *Journal of Econometrics*, 68, 5-28.

Arellano, M. and S. Bond, 1991. Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations, *Review of Economics Studies*, 58, 277-297.

Arellano, M. and O. Bover, 1995. Another Look at the Instrumental-Variable Estimation of Error-Component Models, *Journal of Econometrics*, 68, 29-52.

Ascari, G., 2004. Staggered Prices and Trend Inflation: Some Nuisances, *Journal of Economic Dynamics*, 7, 642-667.

Bakhshi, H., P. Burriel-Llombart, H. Khan and B. Rudolf, 2003. Endogenous Price Stickiness, Trend Inflation, and the New Keynesian Phillips Curve", Bank of England Working Paper No. 191.

Banerjee, A. and B. Rusell, 2004. A Reinvestigation of the Markup and the Business Cycle, *Economic Modelling*, 21, 267-284.

Ball, L., N. G. Mankiw and D. Romer, 1988. The New Keynesian Economics and the Output-Inflation Trade-off, *Brookings Paper on Economic Activity*, 19, 1-65.

Batini, N., B. Jackson and S. Nickell, 2000. Inflation Dynamics and the Labour Share in the UK, Bank of England External MPC Unit Discussion Paper No. 2.

Bénabou, R., 1992. Inflation and Markups: Theories and Evidence from the Retail Trade Sector, *European Economic Review*, 36, 566-574.

Bergin, P. and R. Feenstra, 2000. Staggered Price Setting, Translog Preferences, and Endogenous Persistence, *Journal of Monetary Economics,* 45, 657-680.

Bergin, P. and R. Feenstra, 2001. Pricing-to-market, Staggered Contracts, and Real Exchange Rate Persistence, *Journal of International Economics,* 54, 333-359.

Blundell, R. and S. Bond, 1998. Initial Conditions and Moment Restrictions in Dynamic Panel Data Models, *Journal of Econometrics*, 87, 115-143.

Bowman, D., 2003. Market Power and Inflation, International Finance Discussion Papers No. 783, Board of Governors of the Federal Reserve System.

Broda, C. and D. Weinstein, 2004. Globalization and the Gains from Variety, Staff Report No. 180, Federal Reserve Bank of New York.

Clarida, R., J. Gali and M. Gertler, 1999. The Science of Monetary Policy: A New Keynesian Perspective, *Journal of Economic Literature,* 37, 1661-1707.

Deaton, A. and J. Muellbauer, 1980. An Almost Ideal Demand System, *American Economic Review*, 70, 312-326.

Dupasquier, C. and N. Ricketts, 1998. Non-Linearities in the Output-Inflation Relationship in *Price Stability, Inflation Targets, and Monetary Policy*: *Proceedings of a conference held by the Bank of Canada in May 1997*, 131-173.

Goldfjan, I. and S. Werlang, 2000. The Pass-through from Depreciation to Inflation: A Panel Study, Banco Central Do Brasil Working Paper No. 5.

Jonsson, M. and S. Palmqvist, 2003. Inflation, Markups and Monetary Policy, Sveriges Riksbank Working Paper No. 148.

Loungani, P., A. Razin and C. Yuen, 2001. Capital Mobility and the Output-Inflation Tradeoff, *Journal of Development Economics*, 64, 255-274.

Kamada, K. and N. Hirakata, 2002. Import Penetration and Consumer Prices, Bank of Japan Research and Statistics Department Working Paper Series 02-01.

King, R. and M. Watson, 1994. The Post-war U.S. Phillips Curve: A Revisionist Econometric History, *Carnegie-Rochester Conference Series on Public Policy,* 41, 157-219.

Klein, P., 2000. Using the Generalized Schur Form to Solve a Multivariate Linear Rational Expectation Model, *Journal of Economics Dynamics and Control*, 24, 1405-1423.

Rogoff, K., 2003. Globalization and Global Disinflation, in *Monetary Policy and Uncertainty: Adapting to a Changing Economy*, proceedings of the 2003 Jackson Hole symposium sponsored by the Federal Reserve Bank of Kansas City.

Rotemberg, J., 1982. Sticky Prices in the United States, *Journal of Political Economy*, 60, 1187-1211.

Rotemberg, J. and M. Woodford, 1991. Mark-ups and the Business Cycle, in Blanchard, O. and Fisher, S (eds), *NBER Macroeconomics Annual*, 63-128.

Sargent, T., 1979. *Macroeconomic Theory*, New York, Academic Press.

Taylor, J., 2000. Low Inflation, Pass-through and the Pricing Power of Firms, *European Economic Review,* 44, 1389-1408.

Windmeijer, F., 2004. A Finite Sample Correction for the Variance of Linear Efficient Two-step GMM estimators, *Journal of Econometrics*, forthcoming.

Figure 1: Inflation responses to transitory and persistent shocks to world inflation (PPP case).

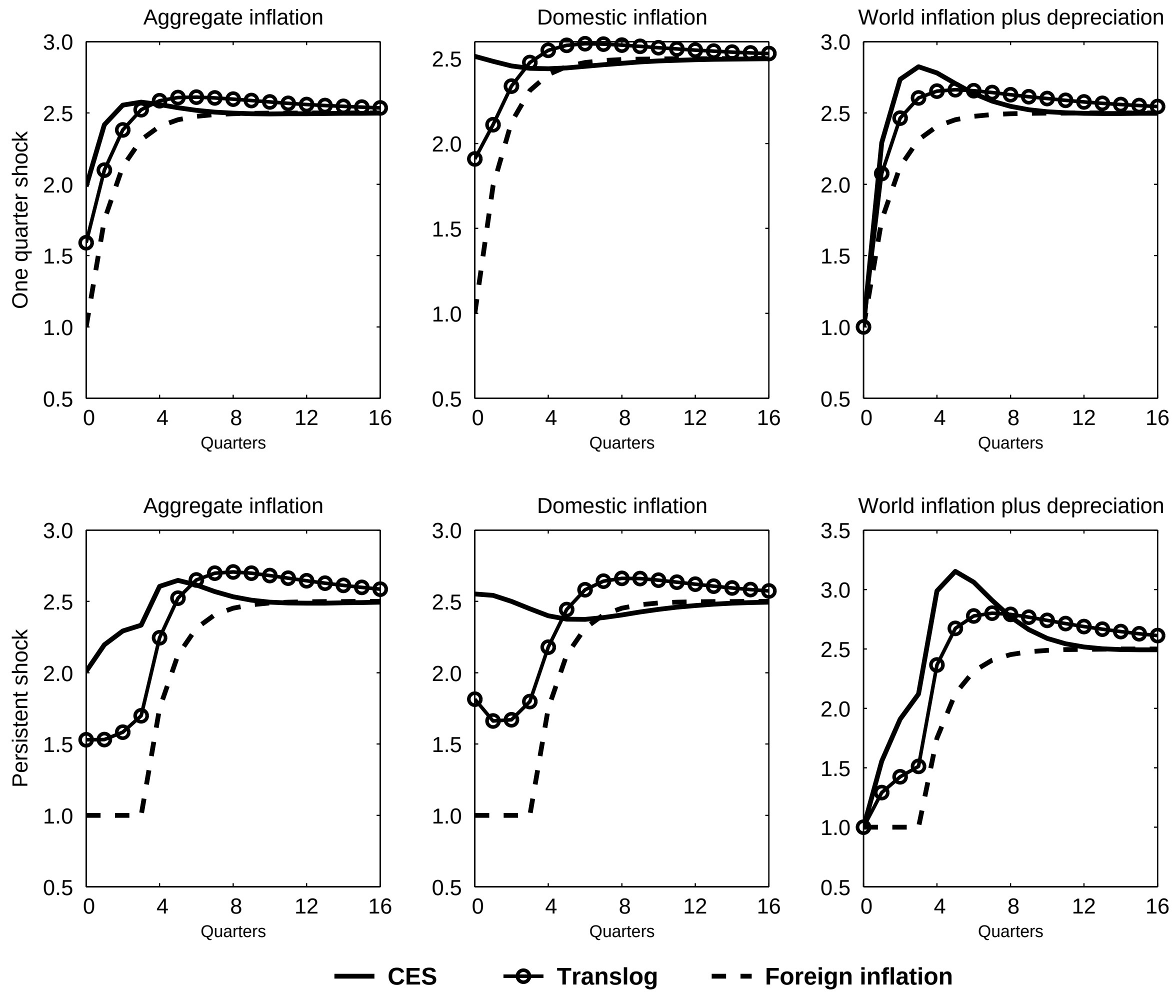

Figure 2: Real wage growth, interest rate and exchange rate responses to transitory and persistent shocks to world inflation (PPP case).

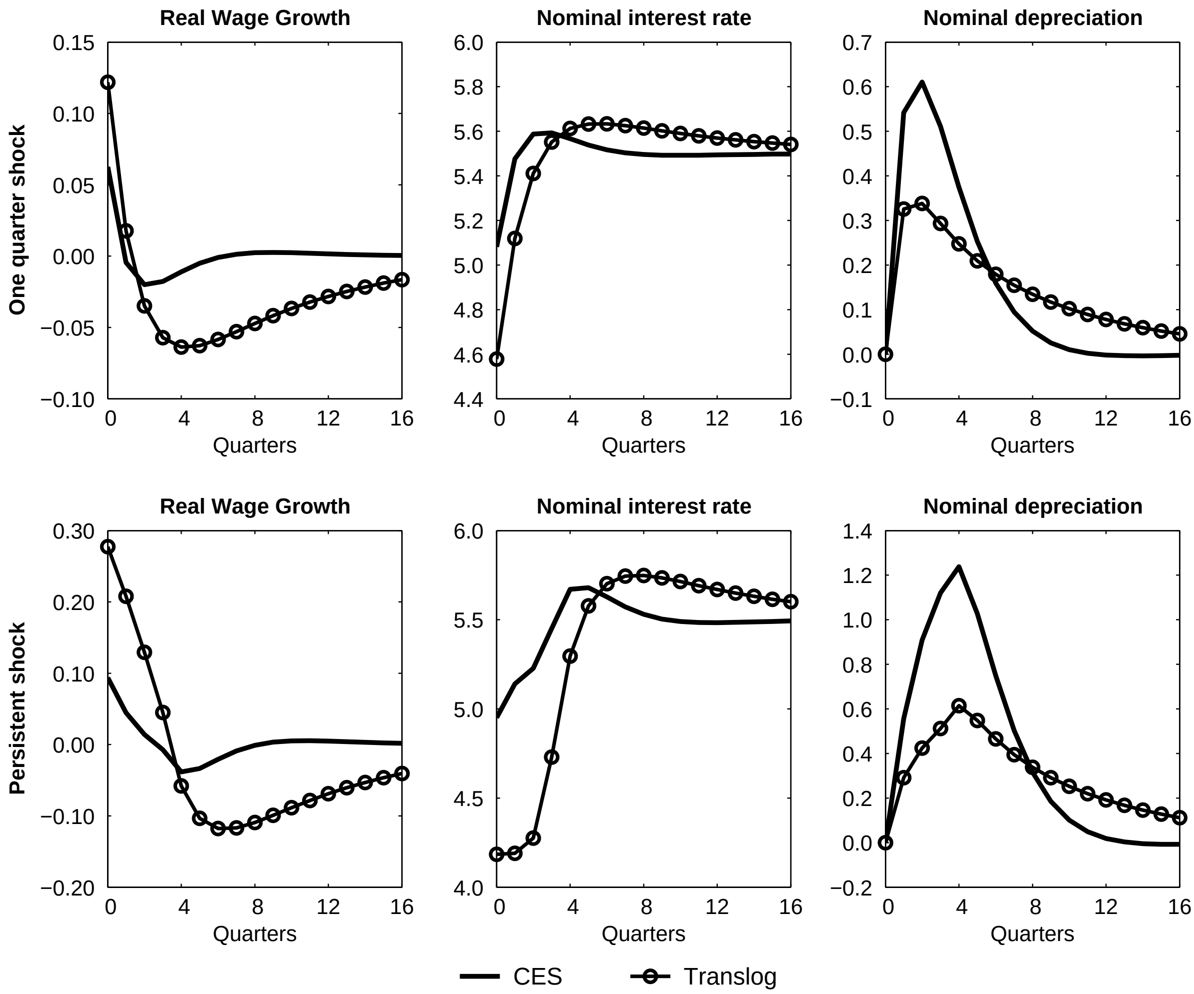

Figure 3: Time-varying parameters with transitory and persistent shocks to world inflation (PPP case).

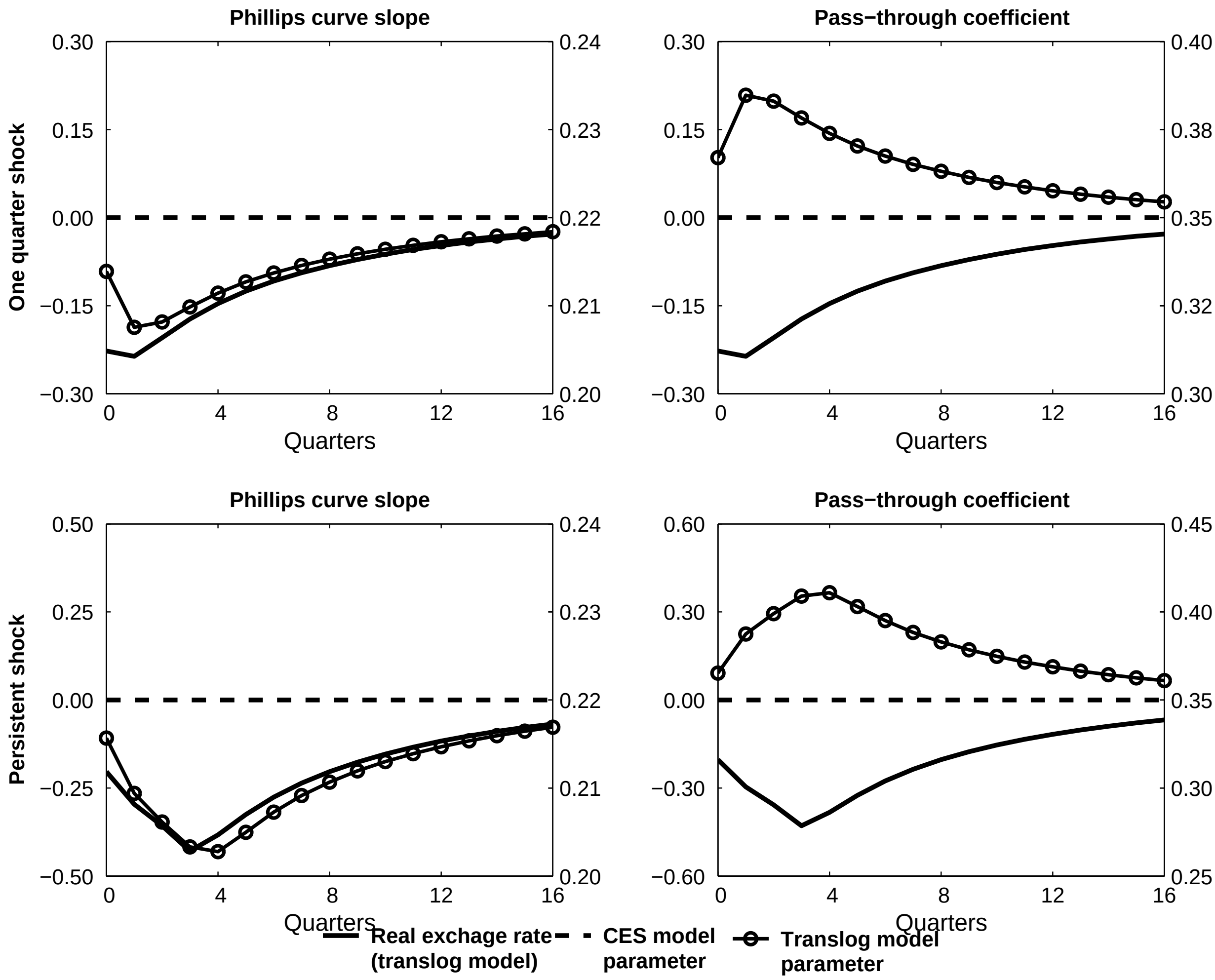

Figure 4: Inflation responses to transitory and persistent shocks to world inflation (UIP case).

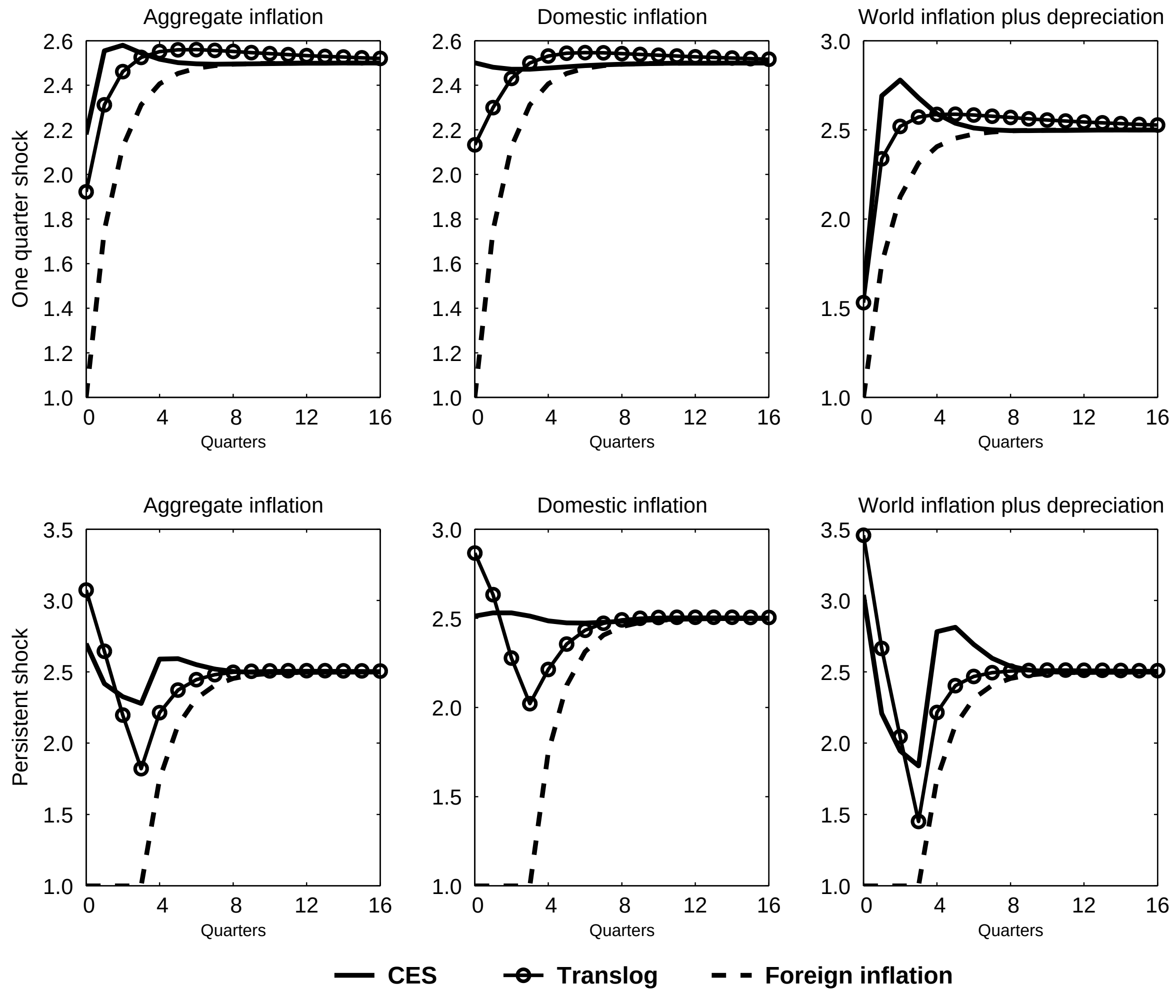

Figure 5: Real wage growth, interest rate and exchange rate responses to transitory and persistent shocks to world inflation (UIP case).

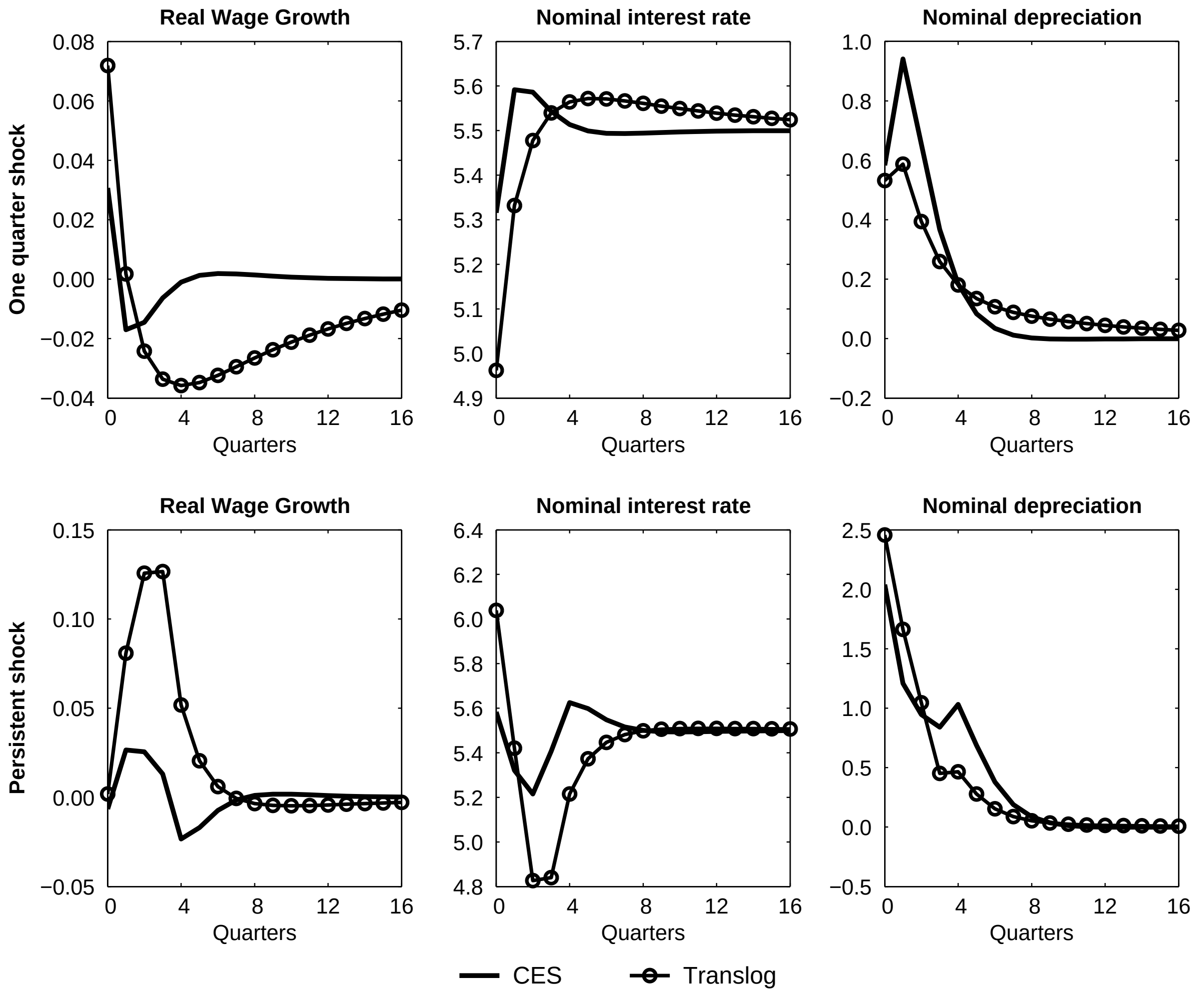

Figure 6: Time-varying parameters with transitory and persistent shocks to world inflation (UIP case).

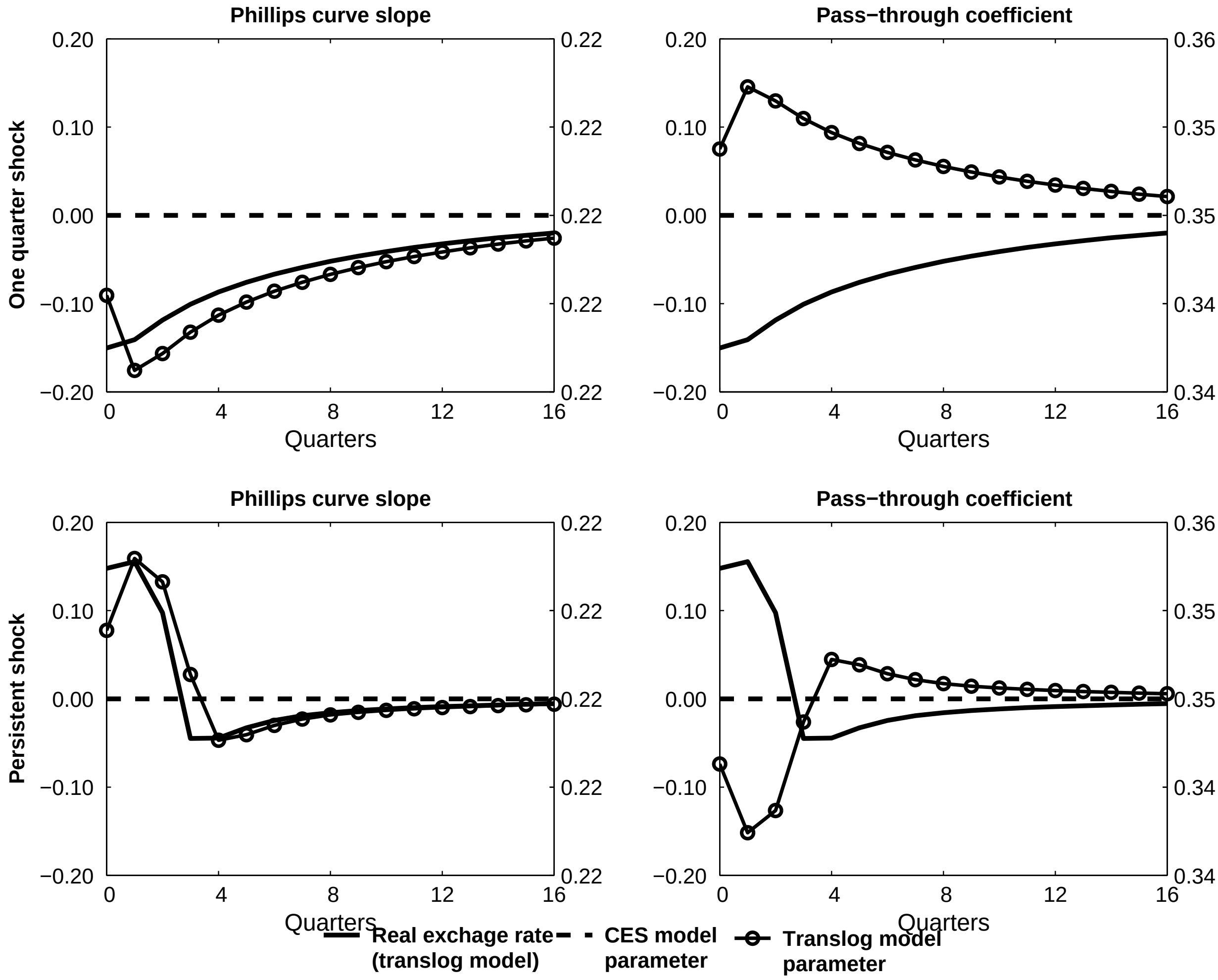

Table 1: Estimation Results

	Full sample		Most open economies		Emerging markets		All Countries in the 1990s	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ϕ_π	0.229	0.163	0.146	0.164	0.229	0.153	0.189	0.214
	(0.003)	(0.005)	(0.082)	(0.108)	(0.022)	(0.006)	(0.062)	(0.021)
ϕ_x	0.650	-0.029	0.414	-0.013	0.124	-0.027	0.587	-0.019
	(0.219)	(0.149)	(0.110)	(0.118)	(0.164)	(0.328)	(0.234)	(0.008)
ϕ_w	0.518	0.871	0.544	1.007	0.564	0.918	0.402	0.993
	(0.095)	(0.091)	(0.071)	(0.008)	(0.111)	(0.062)	(0.137)	(0.066)
φ_π		-0.965		-1.092		-1.056		-1.052
		(0.085)		(0.162)		(0.059)		(0.011)
φ_x		0.448		0.777		0.723		0.338
		(0.248)		(0.241)		(0.351)		(0.160)
φ_w		-0.017		-0.362		-0.543		-0.022
		(0.024)		(0.074)		(0.276)		(0.007)
Observations	833	833	533	533	266	266	532	532
J test (p-value)	0.835	0.887	0.745	0.911	0.894	0.852	0.784	0.762
AR1 (p-value)	0.012	0.023	0.004	0.012	0.027	0.035	0.010	0.013
AR2 (p-value)	0.705	0.927	0.011	0.307	0.063	0.752	0.731	0.268

Samples:

Full sample: OECD countries excluding Korea, Luxemburg, Poland, Slovak Republic and Turkey; plus Bolivia, Brazil, Chile, Colombia, Costa Rica, Cyprus, Dominican Republic, Israel, Malaysia, Morocco, Peru, Philippines, South Africa, Thailand and Uruguay.

Most open economies (average openness ratio ≥ 0.55): exclude Australia, Bolivia, Brazil, Colombia, France, Greece, Italy, Japan, Mexico, Morocco, Peru, South Africa, Spain, UK, USA and Uruguay.

Emerging market economies : exclude OECD countries, Cyprus and Israel but include Mexico.

Notes:

Robust two-step standard errors are reported in parenthesis. These standard errors as well as the test statistics have been corrected for finite sample bias following Windmeijer (2004).

The J test for overidentifying restrictions is asymptotically distributed as χ^2_k under the null of instrument validity, being k the number of overidentifying restrictions. AR1 and AR2 tests for serial autocorrelation of the first-differenced residuals are asymptotically standard normal under the null hypothesis of no serial autocorrelation.

All regressions include a constant. The instrument set consists of year dummies in all regressions, $\pi_{j,k}$, $x_{j,k}$, $\pi^w_{j,k}$, $\Delta q_{j,k}$, $x_{j,k}\Delta q_{j,k}$, $\pi^w_{j,k}\Delta q_{j,k}$ (with $k = t-2, t-3, ...$) for the differenced equations and $\Delta\pi_{j,t-1}$, $\Delta x_{j,t-1}$, $\Delta\pi^w_{j,t-1}$, $\Delta\left(\Delta q_{j,t-1}\right)$, $\Delta\left(x_{j,t-1}\Delta q_{j,t-1}\right)$, $\Delta\left(\pi^w_{j,t-1}\Delta q_{j,t-1}\right)$ for the level equations.