Globalization and the Phillips Curve

Nicola Zaniboni*

Georgetown University SFS-Q

First Draft: October 2008

This version: August 2011

Abstract

This paper investigates the impact of globalization on inflation in the context of a two-country New Keynesian model. Three questions have been raised in the recent literature: Has globalization lowered long-run inflation? Has globalization affected short-run dynamics of inflation? Has globalization been a source of shocks for the inflation process? I frame these questions in terms of the effects of increased openness on different aspects of open-economy Phillips curves, considering different scenarios for the measure of inflation, and for the assumed export-pricing behavior of firms. The main qualitative prediction of the model is that globalization makes Phillips curves flatter. Quantitatively, the effects of globalization on inflation are modest: increased openness only slightly decreases the slope of Phillips curves, domestic factors are still the main determinants of inflation, and globalization does not lead to a substantial increase in the volatility of shocks to the inflation process.

JEL classification codes: F41, E31

1 Introduction

The globalization and inflation debate has become very lively, and not without controversy. From a policymaker's standpoint, if we are to accept the notion that the world is becoming more globalized, it is of course important to understand in which ways inflation is affected, and how (or whether) the conduct of monetary policy has to be adjusted. These issues have received much attention in recent policy discussions. Bernanke (2007) broadly identifies two channels for globalization to potentially impact monetary policy: directly, affecting its ability to influence domestic financial market conditions through short and long term interest rates, and indirectly, modifying the determinants of inflation, which is a key policy variable. This paper focuses on the latter and, in particular, on the effect of increased trade openness.[1]

From a reading of the recent literature on the effects of globalization on inflation, three questions emerge:

1. Has globalization lowered long-run inflation? One argument supporting this view relies on the idea that increased competition due to globalization makes wages and prices more flexible, which in turn steepens the inflation/output relation. Central banks have less incentive to exploit this worse trade-off and equilibrium inflation is lower as a result (Rogoff (2003, 2006)).

2. Has globalization affected short-run dynamics of inflation? More specifically: has it affected the output/inflation trade-off, and does it imply that foreign factors matter in addition to (or more so than) domestic ones?

3. Has globalization been a source of shocks to the inflation process? More specifically: has globalization made inflation more volatile, beyond its effects through domestic and global measures of slack?

This paper informs the debate, providing a theoretical investigation of these claims. Specifically, the model we study implies Phillips curves of the following general form

$$\pi_t = \beta E_t \pi_{t+1} + \alpha(\gamma)\tilde{y}_t + \alpha^*(\gamma)\tilde{y}_t^* + \chi_t(\gamma) \tag{1}$$

relating inflation π_t to expected inflation next period, measures of domestic and foreign output gaps ($\tilde{y}_t$ and $\tilde{y}_t^*$ respectively), with coefficients that depend on some openness parameter γ, and an endogenous shift term χ (also affected by openness). The above questions can then be framed in terms of the effect of increased openness (as measured by γ) on different aspects of these Phillips curves: the argument in the first hypothesis rests on a positive relationship between the slope and openness ($\frac{\partial \alpha}{\partial \gamma} > 0$). The second hypothesis states that the slope and the coefficient on the foreign output gap might be changing with openness ($\frac{\partial \alpha}{\partial \gamma} \neq 0$ and $\frac{\partial \alpha^*}{\partial \gamma} \neq 0$). The third hypothesis predicts that the variance of the shifter is increasing with openness ($\frac{\partial Var(\chi_t)}{\partial \gamma} > 0$).

The analytical framework is an open-economy, two-country New Keynesian model with sticky prices. We allow for pricing-to-market (PTM), whereby firms are potentially able to set different prices for the domestic and export market.[2] We consider three different scenarios for the assumed export-pricing behavior of firms, defined by the currency in which exports' prices are sticky. Let us illustrate this with an example that

---

[1] It's worth noting that the definition of globalization employed here, namely an increase in the share of foreign produced goods in aggregate consumption (or share of imports in GDP, as shown later - see Figure 1), is by no means exhaustive. There are several other dimensions of globalization, including cross border factor mobility and financial integration, that can be relevant for inflation and are beyond the scope of this paper.

[2] The introduction of PTM is motivated by work in the New Open-Economy Macro literature (e.g. Betts and Devereux (2000), Chari et al. (2002) and Devereux and Engel (2003)) that recognizes its importance in affecting exchange rate dynamics and the international transmission of monetary policy.

uses the US Dollar (\$) and the Japanese Yen (¥): with *Producer-Currency Pricing* (PCP), US firms price their exports in \$, whereas Japanese firms set export prices in ¥. With *Local-Currency Pricing* (LCP), US firms use ¥, while Japanese firms use \$. Finally, with *Dollar-Dominant Pricing* (DDP), exports from both countries are invoiced in \$ (so that the Yen is only used to price Japanese goods sold in the Japanese market). These assumptions have different implications for the degree of *exchange rate pass-through*, broadly defined as the sensitivity of import and consumer prices to fluctuations in exchange rates. We also assess whether they have implications for the effects of globalization on inflation. Moreover, the distinction between domestic good-inflation and CPI-inflation is explicitly introduced to highlight the role of import prices.

There is a growing body of empirical literature that explores the globalization and inflation hypothesis. These empirical studies provide conflicting evidence regarding the three questions outlined above. First, there is general consensus that the estimated sensitivity of inflation to domestic output gaps has declined (see for example Roberts (2006) for the US, and Pain et al. (2006) for a group of OECD countries). The issue is how much, if any, of this decline is due to globalization. The IMF (2006) finds a significant negative relation between trade openness and the slope of Phillips curves for some industrial economies. On the other hand, Wynne and Kersting (2007) and Ihrig et al. (2007) report weak or no relation at all. Second, and on a related note, if global as well as domestic markets now matter for firms' price-setting decisions, we should expect global measures of resource utilization to be increasingly important in determining inflation. Evidence is once again mixed: Gamber and Hung (2001) and Borio and Filardo (2007) find a significant role for foreign output gaps, while Ihrig et al. (2007) argue that the result is not robust, and there is little support for the "globe-centric" approach once domestic factors are controlled for. Milani (2009) performs Bayesian estimation of a structural open-economy model for G-7 countries and points to weak evidence for a direct effect of global measures of slack on national inflation rates. Bianchi and Civelli (2010) use VARs with time varying coefficients and stochastic volatilities and report reduced-form results that are consistent with those in Ihrig et al. (2007). They argue, however, that the lack of significant effects of foreign output gaps in this form might be because the observed increase in openness hasn't been large enough, and they employ structural VAR analysis to argue for their potential importance in affecting inflation dynamics. Third, recent studies have explored the role of increased shares of low-cost imports in generating downward pressure on inflation. That is, even if globalization hasn't affected the structural determinants of inflation, it might have acted a source of shocks through this channel. Kamin et al. (2006) specifically study whether there is a "China effect" on global inflation, and conclude that it has been quantitatively modest. Aside from the inherent difficulties in measuring such effects, it might also be argued that such developments can lead to offsetting price increases in other categories of goods, so that the overall impact is unclear.[3]

More generally, a number of policy contributions (e.g. Kohn (2008, 2006), Bean (2006), Yellen (2006)) share a common message: globalization is a phenomenon to be reckoned with, but its effects on inflation and monetary policy have yet to be adequately assessed and should not be overstated. Ball (2006) and Mishkin (2008) go further and argue that globalization has had very little role in changing the determinants of inflation, and the low and stable inflation rates observed in the US during the 1990s are a consequence of better policy and well-anchored inflation expectations. The overall picture is that evidence so far is too scattered to be conclusive.

The main qualitative prediction of the model in this paper is that increased openness makes Phillips curves flatter. This result holds for a broad range of parameter configurations and is true both for domestic good-inflation and CPI-inflation. The basic mechanism works through firms' marginal costs, which are affected by changes in output to a lesser extent. This is because the required terms of trade adjustment

---

[3]For example, as noted in Bean (2006), the rapid growth of the same emerging countries that provide low-cost imports is putting upward pressure on commodity prices.

following an output change is smaller the more open the economy. Quantitatively, however, the effects of globalization on inflation are modest, especially in the case that we consider empirically relevant for the US: First, increased openness only slightly decreases the structural slope of Phillips curves. Second, while foreign measures of output gap are increasingly important, domestic factors are still the main determinants of inflation. Third, globalization amplifies the volatility of shocks to the inflation process, but the increase is not substantial. This set of results is confirmed when we look at "empirical" regressions that use data generated by the model, and are intended to mimic the analysis of earlier studies.

Another implication of this model is that the different export-pricing scenarios don't change the way openness impacts the structural slope of Phillips curves: more specifically, the elasticity of marginal cost with respect to domestic output is not affected by the exporters' currency of choice. The same is true for the coefficient on the foreign output gap. Different assumptions about currency choice do imply, however, different endogenous shift terms in the Phillips curves. These terms reflect differential degrees of exchange rate pass-through into import prices, and affect the way globalization impacts inflation through this channel. We also check the model's implication for pass-through at the aggregate level, across the three pricing assumptions. To do this, we compute the implied short-run elasticity of import prices with respect to the exchange rate, and find it is in line with empirical estimates for the US.

There are some relatively close predecessors to this paper in terms of modelling: Clarida, Gali and Gertler (2002), and Gali and Monacelli (2005), for example, employ similar New Keynesian open-economy models to study how openness affects properties of optimal monetary policy. Monacelli (2005) introduces imperfect pass-through in the analysis. Steinsson (2008) looks at the volatility and persistence properties of the real exchange rate in a two-country model with LCP. Corsetti and Pesenti (2005a, 2005b) allow for partial indexation of prices to fluctuations of the exchange rate for a simpler form of price stickiness, and regard PCP, LCP and DDP as special cases. There is some recent theoretical work that focuses more explicitly on the effects of globalization. Razin and Yuen (2002) look at Phillips curves in the context of a small open economy model with prices set one period in advance, and find that the open-economy case implies a flatter Phillips curve than closed-economy. Woodford (2007) has a slightly different focus: his analysis builds on Clarida, Gali and Gertler (2002) to study several channels through which globalization might affect the impact of monetary policy on domestic variables. His conclusion is that globalization is not likely to impair monetary policy's ability to control domestic inflation. Finally, other papers use a New Keynesian framework to study the theoretical link between the slope of Phillips curves and developments related to globalization other than increased trade openness: Binyamini and Razin (2007) allow for international labor flows and capital mobility and find they make inflation less responsive to domestic real activity. Sbordone (2007) considers the effect of increased competition (modeled through an increase in varieties of traded goods) on the elasticity of demand faced by firms and argues that the impact on the slope of the Phillips curve is not quantitatively relevant. Guerrieri et al. (2010) follow a similar approach to estimate a Phillips curve in the context of an explicit open-economy model, and find that foreign competition has contributed to lowering the level of inflation. We view the results in this strand of the literature as complementary to those in this paper.

The rest of the paper is organized as follows: Section 2 describes the main features of the model, while Section 3 analyzes Phillips curves in detail, establishing the role of open economy aspects. Section 4 presents the main results and provides a qualitative and quantitative assessment of the effects of globalization on the Phillips curves. Section 5 evaluates the model's implications for exchange rate pass-through and Section 6 concludes.

2 The Model

The world economy consists of two large countries, Home (H) and Foreign (F), with representative optimizing households and symmetric preferences. There is a competitive, economy-wide labor market, and financial markets are complete both domestically and across borders, in that agents have access to a complete set of state contingent assets which can be traded internationally. Both countries have monopolistically competitive intermediate-good producers who set nominal prices in a staggered fashion (following Calvo (1983)), and a perfectly competitive final-good producer.

As for the more specific open-economy aspects, we abstract from non tradable goods, so that fluctuations of the real exchange rate are only due to deviations from the Law of One Price (LOP) for tradables and movements of the terms of trade in the presence of consumption home bias. Intermediate-good producers are potentially able to price discriminate across markets.

2.1 Households

The representative household chooses consumption C_t and labor N_t to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\phi}}{1+\phi} \right] \tag{2}$$

subject to a flow budget constraint that reflects market completeness:

$$P_t C_t + E_t\{\rho_{t,t+1} D_{t+1}\} = W_t N_t + D_t + \Upsilon_t \tag{3}$$

where D_{t+1} is the state-contingent payoff of the portfolio at the beginning of period $t+1$ and $\rho_{t,t+1}$ is the relevant stochastic discount factor. W_t is nominal wage and Υ_t denotes profits from firms. σ is the inverse of the intertemporal elasticity of substitution and ϕ is the inverse of the Frisch elasticity of labor supply.[4]

The index C_t is defined as:

$$C_t \equiv \left[(1-\gamma)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{4}$$

where C_H and C_F are consumption bundles of domestic and foreign varieties, respectively:

$$
\begin{aligned}
C_{H,t} &\equiv \left[\int_0^1 C_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \\
C_{F,t} &\equiv \left[\int_0^1 C_{F,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}}
\end{aligned} \tag{5}
$$

Accordingly, $\varepsilon > 1$ is the elasticity of substitution between varieties and η denotes the elasticity of substitution between Home and Foreign goods.

The corresponding price index is:

$$P_t = \left[(1-\gamma) P_{H,t}^{1-\eta} + \gamma P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}}. \tag{6}$$

with

$$
\begin{aligned}
P_{H,t} &= \left[\int_0^1 P_{H,t}(i)^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}} \\
\end{aligned} \tag{7}
$$

$$
\begin{aligned}
P_{F,t} &= \left[\int_0^1 P_{F,t}(i)^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}} \\
\end{aligned} \tag{8}
$$

---

[4] The Appendix provides details and derivations of the model.

P_t is the *Consumer Price Index (CPI)* in the model. We denote $P_{H,t}$ and $P_{F,t}$ as the *domestic price index* and *import price index*, respectively. The corresponding inflation rates are analogously defined as *CPI, domestic* and *import* inflation.

The parameter γ represents the relative preference for foreign vs. domestic goods. Note that $\gamma \in [0; \frac{1}{2})$ implies there is home bias in preferences. We assume the same degree of bias in both countries, so that the aggregate consumption index for country F is given by

$$C_t^* \equiv \left[(1 - \gamma)^{\frac{1}{\eta}} C_{F,t}^{* \frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} C_{H,t}^{* \frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}.$$

As γ increases, both countries become more "open", in that they are less biased towards domestically produced goods.[5] Corresponding price indices for country F are derived accordingly.[6]

Optimal consumption allocation between the domestic and foreign goods implies

$$\frac{C_{H,t}}{C_{F,t}} = \frac{1 - \gamma}{\gamma} \left(\frac{P_{H,t}}{P_{F,t}} \right)^{-\eta} \tag{9}$$

The steady state satisfies $P_H = P_F$ ($P_H^* = P_F^*$ for the foreign country) and $C = C^* = Y = Y^*$, so combining (9) and (4) shows that $\gamma = \frac{C_F}{Y}$ is the ratio of imports to GDP. This is the measure of openness we employ in the analysis that follows.

2.2 Firms

Each economy comprises a continuum of monopolistically competitive firms, producing with a linear technology that uses labor as the sole input. We assume Calvo-style nominal price stickiness: each period, any firm is able to optimally update its price with probability $1 - \theta$ (independent of the time elapsed since the last adjustment). θ is the same in H and F. With the assumed technology, domestic firms' real marginal cost is

$$MC_t = \frac{(W_t/P_{H,t})}{A_t} \tag{10}$$

where A_t is exogenous productivity. The pricing-to-market assumption implies that there are two separate pricing problems, one for the domestic and one for the export market. Expected profits for an optimizing firm in period t are:

$$E_t \left\{ \underbrace{\sum_{j=0}^{\infty} \theta^j \rho_{t,t+j} (X_{H,t} - MC_{t+j} P_{H,t+j}) C_{H,t+j}(i)}_{\text{domestic market}} + \underbrace{\sum_{j=0}^{\infty} \theta^j \rho_{t,t+j} \left(P_{H,t+j}^*(i) \mathcal{E}_{t+j} - MC_{t+j} P_{H,t+j} \right) C_{H,t+j}^*(i)}_{\text{export market}} \right\}$$

where $C_H(i)$ and $C_H^*(i)$ are domestic and foreign demand for good i, and $\mathcal{E}$ is the nominal exchange rate (defined as the price of one unit of Foreign currency in terms of Home currency).

---

[5] In this respect, the setup is different from Clarida, Gali and Gertler (2002), who regard γ as the *size* of the foreign country (the variables are thus in per capita terms). We can still interpret their γ as an openness parameter, but as one country becomes larger, the other becomes smaller in this instance.

[6] A note on notation: subscripts H and F, both for consumption and price variables, define production location, i.e. "home-" and "foreign-" produced goods, respectively. As for the star superscript, C vs. C^* define the identity of the consumer (H vs. F resident), while P vs. P^* will denote the currency in which prices are expressed (H-currency vs. F-currency).

2.2.1 Choice of Domestic Price

The domestic firm chooses the reset price $X_{H,t}$ to maximize the above profit function. The first order condition for this problem reads

$$E_t \sum_{j=0}^{\infty} \theta^j \rho_{t,t+j} (X_{H,t} - \frac{\varepsilon}{\varepsilon-1} MC_{t+j} P_{H,t+j}) C_{H,t+j}(i) = 0 \tag{11}$$

where $\frac{\varepsilon}{\varepsilon-1}$ is the usual expression for the constant (gross) markup over marginal costs. This equation is combined with the evolution of the domestic price index

$$P_{H,t} = [\theta P_{H,t-1}^{1-\varepsilon} + (1-\theta) X_{H,t}^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}} \tag{12}$$

to give rise to the familiar (log-linear) New Keynesian Phillips curve for domestic inflation

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \lambda mc_t \tag{13}$$

where $\lambda = \frac{(1-\theta)(1-\theta\beta)}{\theta}$.

2.2.2 Choice of Export Price

We now turn to the price setting problem for the export market. Since we are ultimately interested in the impact of export pricing behavior on inflation dynamics in the domestic country, we consider a firm in country F exporting its produced good to country H.[7] This producer solves:

$$\underset{?}{Max} \quad E_t \sum_{j=0}^{\infty} \theta^j \rho_{t,t+j} \left(\frac{P_{F,t+j}(i)}{\mathcal{E}_{t+j}} - MC_{t+j}^* P_{F,t+j}^* \right) C_{F,t+j}(i)$$

The actual choice variable depends on the assumed pricing scenario. Under *Producer-Currency Pricing (PCP)*, exporters in both countries set prices in their own currency: producers in F pick $X_{F,t}^*$ and producers in H symmetrically pick $X_{H,t}$. Under *Local-Currency Pricing (LCP)*, exports are priced using the destination market's currency: producers in F pick $X_{F,t}$ and producers in H pick $X_{H,t}^*$. Finally, under *Dollar-Dominant Pricing (DDP)*, H-currency is used to price exports from both countries: producers in F pick $X_{F,t}$, whereas producers in H pick $X_{H,t}$. We argue that this asymmetric case is empirically relevant for the US, where most of imports and exports are priced in dollars (hence the denomination).[8]

The term $P_{F,t+j}(i)$ in the profit function is the H-currency price of the exported good (that is, the import price from the standpoint of country H) in $t+j$, conditional on no further adjustment. It is then converted to F-currency using the nominal exchange rate. The different assumptions about currency choice have implications for the pass-through of exchange rate fluctuations into this price.

- *Producer-Currency Pricing:* $P_{F,t+j}(i) = \mathcal{E}_{t+j} X_{F,t}^*$

The expected profits can be written as

$$E_t \sum_{j=0}^{\infty} \theta^j \rho_{t,t+j} \left(X_{F,t}^* - MC_{t+j}^* P_{F,t+j}^* \right) C_{F,t+j}(i)$$

---

[7] Exporters in country H face an analogous problem, as exemplified by their profit function.

[8] Gopinath and Rigobon (2008) use unpublished US micro data on import and export prices (collected by the Bureau of Labor Statistics in 1994-2005) and report that 90% (97%) of imports (exports) are priced in dollars.

This shows that fluctuations of the exchange rate are fully passed into $P_{F,t+j}(i)$. On the other hand, of course, the price received by the exporter is completely insulated from such fluctuations. Similarly, producers in country H choose X_H, so that $P^*_{H,t+j}(i) = \frac{X_{H,t}}{\mathcal{E}_{t+j}}$. The LOP holds in this instance for both the Home and Foreign composite good.

- *Local-Currency Pricing:* $P_{F,t+j}(i) = X_{F,t}$

Expected profits now become

$$E_t \sum_{j=0}^{\infty} \theta^j \rho_{t,t+j} \left(\frac{X_{F,t}}{\mathcal{E}_{t+j}} - MC^*_{t+j} P^*_{F,t+j} \right) C_{F,t+j}(i)$$

which makes clear that the implications at the single product level are the polar opposite of the PCP assumption: the importing country doesn't see any price change as the exchange rate moves, and the exporter fully bears its fluctuations. Similarly, producers in country H choose $P^*_{H,t+j}(i) = \frac{X_{H,t}}{\mathcal{E}_{t+j}}$

- *Dollar-Dominant Pricing:* $P_{F,t+j}(i) = X_{F,t}$

This case is asymmetric and combines the previous two assumptions. Exporters in country F behave as in the LCP case, while exporters in country H choose $P^*_{H,t+j}(i) = \frac{X_{H,t}}{\mathcal{E}_{t+j}}$. The LOP only holds for the Home good.

2.3 Solving for the Equilibrium

The model (in its three versions) is log-linearized around a zero-inflation steady state. In what follows, all lower case letters denote logarithmic deviations from this steady state. For both countries H and F, the model is characterized by an IS-type relation, which is derived from the household's problem and links output to the real interest rates, and Phillips curves for domestic and CPI inflation. To close the model, we need to specify the determination of the nominal interest rate and the evolution of the exogenous shocks in each country. We assume that monetary policy is conducted according to a Taylor-type rule:

$$r_t = \phi_\pi \pi_t + \phi_y y_t + u_t \tag{14}$$

The shock to technology a_t and the monetary shock u_t both follow AR(1) processes:

$$a_t = \rho_a a_{t-1} + \varepsilon_t \tag{15}$$
$$u_t = \rho_u u_{t-1} + \mu_t \tag{16}$$

where ε_t and μ_t are zero-mean i.i.d. random variables with variance σ_ε^2 and σ_μ^2, respectively. The shocks are assumed to be uncorrelated across countries.

3 Phillips Curves

We now look more in detail at the Phillips curves implied by the model, highlighting the channels through which they are affected by open economy aspects. It is useful at this point to define the following variables:

$$z_t \equiv p^*_{F,t} + e_t - p_{F,t} \tag{17}$$
$$z^*_t \equiv p_{H,t} - e_t - p^*_{H,t} \tag{18}$$

which represent *deviations from LOP* for Foreign and Home goods. With the assumed form of price stickiness, we find:

$$z_t = e_t - (1-\theta)\sum_{i=0}^{\infty}\theta^i e_{t-i}^W$$

$$z_t^* = (1-\theta)\sum_{i=0}^{\infty}\theta^i e_{t-i}^W - e_t \tag{19}$$

where $e_t^W \equiv (1-\theta\beta)E_t\sum_{j=0}^{\infty}(\theta\beta)^j e_{t+j}$. A couple of observations are in order. First, the pricing assumptions have an impact on z_t and z_t^*. Under PCP, $z_t = z_t^* = 0$, as the LOP holds for both types of goods. Under LCP, both z_t and z_t^* are different from zero and they are related by $z_t = -z_t^*$, given that θ is the same in H and F. Under DDP, $z_t \neq 0$ and $z_t^* = 0$. We also note that if prices are flexible (i.e. $\theta \to 0$), $z_t = z_t^* = 0$, which shows that currency choice makes a difference only insofar as there is nominal stickiness. Second, the pricing assumptions have different implications for import inflation π_F. Under PCP, foreign inflation π_F^* and import inflation π_F are simply related by

$$\pi_{F,t} = \pi_{F,t}^* + \Delta e_t \tag{20}$$

where $\pi_{F,t}^* = \beta E_t \pi_{F,t+1}^* + \lambda mc_t^*$. The Phillips curve for π_F can be written as

$$\pi_{F,t} = \beta E_t \pi_{F,t+1} + \lambda mc_t^* + (\Delta e_t - \beta E_t \Delta e_{t+1}) \tag{21}$$

For both LCP and DDP, the corresponding Phillips curve is the result of exporters in country F directly pricing in H currency, which yields

$$\pi_{F,t} = \beta E_t \pi_{F,t+1} + \lambda mc_t^* + \lambda z_t \tag{22}$$

3.1 The Inflation - Marginal Cost Relation

We can now combine domestic inflation as given in (13), with import inflation (21) or (22) to state the following

Proposition 1 *CPI inflation is given by $\pi_t = (1-\gamma)\pi_{H,t} + \gamma\pi_{F,t}$ and can be written in terms of real marginal costs as:*

- PCP:
$$\pi_t = \beta E_t \pi_{t+1} + (1-\gamma)\lambda mc_t + \gamma\lambda mc_t^* + \gamma(\Delta e_t - \beta E_t \Delta e_{t+1}) \tag{23}$$

- LCP & DDP:
$$\pi_t = \beta E_t \pi_{t+1} + (1-\gamma)\lambda mc_t + \gamma\lambda mc_t^* + \gamma\lambda z_t \tag{24}$$

Inflation is affected here by foreign marginal costs mc_t^*, because of their role in the pricing problem of foreign exporters. Currency choice plays a role through its effects on the prices of imports: the different shift terms reflect full or partial pass-through of exchange rate fluctuations. In this instance, LCP and DDP are equivalent. This representation of inflation is conditional on marginal costs. We now examine how they are related to output, and assess whether this provides additional channels for openness to affect inflation.

9

3.2 Linking Marginal Cost and Output

As shown in the Appendix, real marginal cost can be written as a function of the output gap and deviations from the LOP for foreign and domestic goods:

$$mc_t = \kappa \tilde{y}_t + \frac{(1-2\gamma)\omega}{1+4\omega}z_t - \frac{(1+2\gamma)\omega+\gamma}{1+4\omega}z_t^* \tag{25}$$

where $\kappa = \phi + \sigma_0$, and in turn $\sigma_0 = \frac{\sigma(1+2\omega)}{1+4\omega}$, $\omega = \gamma(1-\gamma)(\sigma\eta - 1)$. The output gap is defined as the deviation of output from its flexible-price level. Thus, $\tilde{y}_t \equiv y_t - \bar{y}_t$ with

$$\bar{y}_t = \frac{1}{\phi + \sigma_0}[(1+\phi)a_t - (\sigma - \sigma_0)y_t^*] \tag{26}$$

Open-economy aspects enter (25) through z_t (z_t^*), and by affecting natural output $\bar{y}_t$ and the elasticity of marginal cost with respect to the domestic output gap κ.

Note how the above relations are affected by the openness parameter γ: when $\gamma = 0$, we have $\omega = 0$ and $\sigma_0 = \sigma$, so that the model is equivalent to its closed economy version. We then ask whether openness increases or decreases the elasticity κ relative to closed economy. This in turn depends on the value of σ_0 relative to σ, which also determines the impact of foreign output y_t^* on $\bar{y}_t$ (see (26)). It's clear from inspection that the elasticity of mc_t with respect to $\tilde{y}_t$ is smaller (larger) than in closed economy when $\sigma\eta$ is larger (smaller) than 1. In the special case $\sigma\eta = 1$, neither κ nor $\bar{y}_t$ are affected by open economy considerations, regardless of the value of γ.

What are the channels at work? To gain some intuition, we go back a few steps and use labor supply along with the aggregate production function to express real marginal costs as:

$$mc_t = \phi n_t + \sigma c_t + \gamma s_t - a_t \tag{27}$$

where s_t denotes the terms of trade for country H, defined as $s_t \equiv p_{F,t} - p_{H,t}$. They can be written as a function of relative output:

$$s_t = \frac{\sigma}{1+4\omega}(y_t - y_t^*) - \frac{2\omega + (1-\gamma)}{1+4\omega}z_t - \frac{2\omega + \gamma}{1+4\omega}z_t^* \tag{28}$$

Moreover, consumption c_t is a function of domestic and foreign output, as follows:

$$c_t = \frac{2\omega + (1-\gamma)}{1+4\omega}y_t + \frac{2\omega + \gamma}{1+4\omega}y_t^* + \frac{\omega + \gamma(1-\gamma)}{\sigma(1+4\omega)}(z_t - z_t^*) \tag{29}$$

Openness $(\gamma > 0)$ changes the effect of an output change on marginal costs in two ways. Consider an output increase: First, relative to the closed economy version of the model, the corresponding increase in c_t is smaller because of international risk sharing, as (29) makes clear. This curbs the increase of real wages that works through the marginal rate of substitution between consumption and leisure, thus *dampening* the effect of y_t on mc_t. Second, in order to ensure market clearing, the terms of trade depreciate when domestic output rises relative to foreign output (see (28)), which leads to an increase in marginal costs (see (27)). This additional channel works towards *amplifying* the effect of y_t on mc_t. The overall effect depends on the magnitude of $\sigma\eta$, and the first channel is more likely to dominate with larger values of the parameters $(\sigma\eta > 1)$. Recall that σ is the inverse of the elasticity of intertemporal substitution and η is the elasticity of substitution between domestic and foreign goods: for given η, a larger σ implies that the muted consumption response has a stronger (wealth) effect in limiting the change in real wages. For given σ, a larger elasticity η implies a smaller required relative-price adjustment following an output change, so the terms of trade effect is not strong enough to counteract the dampening due to risk sharing. We regard $\sigma\eta > 1$ as the relevant case. Hence, the open-economy elasticity of marginal cost with respect to the domestic output gap, κ, is smaller than in closed economy.

Table 1: Domestic and CPI inflation Phillips curves

Domestic Inflation	CPI Inflation

PCP:

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \lambda \kappa \tilde{y}_t \qquad\qquad \pi_t = \beta E_t \pi_{t+1} + (1-\gamma)\lambda \kappa \tilde{y}_t + \gamma \lambda \kappa \tilde{y}_t^* + \gamma(\Delta e_t - \beta E_t \Delta e_{+1})$$

LCP:

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \lambda \kappa \tilde{y}_t + \lambda \left[\frac{\gamma+2\omega}{1+4\omega}\right] z_t \qquad \pi_t = \beta E_t \pi_{t+1} + (1-\gamma)\lambda \kappa \tilde{y}_t + \gamma \lambda \kappa \tilde{y}_t^* + 2\lambda \left[\frac{\gamma(1-\gamma)+\omega}{1+4\omega}\right] z_t$$

DDP:

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \lambda \kappa \tilde{y}_t + \lambda \left[\frac{(1-2\gamma)\omega}{1+4\omega}\right] z_t \qquad \pi_t = \beta E_t \pi_{t+1} + (1-\gamma)\lambda \kappa \tilde{y}_t + \gamma \lambda \kappa \tilde{y}_t^* + \lambda \left[\frac{\gamma(1-\gamma)+\omega}{1+4\omega}\right] z_t$$

3.3 The Inflation - Output Relation

We are now ready to state the following

Proposition 2 *Using equation (25) linking domestic marginal costs to output (and an analogous one for foreign marginal costs), Phillips curves for domestic and CPI inflation can be written in terms of output gaps, and are reported in Table 1 for the three pricing assumptions.*

Importantly, Table 1 shows that the structural slope of Phillips curves (that is, the coefficient on the domestic output gap) doesn't change across the different pricing assumptions: the slope is determined by λ, which depends on the degree of price stickiness, and the elasticity κ, which is invariant to the export-pricing scenarios. For CPI inflation, openness additionally matters through $1 - \gamma$.

As is apparent from equation (25), z_t generates endogenous deviations from the simple proportional relation between mc_t and $\tilde{y}_t$, which in turn implies shift terms in the Phillips curves that are different across pricing assumptions.[9] Looking at domestic inflation, we observe that deviations from the LOP matter solely through their role in marginal costs. Indeed, with PCP, we just have $mc_t = \kappa \tilde{y}_t$, and the Phillips curve is isomorphic to closed economy[10]: openness enters the picture only by affecting κ and $\tilde{y}_t$. Also note that, with DDP, z_t only matters as long as preferences are biased ($\gamma \neq \frac{1}{2}$). As for CPI inflation, deviations from LOP now matter both because they affect marginal costs and because of the direct impact on import prices. Moreover, the effect of z_t on CPI inflation is always larger with LCP than DDP for any value of γ.

3.4 "Empirical" Phillips Curves

We also consider alternative specifications of Phillips curves and broadly group them under the "empirical" header, as opposed to the theoretical relationships explored above. We do this in the spirit of recent studies on the globalization-inflation hypothesis (e.g. Ball (2006) and Wynne and Kersting (2007)), and compare the findings to the model's predictions. In particular, we first look at a "New" Keynesian specification:

$$\pi_t - \beta E_t \pi_{t+1} = \alpha(\gamma)\tilde{y}_t + \xi_t \tag{30}$$

---

[9]Under the LCP assumption, we exploit the fact that $z_t^* = -z_t$ to write everything in terms of z_t only.
[10]See Clarida, Gali and Gertler (2002).

This relation uses model-consistent measures of inflation expectations and output gap and is the closest to the theoretical one. We then specify a backward looking ("Old" Keynesian) Phillips curve as

$$\Delta \pi_t = \alpha(\gamma)y_t + \xi_t \tag{31}$$

where we use lagged inflation as a more naive measure of inflation expectations. This specification corresponds to a simple regression of the change in inflation on output. Finally, we consider a similar equation where we also include foreign output:

$$\Delta \pi_t = \alpha(\gamma)y_t + \alpha^*(\gamma)y_t^* + \xi_t \tag{32}$$

For these three specifications, we will study the effects of openness on the slopes by looking at the regression coefficients α (α^*) as predicted by the model, over a range of values of γ. The openness parameter affects the slope through its effect on simulated data.

4   The Effects of Globalization

Figure 1 reports the ratio of US imports of goods and services to GDP for the last fifty years. We regard this measure as the data counterpart of the parameter γ in the model, given the steady state interpretation of the latter. In the analysis that follows, we define globalization as an *increase in* γ.[11] We take the year 1990 as the starting point of the wave of globalization that is at the center of the recent debate, and note that imports have since then increased from 10 to 18% of GDP, approximately. Thus, a little more loosely, we take $\gamma \in (0.1, 0.2)$ as the relevant range for the parameter in the quantitative exercises.

4.1   Calibration

The parameter values are reported in Table 2. Most are relatively non-controversial: we set $\beta = 0.99$, which is consistent with quarterly data, implying a steady-state annualized riskless return of about 4%. We assume $\phi = 3$, so that the elasticity of labor supply is $\frac{1}{3}$. The Calvo parameter is $\theta = 0.75$, which gives an average duration of price spells of one year. This represents a widely used standard, albeit perhaps a little higher than the values implied by recent empirical studies (e.g. Bils and Klenow (2004)). Finally, the coefficients of the interest rate rule are set to $\phi_\pi = 1.5$ and $\phi_y = 0.5/4 = 0.125$ (Taylor (1993)).

As we have seen, the parameters σ and η play an important role in the model. Typical values for the risk aversion parameter σ are in the range of 1 (log-utility) to 5. The elasticity η is hard to pin down, as exemplified by the very wide range of estimates available in the literature. Obstfeld and Rogoff (2000) report estimates from trade studies between 5 and 6. As noted in Adolfson et al. (2007), η has been estimated in the 5 to 20 range using micro data, and much lower (between 1 and 2) using macro data (see also Chari et al. (2002)). Lubik and Schorfheide (2005) estimate a value as low as 0.5. We use $\sigma = 5$ and $\eta = 1$ as the preferred values.[12] The value of σ is on the high end, but it is often used in calibrations of open economy models (e.g. McCallum and Nelson (2000), Chari et al. (2002) and Steinsson (2008)). Our results are robust to changes in the values of those parameters.

---

[11] More precisely, we will be comparing the model's predictions for different, and increasing, steady state values of the import/GDP ratio.

[12] $\eta = 1$ is an interesting special case used, among others, by Corsetti and Pesenti (2005a). It leads to a Cobb-Douglas formulation of the consumption index of Home and Foreign goods. One rationale for this value (or, more generally, for a value that is not larger than 1) is that the elasticity of substitution between varieties (ε in the model) is assumed to be strictly greater than 1, and is presumably higher than the elasticity between Home and Foreign goods. So, without having to take a stand on the exact value of ε, setting $\eta = 1$ "loosely" satisfies the above condition.

Table 2: Parameter values	
Discount factor	$\beta = 0.99$
Inverse of EIS	$\sigma = 5$
Inverse of Frisch elasticity	$\phi = 3$
Calvo probability	$\theta = 0.75$
Elasticity of subs. H/F	$\eta = 1$
Taylor rule	$\phi_\pi = 1.5$
	$\phi_y = 0.5/4$
Tech. shock AR(1)	$\rho_a = 0.89$
Monetary shock AR(1)	$\rho_u = 0.82$
Relative variance	$\frac{\sigma_\varepsilon}{\sigma_\mu} = 0.66$

There is less clear-cut guidance in the literature regarding the parameters of the shock processes. We calibrate ρ_a, ρ_u and $\frac{\sigma_\varepsilon}{\sigma_\mu}$ (i.e. the relative variability of the shocks) to match three moments in US data, namely the first order autocorrelation of output and inflation, and the variance of inflation relative to output. For this calibration exercise, we use the DDP version of the model. The openness parameter γ is set to 0.10, the average value of the import to GDP ratio in the period 1975:1 - 1989:4.[13]

4.2 Structural Slopes

Recall the general formulation (1) for the Phillips curves in the model, $\pi_t = \beta E_t \pi_{t+1} + \alpha(\gamma)\tilde{y}_t + \alpha^*(\gamma)\tilde{y}_t^* + \chi_t(\gamma)$. We now look at the effects of globalization on the slope parameter α and state the following

Result 1: If $\sigma\eta > 1$, the slope of the Phillips curve (both for domestic and CPI inflation) is monotonically *decreasing* in γ (with $\gamma \in (0; \frac{1}{2})$). The result holds with PCP, LCP and DDP.

This is the main qualitative result. Figures 2 and 3 plot the structural slopes of the domestic and CPI Phillips curves, $\alpha = \lambda\kappa$ and $\alpha = (1-\gamma)\lambda\kappa$ respectively, as a function of the openness parameter γ. For *domestic* inflation, all the action takes place in κ. Globalization makes the slope smaller through its effects on the sensitivity of marginal costs with respect to output. The intuition is similar as before: as γ increases, the required terms of trade adjustment following an output change gets smaller and smaller (in equation (28), the elasticity of s_t with respect to relative output is decreasing in γ). With this configuration of parameters ($\sigma\eta > 1$), this implies a decreasing response of marginal costs to output. The Phillips curve thus becomes *flatter*. For *CPI* inflation, the slope includes an additional term $1 - \gamma$, which reflects the "CPI weight" and is obviously decreasing in γ. The $\sigma\eta > 1$ condition is now sufficient but not necessary for the slope to be decreasing in γ. Indeed, the result is robust to different reasonable parametrizations.

When γ ranges from 0.1 to 0.2, the slope of the domestic Phillips curve ranges from 0.56 to 0.53, while the slope of the CPI Phillips curve decreases from 0.5 to 0.43. To have a sense of how these changes translate into differences in the dynamics of the model, Figure 4 compares the responses of inflation and output to a domestic (one standard deviation) monetary shock for $\gamma = 0.1$ and $\gamma = 0.2$. The responses are virtually

---

[13]Output is the HP-filtered quarterly real GDP series, while inflation is given by $400 \times (\ln CPI_t / \ln CPI_{t-1})$. Data is taken from the FRED Economic database maintained by the Federal Reserve Bank of St. Louis. The sample is 1975:1 - 2004:4.

indistinguishable, and this is true for all three pricing assumptions. Thus, in this range, the impact of increased openness is quantitatively very modest. Note by comparing Figures 2 and 3 that this is mostly because of the limited effect of γ on κ, which is captured by the relation between γ and the slope of the domestic Phillips curve. Indeed, this slope hardly changes with γ even for larger values of the latter.

4.3 The Role of Foreign Output Gap

We now turn to the effects of globalization on the foreign output gap coefficient.

Result 2: If $\sigma\eta < 1$ the structural coefficient on the foreign country's output gap is *increasing* in γ. Under the chosen parametrization the coefficient is increasing in γ with $\sigma\eta > 1$ too. The result holds with PCP, LCP and DDP.

Figure 5 shows the coefficient $\alpha^* = \gamma\lambda\kappa$ as a function of γ. When $\sigma\eta$ is less than 1, the elasticity κ increases with γ, and so does α^*. However, this positive association is also preserved with $\sigma\eta > 1$ (which we argued is the relevant case) given the chosen values for the other parameters. Importantly, this qualitative result is once again robust to different calibrations.[14] Given that κ is decreasing in γ for $\sigma\eta < 1$, the result is mostly driven by the direct impact of γ on α^*.

In the $(0.1, 0.2)$ range for γ, α^* changes from 0.06 to 0.11. The model thus predict an increased role for foreign measures of slack as a consequence of increased openness (and according to Result 1, this is happening at the expense of the domestic output gap, at least qualitatively). However, domestic factors still remain the main determinants of inflation.

As a check on the robustness of these results, Figure A.1 in the Appendix plots the slopes of domestic and CPI Phillips curves and the coefficients on the foreign output gaps as a function of openness, for alternative values of σ and η. The basic qualitative and quantitative conclusions are confirmed under these different calibrations.

4.4 Shift Terms

Going back again to the general specification $\pi_t = \beta E_t \pi_{t+1} + \alpha(\gamma)\tilde{y}_t + \alpha^*(\gamma)\tilde{y}_t^* + \chi_t(\gamma)$, we now look at how globalization affects the volatility of the χ_t terms.

Result 3: The variance of the Phillips curves' shift terms is *increasing* in γ. The result holds with PCP, LCP and DDP.

We recall that this is the aspect of the model's Phillips curves where the export-pricing scenarios make a difference. Depending on the assumption, CPI Phillips curves have endogenous shifters that depend on fluctuations of the exchange rate and/or the domestic-currency relative to foreign-currency prices of imports. Figure 6 plots $Var(\chi_t)$ as a function of γ for the PCP, LCP and DDP assumptions. The positive relation between the variance of endogenous shocks to the Phillips curves and openness holds in all cases, but while the increase is comparable for PCP and LCP in the relevant range, it is notably less pronounced for DDP: an increase in γ amplifies the implied variance of z_t to a smaller extent in the DDP vs. the LCP version of the model. Moreover, as reported in Table 1, the coefficient on z_t is always larger in the former case.

As a further assessment of the quantitative relevance of globalization, Figure 7 plots the responses of inflation and output to a foreign monetary shock, again for $\gamma = 0.1$ and $\gamma = 0.2$. The effects on the dynamic responses are not substantial, especially for inflation. This is particularly true with DDP.

---

[14]It can be shown that, if $\sigma \geq 1$, the derivative of α^* with respect to γ is positive regardless of the value η and the other parameters.

4.5 Empirical Phillips curves

Figure 8 reports the coefficient $\alpha(\gamma)$ in the "New" Keynesian specification (30) for the three pricing assumptions, along with the structural slope $(1-\gamma)\lambda\kappa$. The coefficient results from an OLS regression of $\pi_t - \beta E_t\pi_{t+1}$ (where $E_t\pi_{t+1}$ are model-consistent expectations) on $\tilde{y}_t$, the theoretical measure for the domestic output gap. This exercise thus compares the model's predictions to those of an (intentionally) misspecified relation, showing the results we would obtain if we had available the "correct" measures of output gap and inflation expectations and were to run this simpler regression with the model as the "true" data generating process. The regression coefficient is computed using the relevant variables' covariances and variances, which vary across the three different versions of the model. The qualitative findings are by and large confirmed. We observe some difference in the level of the estimated slopes relative to the structural coefficient, especially for PCP and DDP, and this is due to the correlation of the domestic output gap with the variables we are omitting. The negative but weak relationship between openness and the slope in the relevant range for γ, however, continues to hold with this specification in all cases (with DDP, α decreases from 0.58 to 0.53).

We then ask the same question when the Phillips curve is as in (31). Now, the relation is further misspecified in that we are not using the correct measurements of the variables. Figure 9 plots the coefficients $\alpha(\gamma)$ we obtain when we run this regression: the effect of globalization on the slope is now harder to detect, especially for LCP and DDP. The value of the coefficient in the latter case is basically constant at just below 0.2. Interestingly, this is in line with the estimated value in Ball (2006), who uses an analogous specification. Figure 10 reports the mean value of the coefficient, along with the 5th and 95th percentile, over several simulated economies for the DDP version of the model: small sample uncertainty is substantial and dominates any detected change of the slope as a function of γ.[15] If DDP is a reasonable assumption for US data, this result would lead to conclude that increased openness played a very little role (or no role at all) in flattening US Phillips curves. Given the model's prediction, this implies that, if anything, a specification like (31) tends to *understate* the effects of globalization. These effects, however, are small to start with and thus hard to uncover in a limited sample.

Finally, Figure 11 reports the coefficients $\alpha(\gamma)$ and $\alpha^*(\gamma)$ for the specification in (32). Recall that the way the foreign output gap $\tilde{y}_t^*$ affects inflation in the model's Phillips curve is rather mechanical, and mainly depends on the direct impact of γ. However, foreign output y_t^* has an effect on inflation also through the domestic output gap. Here, we run a more "reduced-form" regression on domestic and foreign output and assess whether the resulting implications are similar. We still find a positive relationship between openness and the coefficient on y_t^* especially for DDP. On the other hand, the coefficient on y_t is not greatly affected by the inclusion of foreign output (compare the upper panel of Figure 11 to Figure 9). In the relevant range for γ, the coefficients look similar across the three versions of the model.[16] Overall, the empirical specification confirms the increased role of foreign output and the prevalence of domestic factors in explaining inflation dynamics.

4.6 The Contribution to the Debate

We conclude the discussion of the results by relating these findings to the three questions outlined earlier. The questions were framed in terms of different aspects of the model's Phillips curves, generally written as $\pi_t = \beta E_t\pi_{t+1} + \alpha(\gamma)\tilde{y}_t + \alpha^*(\gamma)\tilde{y}_t^* + \chi_t(\gamma)$.

    1. *Has globalization lowered long-run inflation?*

---

[15] The 95% bands are based on 1000 simulations of the model with sample size T=120.

[16] One possible exception is the coefficient on y_t^* with LCP, which is predicted to be considerably lower in this range.

We find $\frac{\partial \alpha}{\partial \gamma} < 0$. Rogoff's political-economy argument for a lower equilibrium inflation rests on the premise that globalization should make Phillips curves *steeper*. The model instead predicts the globalization makes Phillips curves *flatter*. Recall that the slope parameter α has three components: First, one that is directly related to openness $(1-\gamma)$. Second, a factor that depends on the degree of price stickiness (λ). Third, a component that relates marginal costs to output (κ). Rogoff's argument relies on increased competition making wages and prices more flexible: that is, globalization affects the slope of Phillips curve by affecting λ. The model in this paper has nothing to say about this channel, but argues that openness lowers marginal costs' sensitivity to domestic output: globalization affects the slope by affecting κ.

In this sense, the analysis in Sbordone (2007) can be regarded as complementary to ours and looks at a channel that is more directly related to the argument above. Her paper studies the slope-openness relation in a model with non-constant elasticity of demand. More specifically, increased openness is related to an increase in the variety of traded goods, which impacts the degree of competition. In turn, this affects the demand elasticity and ultimately the firms' markups. This feature introduces real rigidities in pricing and has an effect on the relation between inflation and marginal costs (i.e. the parameter λ in our model). Sbordone argues that it's not clear whether globalization increases or decreases the slope through this mechanism and finds that the effect is not quantitatively relevant in either direction.

2. Has globalization affected the short-run dynamics of inflation?

We find $\frac{\partial \alpha}{\partial \gamma} < 0$ and $\frac{\partial \alpha^*}{\partial \gamma} > 0$. The *qualitative* prediction of the model is that more openness leads to an increased role for global factors at the expense of domestic factors. This prediction parallels the results in Borio and Filardo (2007). Differently from their analysis, though, we have shown that, *quantitatively*, globalization has a modest role in the flattening of Phillips curves. Moreover, and importantly, domestic conditions still retain the lion's share in determining inflation. Overall, globalization only slightly impacts the structural short-run dynamics of inflation as summarized by open-economy Phillips curves.

3. Has globalization been a source of shocks to inflation?

We find $\frac{\partial Var(\chi_t)}{\partial \gamma} > 0$. Globalization magnifies the volatility of the endogenous shift terms to the model's Phillips curves, though the increase is less evident with DDP. Under PCP, when the LOP holds for both domestic and foreign goods, these terms reflect the impact on inflation of full pass-through of exchange rate fluctuations into import prices. Under LCP and DDP, the short run pass-through is partial, and this is reflected in deviations from the LOP that enter both import prices and the marginal costs of firms. Interestingly, the DDP scenario limits the effects of globalization through this channel. This is a relevant result for the US and, for that matter, any country whose currency is used to price most imports and exports.

5   Exchange rate pass-through

It's a well established empirical observation that exchange rate fluctuations are not fully passed through into import and consumer prices. For example, Campa and Goldberg (2005) estimate short-run (within one quarter) pass-through elasticities into aggregate import prices for 23 OECD countries and find an average value of about 46%. The US in particular ranks among the lowest, with a value around 25%. Pass-through increases with the time horizon, but it is in general still far from complete: long(er) run elasticities (cumulated over four quarters) for the same set of countries have an average value of about 64% (40% for the US). Moreover, there is some work that documents a substantial *decline* in pass-through for the US and other industrialized countries, comparing the 70s and 80s to the last decade. Olivei (2002) and Marazzi and Sheets (2007) explore some potential explanations for this development, such as shifting composition of imports and changes in the pricing behavior of exporters. More related to the questions in this paper, Gust

et al. (2010) link declining pass-through to increased trade integration: strategic complementarities, lower trade costs and more competition interact to lower the sensitivity of prices to exchange rate fluctuations.

In this paper, imperfect pass-through is a consequence of sticky prices and local-currency pricing. Hence, it is solely a consequence of the behavior of exporters.[17] We abstract from any distribution sector or other intermediate steps between the dock and the final consumer, which would introduce local cost components into the price of imported goods. These have been shown to be potentially important explanations for imperfect exchange rate pass-through.[18]

We now turn to assessing the implications of the model for the short-run pass-through of exchange rate movements into aggregate import prices. While exchange rate pass-through is not a main focus of this paper, it is arguably an important check for the model, given its emphasis on export-pricing behavior. Moreover, it is interesting to look at pass-through magnitudes in a general equilibrium context. Figure 12 reports the coefficient of an OLS regression of $\pi_{F,t}$ on Δe_t as a function of γ, for the PCP, LCP and DDP versions of the model. While regressions in the empirical pass-through literature usually control for additional variables, mainly proxying for exporters' costs, we follow Gust et al. (2010), who find that results are similar with this simpler specification.[19] First, as expected, the degree of pass-through is much higher with PCP across the entire range of values for γ. Clearly, though, it is unrealistically high for the United States. Second, focusing on the DDP case, the values are line with empirical evidence for the US, being just above 20% when $\gamma \in (0.1, 0.2)$. Third, this pass-through measure is roughly constant as a function of γ (if anything, it is slightly increasing): increased openness doesn't seem to play a role, which is not consistent with the findings cited earlier. Note, however, that this model abstracts from the channels highlighted in Gust et al. (2010), which involve non-constant elasticities of demand that give rise to variable desired markups. Hence, in a way, this observation can be regarded as complementary to their results.

6   Conclusion

We have examined the role of globalization in affecting the determinants of inflation as described by open-economy Phillips curves in the context of a two-country New Keynesian model. Overall, we find support for the claims that the effects of globalization are quantitatively modest: increased openness only slightly decreases the slope of Phillips curves and while foreign factors have an increased role, domestic factors are still relatively more important. Globalization increases the volatility of shocks to the Phillips curves, but not to a large extent. This set of result is robust to different measures of inflation and different assumptions for the exporters' currency of choice.

The Dollar-dominant version of the model, which we argue is empirically relevant for the US, provides a reasonable approximation to empirical measures of short-run exchange rate pass-through into import prices, although LCP gives similar results. Moreover, we show that this peculiar position in terms of "vehicle currency" suggests a more muted impact of globalization on inflation beyond its effects through measures of slack: while the structural slopes of Phillips curves are invariant to currency choice assumptions, the variance of shocks to inflation (as measured by the Phillips curves' shift terms) is less sensitive to increased openness

---

[17]As an example of a different approach, Smets and Wouters (2002) and Monacelli (2005) (for a small open economy) introduce to a similar effect importing firms (local distributors) that set the domestic price of foreign goods in a staggered fashion, thus generating short run deviations from the LOP. In Monacelli (2005), the LOP is assumed to hold at the dock, which might be a good approximation for commodities (see e.g. Nakamura (2007) on the coffee industry) but not for most traded goods.

[18]See for example Corsetti and Dedola (2005), Hellerstein (2006) and Goldberg and Hellerstein (2007).

[19]Gust et al. (2010) actually use *relative* import prices and the *real* exchange rate to be consistent with their model. We instead use nominal variables in keeping with the cited empirical literature.

in the DDP version of the model.

Obvious *caveats* apply for the generality of these results. This study is purposely specific in isolating a potential channel for openness to affect inflation, and assessing its importance in the context of a stylized general equilibrium model which is widely used for policy analysis. Moreover, this is done taking into account the possibility of imperfect exchange rate pass-through, which is very much at the center of the debate in current open-macroeconomy research. There are sensible extensions that are worth pursuing: for example, introducing imported intermediate goods in production would likely allow for a richer interaction between the output-marginal cost channel and the determinants of imperfect pass-through, and thus between inflation and openness. More generally, it would be interesting to disentangle the concepts of openness and size of the countries, allowing for an element of asymmetry. This would likely matter in the discussion about currency choice.

References

[1] Adolfson, M., Laséen, S., Lindé, J. and M. Villani (2007), "Bayesian estimation of an open economy DSGE model with incomplete pass-through", *Journal of International Economics* 72(2): 481-511.

[2] Ball, L. (2006), "Has globalization changed inflation?", NBER WP #12687.

[3] Bean, C. (2006), "Globalisation and inflation", Bank of England Quarterly Bulletin 46 (4).

[4] Bernanke, B. (2007), "Globalization and monetary policy", Speech at the Fourth Economic Summit, Stanford Institute for Economic Policy Research, Stanford, CA.

[5] Betts, C. and M.B. Devereux (2000), "Exchange rate dynamics in a model of pricing-to-market", *Journal of International Economics* 50: 215-244.

[6] Bianchi, F. and A. Civelli (2010), "A structural approach to the globalization hypothesis for national inflation rates", Unpublished working paper.

[7] Bils, M. and P.J. Klenow (2004), "Some evidence on the importance of sticky prices", *Journal of Political Economy* 112(5): 947-985.

[8] Binyamini, A. and A. Razin (2007), "Flattened inflation-output tradeoff and enhanced anti-inflation policy as an equilibrium outcome of globalization", Honk Kong Institute for Monetary Research WP #23, December.

[9] Borio, C. and A. Filardo (2007), "Globalisation and inflation: New cross-country evidence on the global determinants of domestic inflation", Bank for International Settlements WP #227.

[10] Calvo, G. (1983), "Staggered prices in a utility-maximizing framework", *Journal of Monetary Economics* 12: 383-398.

[11] Campa, J.M. and L.S. Goldberg (2005), "Exchange rate pass-through into import prices", *Review of Economics and Statistics* 87(4): 679-690.

[12] Chari, V.V., Kehoe, P.J. and E.R. McGrattan (2002), "Can sticky price models generate volatile and persistence real exchange rates?", *Review of Economic Studies* 69: 533-563.

[13] Clarida, R., Gali, J. and M. Gertler (2002), "A simple framework for international monetary policy analysis", *Journal of Monetary Economics* 49: 879-904.

[14] Corsetti, G. and L. Dedola (2005), "A macroeconomic model of international price discrimination", *Journal of International Economics* 67: 129-155.

[15] Corsetti, G. and P. Pesenti (2005a), "International dimensions of optimal monetary policy", *Journal of Monetary Economics* 52(2): 281-305.

[16] Corsetti, G. and P. Pesenti (2005b), "The simple geometry of transmission and stabilization in closed and open economies", NBER WP #11341.

[17] Devereux, M.B. and C. Engel (2003), "Monetary policy in the open economy revisited: Price setting and exchange-rate flexibility", *Review of Economic Studies* 70: 765-783.

[18] Gali, J. and T. Monacelli (2005), "Monetary policy and exchange rate volatility in a small open economy", *Review of Economic Studies* 72: 707-734.

[19] Gamber, E.N. and J.H. Hung (2001), "Has the rise in globalization reduced U.S. inflation in the 1990s?", *Economic Inquiry* 39(2), 58-73.

[20] Goldberg, P.K. and R. Hellerstein (2007), "A framework for identifying the sources of local-currency price stability with an empirical application", NBER WP #13183.

[21] Gopinath, G., Itskhoki, O. and R. Rigobon (2008), "Currency choice and exchange rate pass-through", NBER WP #13432.

[22] Gopinath, G. and R. Rigobon (2008), "Sticky borders", *Quarterly Journal of Economics* 123(2): 531-575.

[23] Guerrieri, L., Gust, C. and J. D. Lopez-Salido (2010), "International competition and inflation: A New Keynesian perspective", *American Economic Journal: Macroeconomics* 2: 247-280.

[24] Gust, C., Leduc, S. and R.J. Vigfusson (2010), "Trade integration, competition, and the decline in exchange-rate pass-through", *Journal of Monetary Economics* 57: 309-324.

[25] Hellerstein, R. (2006), "A decomposition of the sources of incomplete cross-border transmission", Federal Reserve Bank of New York Staff Report No. 250.

[26] Ihrig, J., Kamin, S.B., Lindner, D. and J. Marquez (2007), "Some simple tests of the globalization and inflation hypothesis", International Finance Discussion Papers #891, Federal Reserve Board.

[27] International Monetary Fund (2006), "How has globalization changed inflation?", IMF World Economic Outlook, April.

[28] Kamin, S.B., Marazzi, M. and J.W. Schindler (2006), "The impact of Chinese exports on global import prices", *Review of International Economics* 14(2): 179-201

[29] Kohn, D.L. (2006), "The effects of globalization on inflation and their implications for monetary policy", Speech at the Federal Reserve Bank of Boston's 51st Economic Conference, Chatham, MA.

[30] Kohn, D.L. (2008), "Implications of globalization for the conduct of monetary policy", Speech at the International Symposium on "Globalisation, inflation and monetary policy", Bank of France, Paris.

[31] Lubik, T. and F. Schorfheide (2005), "A Bayesian look at new open economy macroeconomics", Economics Working Paper 521, Johns Hopkins University.

[32] Marazzi, M. and N. Sheets (2007), "Declining exchange rate pass-through to U.S. import prices: The potential role of global factors", *Journal of International Money and Finance* 26: 924-947

[33] McCallum, B.T. and E. Nelson (2000), "Monetary policy for an open economy: An alternative framework with optimizing agents and sticky prices", *Oxford Review of Economic Policy* 16(4): 74-91.

[34] Milani, F. (2009), "Global slack and domestic inflation rates: A structural investigation for G-7 countries", Mimeo, University of California, Irvine.

[35] Mishkin, F.S. (2008), "Globalization, macroeconomic performance, and monetary policy", NBER WP #13948.

[36] Monacelli, T. (2005), "Monetary policy in a low pass-through environment", *Journal of Money, Credit, and Banking* 37(6), 1047-1066.

[37] Nakamura, E. (2007), "Accounting for incomplete pass-through", Unpublished working paper.

[38] Obstfeld, M. and K. Rogoff (2000), "The six major puzzles in international macroeconomics: Is there a common cause?", *NBER Macroeconomics Annual* 15: 339-390

[39] Olivei, G.P. (2002), "Exchange rates and the prices of manufacturing products imported into the United States", *Federal Reserve Bank of Boston New England Economic Review*: 3-18

[40] Pain, N., Koske, I. and M. Sollie (2006), "Globalisation and inflation in the OECD economies", OECD Economics Department WP #524.

[41] Razin, A. and C. Yuen (2002), "The 'New Keynesian' Phillips curve: Closed economy versus open economy", *Economics Letters* 75: 1-9.

[42] Roberts, J. (2006), "Monetary policy and inflation dynamics", *International Journal of Central Banking* 2: 193-230.

[43] Rogoff, K. (2003), "Globalization and global disinflation", Paper prepared for the Federal Reserve Bank of Kansas City conference on "Monetary policy and uncertainty: Adapting to a changing economy", Jackson Hole, WY.

[44] Rogoff, K. (2006), "Impact of globalization on monetary policy", Paper prepared for the Federal Reserve Bank of Kansas City symposium on "The new economic geography: Effects and policy implications", Jackson Hole, WY.

[45] Sbordone, A. M. (2007), "Globalization and inflation dynamics: The impact of increased competition", NBER WP #13556.

[46] Sims, C.A. (2002), "Solving linear rational expectations models", *Computational Economics* 20(1-2): 1-20.

[47] Smets, F. and R. Wouters (2002), "Openness, imperfect exchange rate pass-through and monetary policy", *Journal of Monetary Economics* 49: 947-981.

[48] Steinsson, J. (2008), "The dynamic behavior of the real exchange rate in sticky price models", *American Economic Review* 98(1): 519-533.

[49] Taylor, J.B. (1993), "Discretion versus policy rules in practice", *Carnegie-Rochester Conference Series on Public Policy* 39: 195-214.

[50] Woodford, M. (2007), "Globalization and monetary control", NBER WP #13329.

[51] Wynne, M.A. and E.K. Kersting (2007), "Openness and inflation", Federal Reserve Bank of Dallas Staff Papers, April No.2.

[52] Yellen, J.L. (2006), "Monetary policy in a global environment", Speech at the Euro and the Dollar in a Globalized Economy Conference, UC Santa Cruz, Santa Cruz, CA.
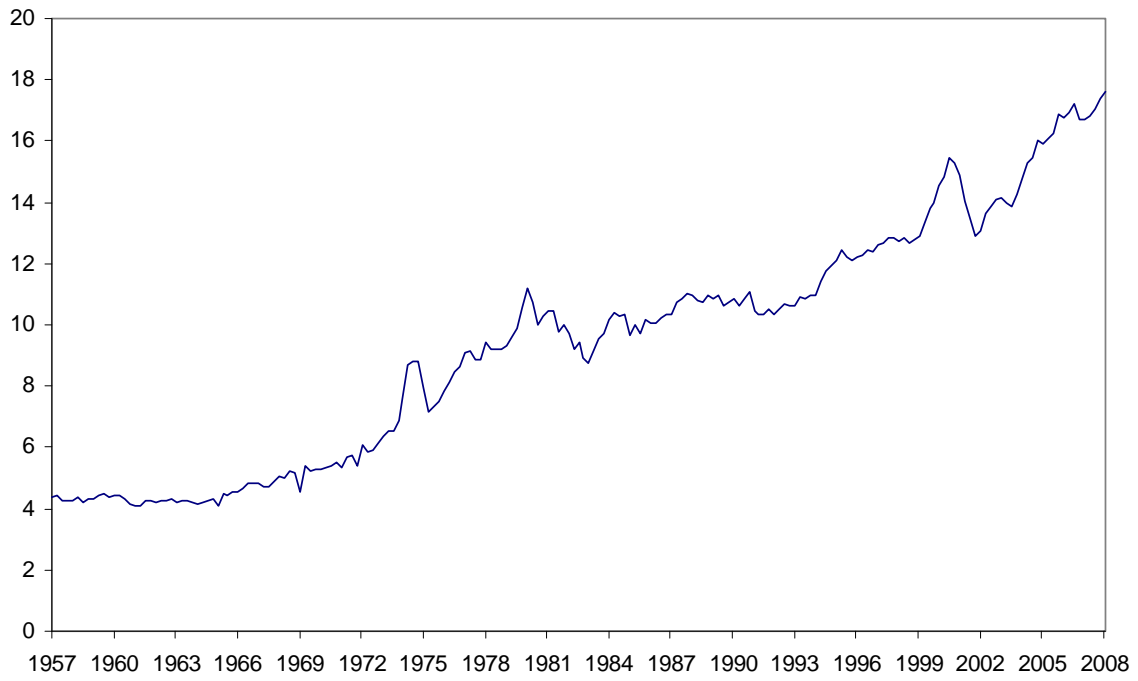
Figures

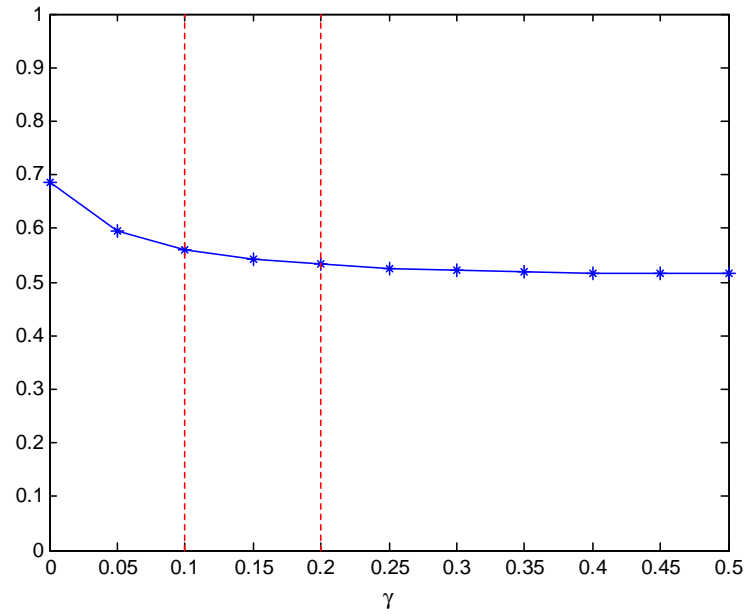Figure 1: Imports of goods and services (% GDP) (Source: IMF)

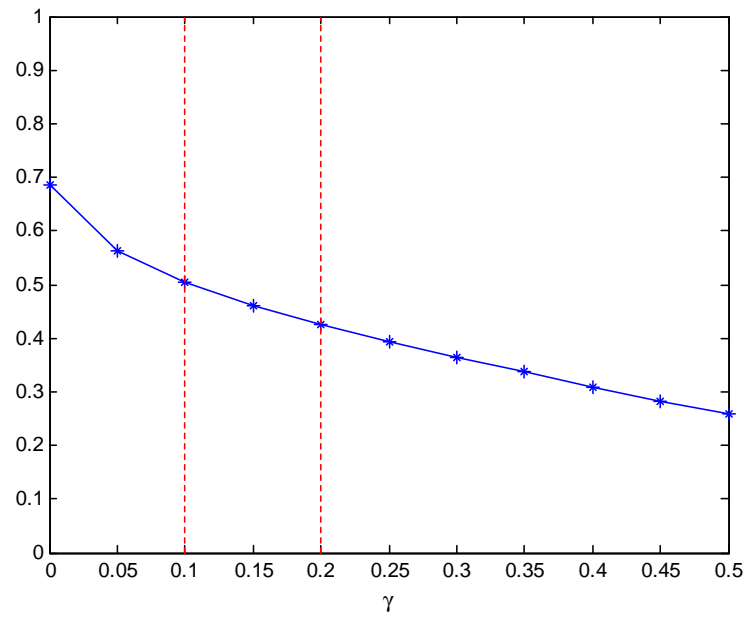Figure 2: Structural slope of domestic Phillips curve

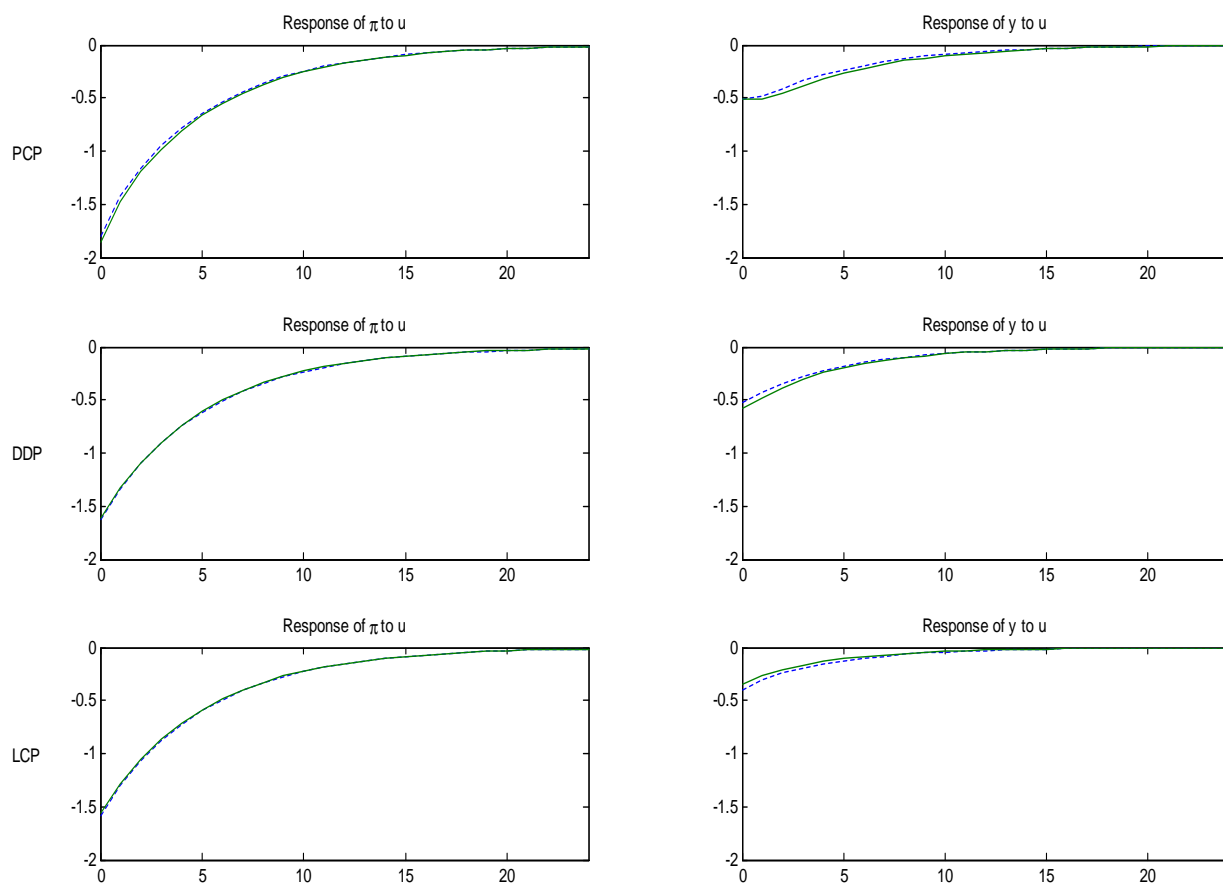Figure 3: Structural slope of CPI Phillips curve

Figure 4: Responses of inflation and output to a domestic monetary shock.

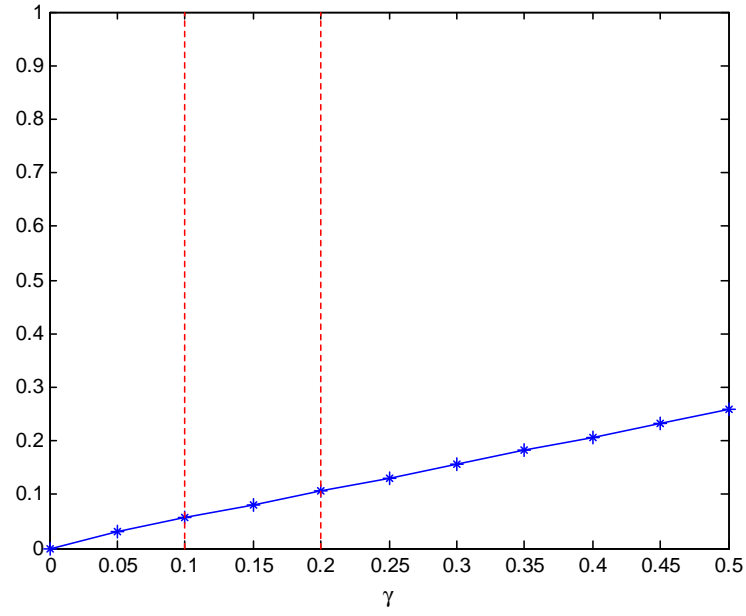Note: $\gamma = 0.1$ (Dashed line), $\gamma = 0.2$ (Solid line)

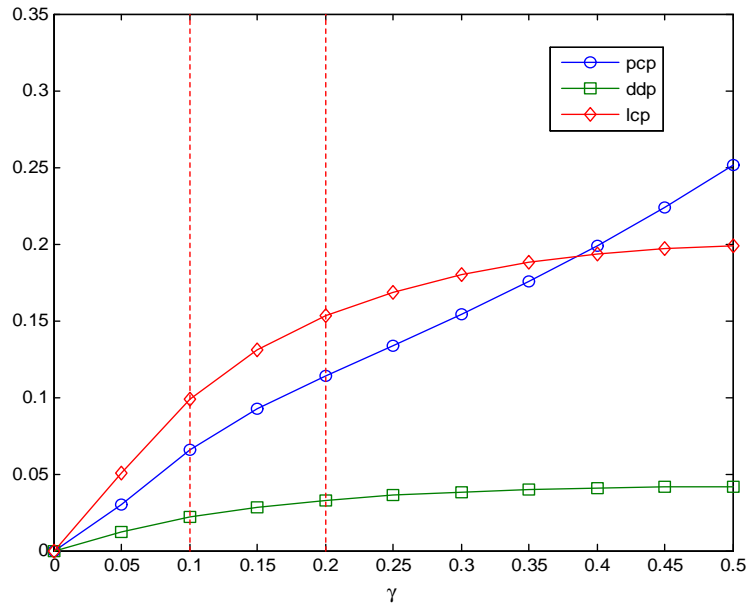Figure 5: Structural coefficient on foreign output gap

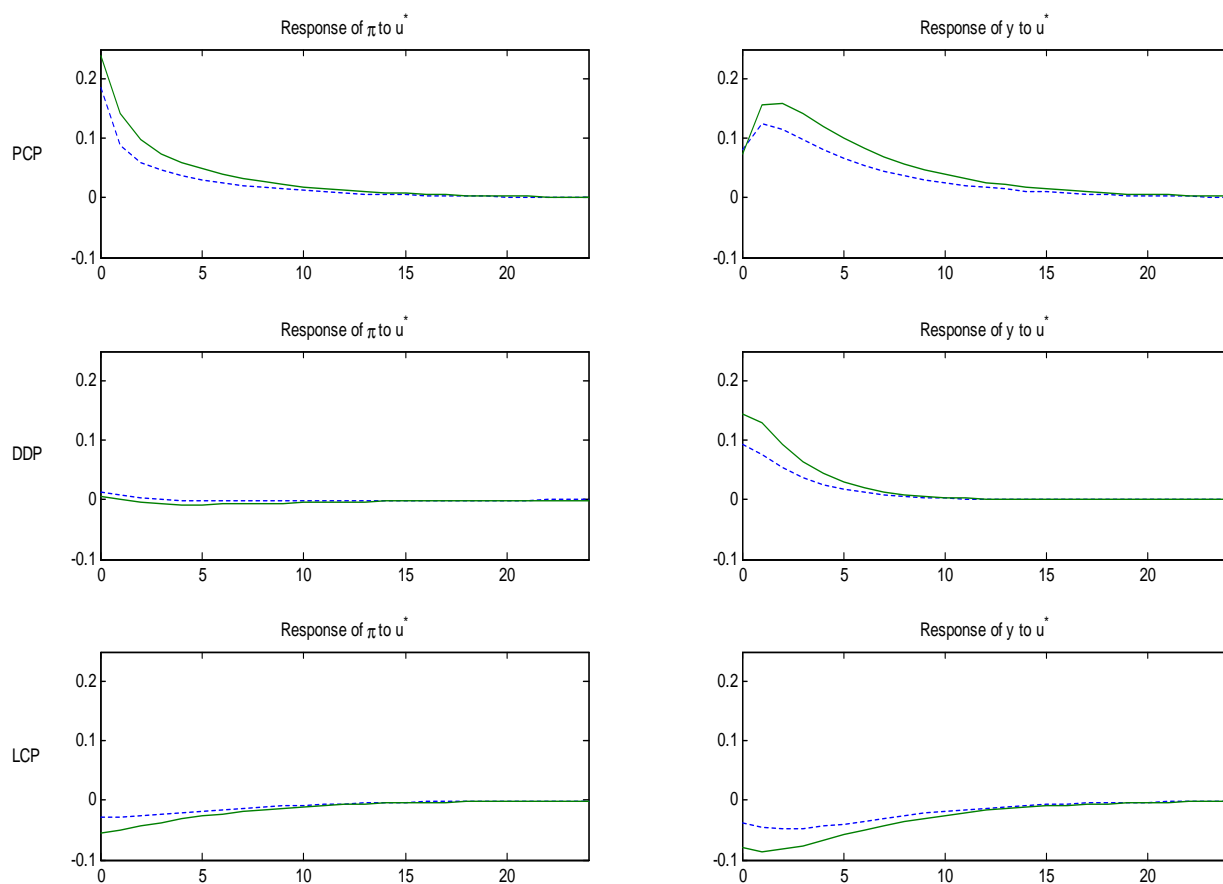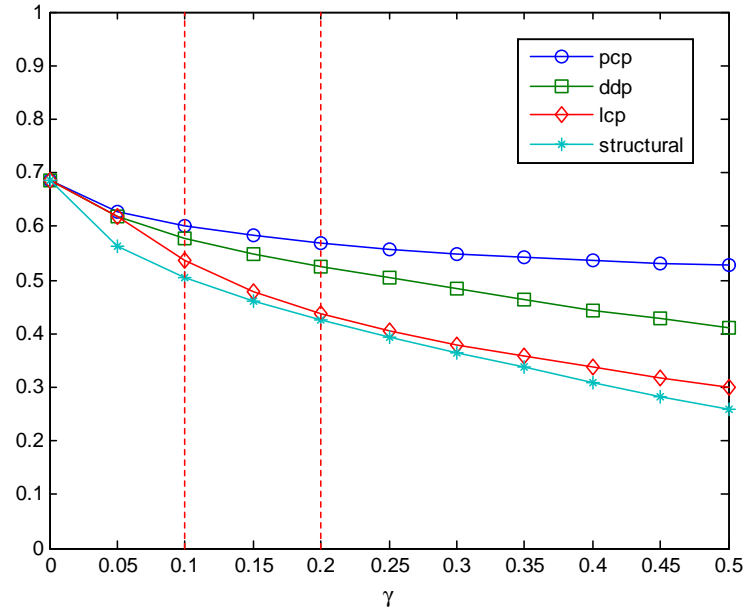Figure 6: Variance of CPI Phillips curves shifters

Figure 7: Responses of inflation and output to a foreign monetary shock.

Note: $\gamma = 0.1$ (Dashed line), $\gamma = 0.2$ (Solid line)

Figure 8: Slopes of "New" Keynesian Phillips curve
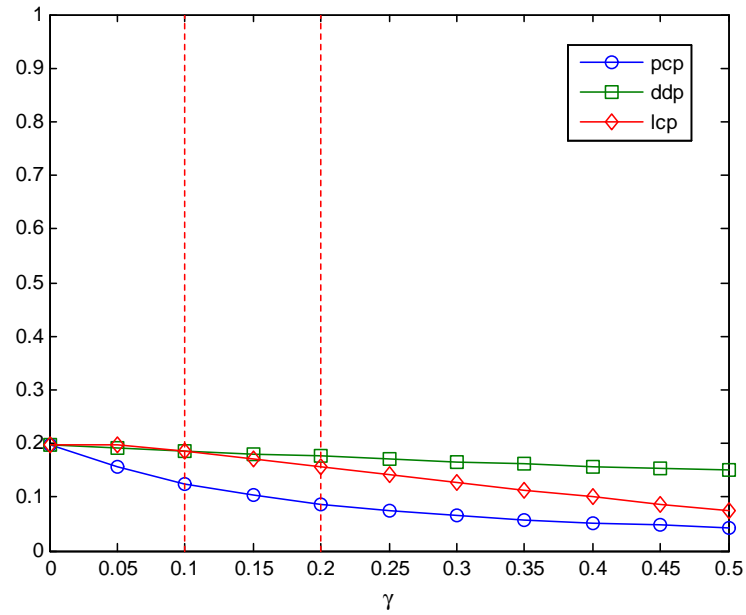
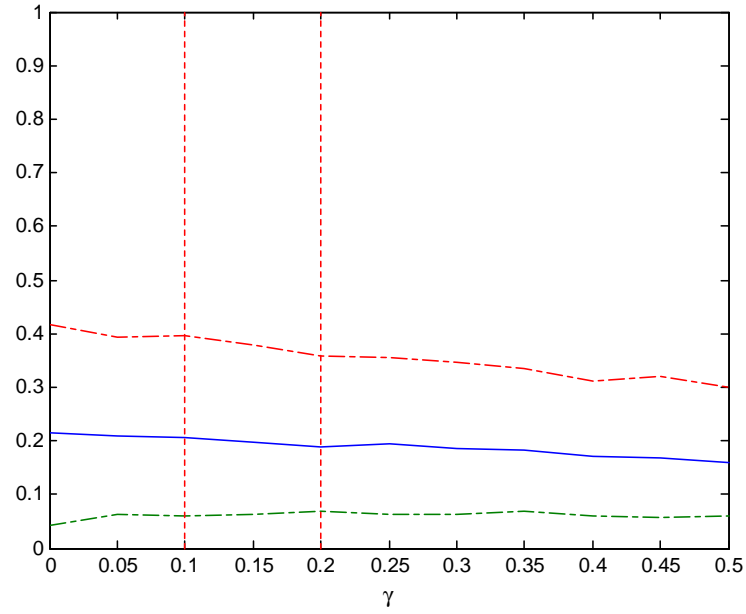

Figure 9: Slopes of Backward looking Phillips curve

Figure 10: Backward looking Phillips curve (DDP) - 5th and 95th percentile
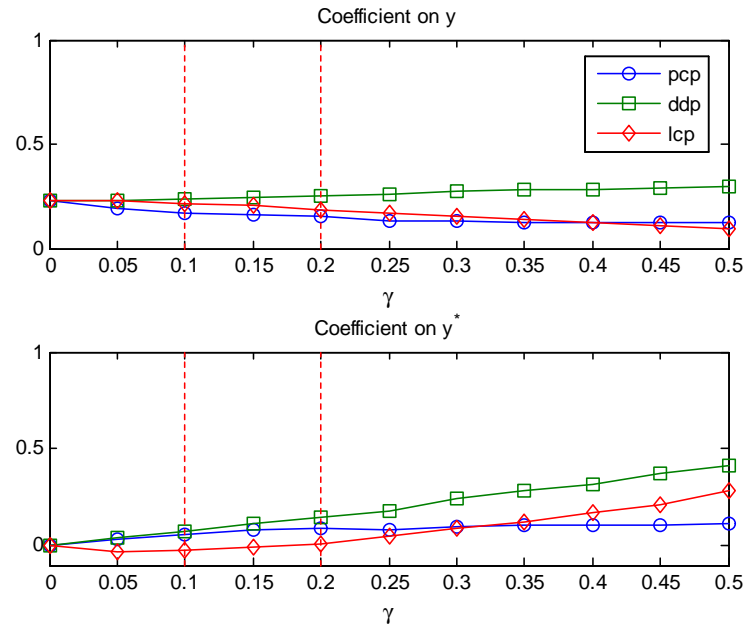

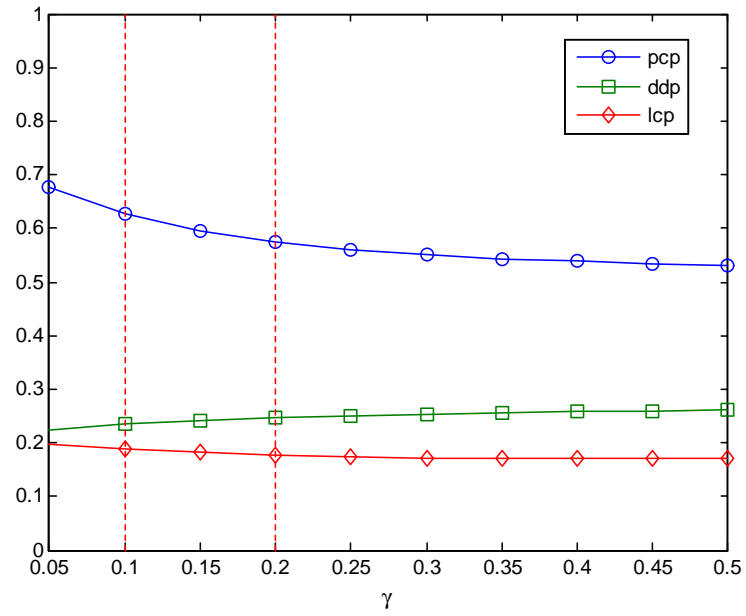Figure 11: Backward looking Phillips curve with domestic and foreign output

Figure 12: Regression of import prices on exchange rate

A Appendix

This Appendix provides additional derivations of relations in the main text

A.1 Aggregate Demand and Output

The representative household in country H maximizes (2) subject to (3). First order conditions with respect to consumption and assets give:

$$\rho_{t,t+1} = \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \left(\frac{P_t}{P_{t+1}} \right) \tag{A.1}$$

for each state or, taking expectations:

$$\frac{1}{R_t} = \beta E_t \left\{ \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \left(\frac{P_t}{P_{t+1}} \right) \right\} \tag{A.2}$$

(where $R_t = \frac{1}{E_t\{\rho_{t,t+1}\}}$ is the (gross) nominal interest rate, i.e. the return on the one-period discount bond). Labor supply is:

$$\frac{W_t}{P_t} = N_t^\phi C_t^\sigma \tag{A.3}$$

Similarly for the representative household in country F, given that the state-contingent assets are denominated in Home currency, the budget constraint reads:

$$P_t^* C_t^* + E_t \left\{ \rho_{t,t+1} \frac{D_{t+1}}{\mathcal{E}_{t+1}} \right\} = W_t^* N_t^* + \frac{D_t}{\mathcal{E}_t} + \Upsilon_t^*$$

First order conditions imply:

$$\rho_{t,t+1} = \beta \left(\frac{C_{t+1}^*}{C_t^*} \right)^{-\sigma} \left(\frac{P_t^*}{P_{t+1}^*} \right) \left(\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}} \right)$$

which, with (A.1), lead to

$$C_t = C_t^* Q_t^{\frac{1}{\sigma}} \tag{A.4}$$

where $Q = \frac{\mathcal{E}P^*}{P}$ is the real exchange rate, and we have assumed without loss of generality that the constant $\mathcal{E}_0 \left(\frac{C_0^{*\sigma}}{C_0^\sigma} \right) \left(\frac{P_0^*}{P_0} \right)$ is equal to 1. This is a typical international risk sharing condition, which predicts that relative consumption moves proportionally with the real exchange rate.

The model is log-linearized around a steady state where $P_H = P_F$ (and $P_H^* = P_F^*$) holds. Recall that the *terms of trade* in both countries are defined as

$$
\begin{aligned}
s_t &\equiv p_{F,t} - p_{H,t} \\
s_t^* &\equiv p_{H,t}^* - p_{F,t}^*
\end{aligned}
$$

Using the definitions (17) and (18), we can relate Home and Foreign terms of trade as

$$s_t = -s_t^* - (z_t + z_t^*) \tag{A.5}$$

which shows that if the LoP holds for both type of goods (so that $z_t = z_t^* = 0$), Home and Foreign terms of trade are just the inverse of one another.

The log-linear versions of the Home country CPI (6) and the Foreign counterpart are written as:

$$
\begin{aligned}
p_t &= (1-\gamma)p_{H,t} + \gamma p_{F,t} = p_{H,t} + \gamma s_t \tag{A.6} \\
p_t^* &= (1-\gamma)p_{F,t}^* + \gamma p_{H,t}^* = p_{F,t}^* + \gamma s_t^* \tag{A.7}
\end{aligned}
$$

Defining inflation rates as the first differences of the relevant price indices, it follows that:

$$\pi_t = (1-\gamma)\pi_{H,t} + \gamma\pi_{F,t} = \pi_{H,t} + \gamma\Delta s_t \tag{A.8}$$

$$\pi_t^* = (1-\gamma)\pi_{F,t}^* + \gamma\pi_{H,t}^* = \pi_{F,t}^* + \gamma\Delta s_t^* \tag{A.9}$$

The log real exchange rate is then

$$
\begin{aligned}
q_t &\equiv p_t^* + e_t - p_t \\
&= (1-2\gamma)s_t + (1-\gamma)z_t - \gamma z_t^* \tag{A.10}
\end{aligned}
$$

where we have used (A.6) and (A.7) with (A.5). Note that for Purchasing Power Parity (PPP) to hold in the model (so that $q_t = 0$), the LOP has to hold for both types of goods *and* the consumption baskets must be the same in H and F (i.e. $\gamma = \frac{1}{2}$, so that there is no home bias in preferences). The international risk sharing condition (A.4) then becomes

$$
\begin{aligned}
c_t &= c_t^* + \frac{1}{\sigma}q_t \\
&= c_t^* + \frac{1}{\sigma}[(1-2\gamma)s_t + (1-\gamma)z_t - \gamma z_t^*] \tag{A.11}
\end{aligned}
$$

Log-linearizing the Home demand functions $C_{H,t} = (1-\gamma)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta}C_t$ and $C_{F,t} = \gamma\left(\frac{P_{F,t}}{P_t}\right)^{-\eta}C_t$, and the Foreign counterparts yields:

$$c_{H,t} = -\eta(p_{H,t} - p_t) + c_t \qquad c_{F,t} = -\eta(p_{F,t} - p_t) + c_t$$

$$c_{F,t}^* = -\eta(p_{F,t}^* - p_t^*) + c_t^* \qquad c_{H,t}^* = -\eta(p_{H,t}^* - p_t^*) + c_t^*$$

The (log-linearized) market clearing conditions in the two countries are given by:

$$
\begin{aligned}
y_t &= (1-\gamma)c_{H,t} + \gamma c_{H,t}^* \\
y_t^* &= \gamma c_{F,t} + (1-\gamma)c_{F,t}^* \tag{A.12}
\end{aligned}
$$

Substituting in the demand functions (along with equations (A.6) and (A.7)), and using (A.11), we can write output in each country as a function of respective domestic aggregate consumption, the terms of trade and the deviations from the LOP, that is

$$y_t = c_t + \frac{2\omega + \gamma}{\sigma}s_t + \frac{\omega}{\sigma}z_t + \frac{\omega + \gamma}{\sigma}z_t^* \tag{A.13}$$

$$y_t^* = c_t^* - \frac{2\omega + \gamma}{\sigma}s_t - \frac{\omega}{\sigma}z_t - \frac{\omega + \gamma}{\sigma}z_t^* \tag{A.14}$$

We can subtract (A.14) from (A.13) (after using (A.11) again to eliminate c_t^*) to solve for the terms of trade as a function of relative output:

$$s_t = \frac{\sigma}{1+4\omega}(y_t - y_t^*) - \frac{2\omega + (1-\gamma)}{1+4\omega}z_t - \frac{2\omega + \gamma}{1+4\omega}z_t^*$$

which is equation (28) in the text. We can now write an aggregate demand equation for country H, combining (A.13) and (28):

$$c_t = \frac{2\omega + (1-\gamma)}{1+4\omega}y_t + \frac{2\omega + \gamma}{1+4\omega}y_t^* + \frac{\omega + \gamma(1-\gamma)}{\sigma(1+4\omega)}(z_t - z_t^*)$$

which is equation (29) in the text. The log-linearized Home Euler equation (A.2) reads

$$c_t = E_t c_{t+1} - \frac{1}{\sigma}(r_t - E_t \pi_{t+1})$$

Using (29), (A.8) and (28), we can write an IS-type relation in terms of output and domestic inflation:

$$y_t = E_t y_{t+1} - \frac{1}{\sigma_0}(r_t - E_t \pi_{H,t+1}) + \frac{2\omega}{1+2\omega} E_t \Delta y_{t+1}^* + \frac{(1-2\gamma)\omega}{\sigma(1+2\omega)} E_t \Delta z_{t+1} - \frac{(1+2\gamma)\omega + \gamma}{\sigma(1+2\omega)} E_t \Delta z_{t+1}^* \quad \text{(A.15)}$$

where we recall that $\sigma_0 = \frac{\sigma(1+2\omega)}{1+4\omega}$ and $\omega = \gamma(1-\gamma)(\sigma\eta - 1)$.

A corresponding IS curve is derived for country F, following similar steps. Here we just highlight that we can write the log-linear consumption Euler equation as

$$c_t^* = E_t c_{t+1}^* - \frac{1}{\sigma}(r_t^* - E_t \pi_{t+1}^*)$$

where we have used $r_t^* = r_t - E_t \Delta e_{t+1}$, an approximate version of the uncovered interest parity (UIP). The resulting Foreign IS curve is

$$y_t^* = E_t y_{t+1}^* - \frac{1}{\sigma_0}(r_t^* - E_t \pi_{F,t+1}^*) + \frac{2\omega}{1+2\omega} E_t \Delta y_{t+1} + \frac{(1-2\gamma)\omega}{\sigma(1+2\omega)} E_t \Delta z_{t+1}^* - \frac{(1+2\gamma)\omega + \gamma}{\sigma(1+2\omega)} E_t \Delta z_{t+1} \quad \text{(A.16)}$$

A.2 Phillips Curves and Marginal Costs

With PCP, the exporter in country F solves

$$\underset{X_F^*}{Max} \quad E_t \sum_{j=0}^{\infty} \theta^j \rho_{t,t+j} \left(X_F^* - MC_{t+j}^* P_{F,t+j}^* \right) C_{F,t+j}(i)$$

where $MC_t^* = \frac{(W_t^*/P_{F,t}^*)}{A_t^*}$. The first order conditions for this problem are:

$$E_t \sum_{j=0}^{\infty} \theta^j \rho_{t,t+j} \left(X_{F,t}^* - \frac{\varepsilon}{\varepsilon - 1} MC_{t+j}^* P_{F,t+j}^* \right) C_{F,t+j}(i) = 0 \quad \text{(A.17)}$$

The log-linear optimal reset price in Foreign currency is thus given by:

$$x_{F,t}^* = (1 - \theta\beta) E_t \sum_{j=0}^{\infty} (\theta\beta)^j (p_{F,t+j}^* + mc_{t+j}^*) \quad \text{(A.18)}$$

The aggregate $p_{F,t}^*$ can be written as:

$$p_{F,t}^* = (1 - \theta) \sum_{i=0}^{\infty} \theta^i x_{F,t-i}^*$$

What is the relation between $p_{F,t}^*$ and $p_{F,t}$? At time t, each $x_{F,t-i}^*$ is converted to Home currency by $x_{F,t-i}^* + e_t$, so

$$\begin{aligned} p_{F,t} &= (1 - \theta) \sum_{i=0}^{\infty} \theta^i (x_{F,t-i}^* + e_t) \\ &= p_{F,t}^* + e_t \end{aligned}$$

and $\pi_{F,t} = \pi_{F,t}^* + \Delta e_t$, as in (20).

With LCP, the exporter in country F solves

$$\underset{X_F}{Max} \quad E_t \sum_{j=0}^{\infty} \theta^j \rho_{t,t+j} \left(\frac{X_{F,t}}{\mathcal{E}_{t+j}} - MC^*_{t+j} P^*_{F,t+j} \right) C_{F,t+j}(i)$$

The first order conditions read:

$$E_t \sum_{j=0}^{\infty} \theta^j \rho_{t,t+j} \left(\frac{X_{F,t}}{\mathcal{E}_{t+j}} - \frac{\varepsilon}{\varepsilon - 1} MC^*_{t+j} P^*_{F,t+j} \right) C_{F,t+j}(i) = 0 \qquad (A.19)$$

Log-linearization of (A.19) gives:

$$
\begin{aligned}
x_{F,t} &= (1-\theta\beta)E_t \sum_{j=0}^{\infty} (\theta\beta)^j (p^*_{F,t+j} + mc^*_{t+j} + e_{t+j}) \\
&= (1-\theta\beta)E_t \sum_{j=0}^{\infty} (\theta\beta)^j (p_{F,t+j} + mc^*_{t+j} + z_{t+j}) \qquad (A.20)
\end{aligned}
$$

where we have used the definition of z_t in (17). Combining (A.20) with $p_{F,t} = \theta p_{F,t-1} + (1-\theta)x_{F,t}$ yields the following:

$$\pi_{F,t} = \beta E_t \pi_{F,t+1} + \lambda mc^*_t + \lambda z_t$$

which is country H's import inflation Phillips curve under LCP and DDP (equation (22) in the text).

Note that using (A.18) and (A.20) gives[20]:

$$x_{F,t} = x^*_{F,t} + (1-\theta\beta)E_t \sum_{j=0}^{\infty} (\theta\beta)^j e_{t+j}$$

which implies that the following relationship now holds between $p^*_{F,t}$ and $p_{F,t}$:

$$p_{F,t} = p^*_{F,t} + (1-\theta) \sum_{i=0}^{\infty} \theta^i e^W_{t-i}$$

where $e^W_t \equiv (1-\theta\beta)E_t \sum_{j=0}^{\infty} (\theta\beta)^j e_{t+j}$ (Note that when $\theta \to 0$, $e^W_t = e_t$ and the above reduces to $p_{F,t} = p^*_{F,t} + e_t$). The expression for z_t implied by this model of pricing is thus:

$$z_t = e_t - (1-\theta) \sum_{i=0}^{\infty} \theta^i e^W_{t-i}$$

as in equation (19) in the text (an analogous equation for z^*_t is derived solving the pricing problem of exporters in country H).

We now derive real marginal costs as a function of output. We have:

$$
\begin{aligned}
mc_t &= w_t - p_{H,t} - a_t \\
&= w_t - p_t + \gamma s_t - a_t \\
&= \phi n_t + \sigma c_t + \gamma s_t - a_t
\end{aligned}
$$

where we have used (A.6) and the linearized version of (A.3). To substitute for n_t, we approximate the aggregate production function with $y_t = a_t + n_t$, which holds up to first order. Thus, real marginal costs can generally be written as

$$mc_t = -(1+\phi)a_t + \phi y_t + \sigma c_t + \gamma s_t$$

---

[20] This replicates the result in Gopinath, Itskhoki and Rigobon (2007) when the exchange rate is a random walk, as is assumed there.

and we eliminate c_t and s_t using (29) and (28) to obtain:

$$mc_t = -(1 + \phi)a_t + (\phi + \sigma_0)y_t + (\sigma - \sigma_0)y_t^* + \frac{(1 - 2\gamma)\omega}{1 + 4\omega}z_t - \frac{(1 + 2\gamma)\omega + \gamma}{1 + 4\omega}z_t^* \qquad (A.21)$$

In the equilibrium under flexible prices, $z_t = z_t^* = 0$ and prices chosen by firms in each period are the usual markup over the relevant marginal cost. This implies that real marginal cost is *constant* and equal to the inverse of the markup. In log-linear terms we then have

$$\overline{mc} = -(1 + \phi)a_t + (\phi + \sigma_0)y_t + (\sigma - \sigma_0)y_t^* = 0$$

which can be solved for y_t to obtain the *flexible-price (natural) level of output* (equation (26)):

$$\bar{y}_t = \frac{1}{\phi + \sigma_0}[(1 + \phi)a_t - (\sigma - \sigma_0)y_t^*]$$

Finally, we define the domestic output gap $\tilde{y}_t \equiv y_t - \bar{y}_t$ and derive the general expression for real marginal costs as a function of $\tilde{y}_t$ (equation (25)):

$$mc_t = \kappa\tilde{y}_t + \frac{(1 - 2\gamma)\omega}{1 + 4\omega}z_t - \frac{(1 + 2\gamma)\omega + \gamma}{1 + 4\omega}z_t^*$$

where $\kappa = \phi + \sigma_0$. This general formulation is then specialized according to the pricing assumption. Under PCP, $z_t = z_t^* = 0$, so:

$$mc_t = \kappa\tilde{y}_t \qquad (A.22)$$

Under LCP, $z_t^* = -z_t$, so we write everything in terms of z_t only:

$$mc_t = \kappa\tilde{y}_t + \frac{2\omega + \gamma}{1 + 4\omega}z_t \qquad (A.23)$$

Finally, under DDP, $z_t^* = 0$, so:

$$mc_t = \kappa\tilde{y}_t + \frac{(1 - 2\gamma)\omega}{1 + 4\omega}z_t \qquad (A.24)$$

These expressions for domestic marginal costs (and analogous ones for the foreign counterparts) are combined with the relevant Phillips curves to obtain the equations reported in Table 1.

A.3   Solving the model

In solving the model, we use the following equations (appropriately specialized for the different pricing assumptions, when applicable): the IS curves (A.15) and (A.16); the Taylor rules determining r and r^*; the Phillips curves for π_H and π_F^* written in terms of output; the corresponding equations for π and π^*, using (A.8) and (A.9); the Phillips curve for π_F; an equation that links π_H and π_F using the expression for the terms of trade (28); finally, for LCP and DDP, the definition of z. Given initial conditions, these equations and the specifications for the exogenous shocks determine a fully specified model that can be solved for the endogenous variables $\pi_{H,t}, \pi_t, y_t, r_t, \pi_{F,t}^*, \pi_{F,t}, \pi_t^*, y_t^*, r_t^*, e_t$, (and z_t in the relevant cases). We do so following Sims (2001).
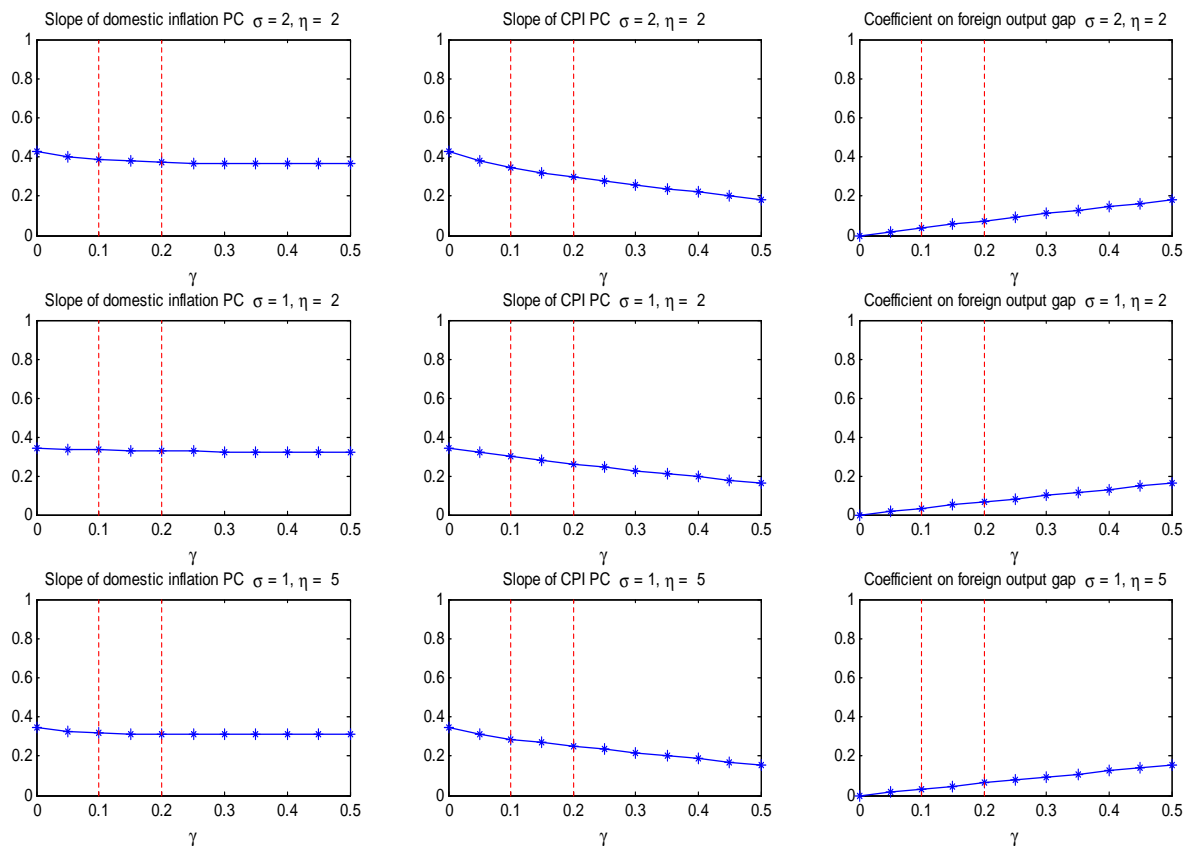
Figure A.1: Sensitivity of the relation between γ and the slopes of domestic/ CPI Phillips curves and the coefficient on foreign output gap, for different parametrizations of σ and η