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Pierpaolo Benigno and Ester Faia

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Pierpaolo Benigno* and Ester Faia**

Abstract

An important aspect of the globalization process is the increase in interdependence among countries through the deepening of trade linkages. This process should increase competition in each destination market and change the pricing behavior of firms. We present an extension of Dornbusch (1987)'s model to analyze the extent to which globalization, interpreted as an increase in the number of foreign products in each destination market, modifies the slope and the position of the New-Keynesian aggregate-supply equation and, at the same time, affects the degree of exchange rate pass-through. We provide empirical evidence that supports the results of our model.

Keywords: AS equations; Oligopolistic Competition; Inflation Dynamic
JEL classification: E31, F41

***Professor, LUISS Guido Carli and EIEF (E-mail: pbenigno@luiss.it)
****Professor, Goethe University Frankfurt, Kiel IfW and CEPREMAP (E-mail: faia@wiwi.uni-frankfurt.de)

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1 Introduction

The increased interdependence among countries through the deepening of trade linkages in goods and financial assets, spurred by the so-called process of globalization, has attracted the attention of economists and policy makers. One important theme, which has been the subject of considerable discussion, has been the 'global slack' hypothesis, namely the increased dependence of inflation dynamics on global factors rather than just on domestic economic activity.[1]

This paper focuses on two channels through which globalization affects inflation dynamics. First, we ask how globalization, interpreted as an increase in the presence of foreign goods in the domestic market, affects the pass-through of foreign marginal costs and the exchange rate into import prices, through its influence on the degree of competition. As a large fraction of consumption and intermediate goods is represented by imported goods, the overall price index becomes more sensitive to external conditions, namely the combined dynamic of nominal exchange rate and foreign marginal costs.[2] The second channel through which globalization influences the dynamic of inflation is, indirectly, through its effect on the pricing strategies of domestic firms selling in the internal market. The latter channel affects the slope and the position of the aggregate-supply equation.

To address these issues we extend the Dornbusch's [16] model to a dynamic context with price stickiness. Domestic and foreign firms compete in a strategic way to increase their market shares through their pricing decisions. In this context, the mark-up is a function of a firm's market share, which in turn is a function of competitors' prices and marginal costs. Hence domestic and foreign marginal costs affect each other through their influence on firms' market shares and mark-ups.

We study the implications of this model for the exchange-rate pass-through and the dynamic of prices set by foreign and domestic firms in the domestic market.

On the one side, we show that the degree of exchange-rate pass-through depends on the degree of concentration in the market and in particular on the share of foreign products in the market. Greater competition, due to the increase in the share of foreign products sold in a specific industry – a phenomenon strongly connected to globalization – raises the degree of exchange-rate pass-through, both in the short and the long run. Through this channel, globalization amplifies the dependence of inflation for imported goods upon external conditions. Our theoretical results are confirmed through an empirical analysis

[1] See among others Bernanke [4], Borio and Filardo [7], Fisher [18], Rogoff [31].

[2] Globalization also implies that agents have access to a larger variety of goods, due to the increase in the intensity of trade and in the number of trading partners. We do not explore this additional dimension.

based on manufacturing sectors in the US. Indeed, there is evidence of an increase in the degree of exchange rate pass-through exactly at the time in which the globalization process took place.

On the other side, our framework has important implications for the reduced form of the New-Keynesian Phillips curve. The Phillips curve of our model is augmented by a link between domestic inflation and the market share of domestic firms, with the latter proxied by the relative price of foreign versus domestic products. This channel reflects the strategic competition in pricing between domestic and foreign firms, which influences directly the inflation dynamic of domestic firms, even when domestic marginal costs do not vary. The presence of foreign prices into the new augmented Phillips curve creates a link between domestic inflation and foreign marginal costs, which in turn is connected to the foreign output gap. This is the essence of the 'global-slack' hypothesis.

In traditional open economy models, domestic real marginal costs are affected by terms of trade (see Benigno and Benigno [3]) which can shift the Phillips curve for given domestic output gap. This channel runs as follows. When foreign prices decrease and terms of trade improve, there are inflationary pressure on domestic prices. This shifts the Phillips curve upward. However, Woodford [39] has pointed out that such shift is at odd with the common wisdom regarding the effects of globalization on inflation dynamic. The *relative-price* channel emphasized by our model moves instead the Phillips curve consistently with the global-slack hypothesis: downward (upward) when foreign prices decrease (increase). In addition, we show that the degree of market concentration also influences the slope of the Phillips curve, namely the sensitivity of inflation to marginal costs. Higher competition, captured by a higher number of firms in the market, steepens the Phillips curve, implying that domestic prices become more sensitive to domestic marginal costs.

We provide support for the *relative-price* channel by estimating, with US data on the non-farm business sector and the manufacturing sector, the reduced form Phillips curve implied by our model. Such channel is more evident in the manufacturing sector, as the latter is more exposed to the globalization process. Over the last decade unit labour costs and prices have indeed decreased in this sector while they have increased in the manufacturing sector. Consistently with the results highlighted in our model, this pattern is well explained by the rise in the manufacturing import price, namely the price of competitors.

The rest of the paper proceeds as follows. Section 2 discusses the relation of our paper with the most recent literature on the effects of globalization on inflation dynamics and pass-through. Section 3 shows the model. Section 4 solves the model under flexible prices. Section 5 solves the model under sticky prices. Section 6 discusses the empirical analysis on the exchange rate pass-through and that on the domestic AS equation. Section 7 concludes.

2 Comparison with the Literature

This work is related to a recent literature that has addressed the implications of globalization for the reduced form of the Phillips curve. Sbordone's [36] presents a modification of the standard Calvo's [10] pricing mechanism by allowing for time-varying elasticity of demand using Kimball's [30] preferences. It follows that the number of variety produced in a sector affects the degree of strategic complementarity in price setting, and hence influences the dynamic response of inflation to marginal costs. She finds that an increase in trade globalization reduces the slope of the Phillips curve only under certain parameters' configuration. Sbordone [36] uses a closed-economy model and focuses on the slope of the Phillips curve. Instead, Guerrieri et al. [25] apply Kimball's [30] preferences to an open-economy model in which the elasticity of demand depends upon the ratio of domestic prices to foreign competitors' prices. They show that this type of preferences implies a new reduced form for the New-Keynesian Phillips curve, in which domestic inflation depends on the ratio between prices of imported goods and domestic prices, alongside with domestic real marginal cost. The reduced form of the Phillips curve derived in Guerrieri et al. [25] is observationally equivalent to the one derived in our model, although micro-foundations are significantly different. Since we model variable mark-up through strategic pricing we are able to highlight the pro-competitive dimension backing the relation between inflation and globalization. Finally, Bilbiie et al. [5] and Cecioni [13], in a closed-economy context, have emphasized the role of changes in the total number of varieties for the dynamic of marginal costs. On the contrary, in our model we show that the mark-up can vary even when holding constant the domestic marginal costs and the number of traded varieties and as a result of relative price changes.

The competitive effect of globalization in our model resembles the one explored in Chen, Imbs and Scott [14]. They test the heterogenous-firm model of Melitz and Ottaviano [29], according to which greater competition by foreign firms and an increased share of imports induce a fall in profit margins and markups. There are important differences between our approach and theirs: first firms' heterogeneity is not essential in our framework as competition is determined by the oligopolistic structure; second our model also accounts for long-run dynamics.

Our paper contains several implications about the impact of globalization on the degree of pass-through. In this respect it is useful to compare our results to the most recent literature on exchange rate pass-through.[3] Gopinath and Itskhoki [22] find a robust link between pass-through and the duration of price adjustment and show that the latter is very much related to variations in mark-ups. Gopinath and Rigobon [23] look at data with high level of dis-aggregation and find that the probability of price adjustment of US imports has decreased. Moreover, they show that the exchange rate pass-through is inversely related to the probability of price adjustment. Campa and Goldberg [12] and Sekine [34] have found that the sensitivity of retail prices to exchange rates changes may have decreased in the last decade. However, Campa and Goldberg [12] do not find significant evidence for the United States. Our results, indeed, point strongly in this direction as we show that the degree of pass-through has increased for some US manufacturing sectors during the period 2001-2009. For this time span we document a stronger correlation between price variations and exchange-rate changes than for previous periods. Gust et al. [26] also argue that the increase in trade integration, observed over the last decades, has decreased the degree of exchange rate pass-through. However, their results are based on a comparison of different set of time samples, namely the 80s versus the 90s, and on different sectors. We focus our analysis on the last fifteen years and analyze data for the manufacturing sector. As discussed above, imperfect pass-through in the Gust et al. [26] is obtained by introducing Kimball's [30] preferences and this might limit the ability of their model to trace the parameters of the Phillips curve with reference to the competitive pressure experienced during the globalization process.

The relationship between market share and exchange rate pass-through has first been tested by Feenstra et al. [17], who shows that pass-through should be high for exporters with large market shares. Our model features a dynamic dimension that allows to disentangle short-run versus long-run pass-through and accounts for the effects of expectations. Finally, Bodnar et al. [6] have also estimated the degree of exchange rate pass-through using a model in which competition between domestic and foreign firms is modelled using elements from the industrial organization literature. However Bodnar et al. [6] focus mainly on the relationship between the exposure of firms' profits to exchange rate fluctuations and the exchange rate pass-through.

Our work is also related to the vast literature estimating New-Keynesian Phillips curves, more closely to the analysis conducted by Sbordone [35] and Guerrieri et al. [25]. Although we refer to different type of micro-foundations, we largely confirm the results in Guerrieri et al. [25] regarding the importance of the relative-price channel in the Phillips curve.

[3] See also Goldberg and Knetter [24].

3 A model of international strategic pricing

We analyze a two-country model in which the home economy is indexed by h and the foreign economy by f. In each economy there are multiple sectors, indexed by k. In each sector of the home country, there are N differentiated goods, of which N_h are produced by firms residing in country h and the remaining N_f by firms residing in country f. Similarly in country f there are N^* differentiated goods, of which N_h^* are produced by firms residing in country h and N_f^* by firms residing in country f. Assuming that in each sector individual varieties are aggregated according to a Dixit-Stiglitz aggregator, optimal demand for a generic good i, produced in country h and belonging to a sector k, is given by:

$$Y_i = (\frac{P_i}{P_k})^{-\sigma}(\frac{P_k}{P})^{-\theta}Y \tag{1}$$

where σ is the elasticity of substitution among different varieties produced in the generic sector k and θ is the elasticity of substitution across sectors. We define the overall demand in the economy, Y, the economy-wide price index, P, the price of good i, P_i, and the aggregate price of the sector k, P_k, with the latter given by:

$$P_k = (\sum_{i=1}^{N_h} P_i^{1-\sigma} + \sum_{j=1}^{N_f} P_j^{1-\sigma})^{\frac{1}{1-\sigma}} \tag{2}$$

where P_j denotes the price of a generic good j in the sector k, produced in country f.

Following Dornbusch [16], we assume that firms are not small with respect to their sector meaning that, in their pricing decisions, they internalize the fact that they can influence the sectorial price.[4] The elasticity of demand of good i with respect to its price P_i is not necessarily constant and is instead given by:

$$\frac{\partial Y_i}{\partial P_i}\frac{P_i}{Y_i} = -\sigma + \sigma\frac{P_i}{P_k}\frac{\partial P_k}{\partial P_i} - \theta\frac{P_i}{P_k}\frac{\partial P_k}{\partial P_i} \tag{3}$$

which can be written in a more compact form, and in absolute value, as:

$$\tilde{\sigma}_i \equiv \left|\frac{\partial Y_i}{\partial P_i}\frac{P_i}{Y_i}\right| = \sigma - (\sigma - \theta)\xi_i \tag{4}$$

[4] Feenstra et al. [17] present a similar model. Instead, Soto and Selaive [37] develop a general equilibrium model in which firms compete on quantities rather than on prices. Atkeson and Burstein [1] study also a flexible-price model with strategic competition in quantities.

where ξ_i identifies the market share of firm i in sector k given by

$$\xi_i \equiv \frac{P_i Y_i}{P_k Y_k} = \frac{P_i}{P_k}\frac{\partial P_k}{\partial P_i}. \tag{5}$$

The elasticity of demand faced by the generic firm i, $\tilde{\sigma}_i$, boils down to that of monopolistic competition under two cases. The first when all firms are small, i.e. when their market share goes to zero, $\xi_i \to 0$. The second case occurs when the demand elasticity across different varieties and that across different sectors coincide, $\theta = \sigma$; under this condition firms do not have leverage in affecting sectorial aggregate prices. The empirically-relevant case is that in which the elasticity across different varieties, within a single sector, is higher than that across sectors, $\sigma > \theta$. In this case $\tilde{\sigma}_i$ is a decreasing function of firm´s i market share. In the limiting case in which there is only one firm i in each sector we can obtain that $\tilde{\sigma}_i = \theta$. Intuitively monopoly power rises with the market share.

The equilibrium is symmetric since all firms in a sector face the same technology and optimization problem. Therefore we drop the index i. The market share of firms based in country H is then given by

$$\xi_i = \xi_h = \frac{P_h Y_h}{N_h P_h Y_h + N_f P_f Y_f} \tag{6}$$

where P_h, P_f, Y_h, Y_f are prices and output in country h for firms resident respectively in country h and f.

Our model implies that variation in the market share causes changes in the mark up. Since relative prices influence the market shares, firms internalize the impact of their pricing decisions on the overall market equilibrium. An important implication is that prices become more sensitive to other firms' marginal costs and, with international competition, to exchange rate fluctuations. We label this channel as the pro-competitive effect since it echoes the ones analyzed in Ghironi and Melitz [5], Melitz and Ottaviano [29] and Chen, Imbs and Scott [14] in models that allow for firm heterogeneity. Notice that this pro-competitive channel survives in our model even in absence of firm heterogeneity because of strategic pricing competition.

As mentioned earlier, we focus on one aspect of the globalization process, namely the increase in the number of foreign products in the domestic market. Such an increase reduces the market share of both domestic and foreign firms, therefore increases the elasticity $\tilde{\sigma}_i$ and reduces the monopoly power. First, we study the model's implications for the sensitivity of prices to marginal costs and, in particular, we analyze the degree of exchange rate pass-through, when prices are fully flexible prices. Later, we introduce sticky prices.

4 Flexible prices

Under flexible prices, a firm i, producing and selling in country H, chooses P_i to maximize the following profit function:

$$\Pi_{i,t} = P_{i,t}Y_{i,t} - \frac{W_t}{A_t}Y_{i,t} \tag{7}$$

under the demand function (1), where W_t are the nominal wages in the labor market of country H and A_t denotes a common productivity shifter in country H. The production function is assumed to be linear in labor, the only factor of production.

Standard optimization implies the following first-order condition:

$$P_{i,t} = \frac{\tilde{\sigma}_{i,t}}{\tilde{\sigma}_{i,t} - 1}\frac{W_t}{A_t} \tag{8}$$

which shows that prices are set as a time-varying mark-up over marginal costs, where $\tilde{\sigma}_{i,t}$ is given by (4). Since all firms face the same problem, they will set the same price. We can therefore eliminate the index i and introduce the index h or f indicating the country of residence of the firm. Prices set by domestic firms selling in market h reads as follows:

$$P_{h,t} = \frac{\tilde{\sigma}_{h,t}}{\tilde{\sigma}_{h,t} - 1}\frac{W_t}{A_t}, \tag{9}$$

while prices of foreign firms selling in market h are:

$$P_{f,t} = \frac{\tilde{\sigma}_{f,t}}{\tilde{\sigma}_{f,t} - 1}\frac{S_t W_t^*}{A_t^*} \tag{10}$$

in which S_t denotes the nominal exchange rate (the price of foreign currency in terms of domestic currency), W_t^* denotes nominal wages determined in a foreign labour market (denominated in foreign currency) and A_t^* is the common productivity shifter for firms based in country F. Prices (9) and (10) have to be solved jointly since the market shares of domestic firms ξ_h, as shown in equation (6), and that of foreign firms, ξ_f, depend themselves on prices.

To analyze more deeply the implications of conditions (9) and (10), it is convenient to take a log-linear approximation together with that of the market shares to obtain

$$\hat{P}_{h,t} = \kappa s_f(\hat{P}_{f,t} - \hat{P}_{h,t}) + \hat{W}_t - \hat{A}_t \tag{11}$$

$$\hat{P}_{f,t} = \kappa s_h(\hat{P}_{h,t} - \hat{P}_{f,t}) + \hat{W}_t^* + \hat{S}_t - \hat{A}_t^* \quad (12)$$

where the parameter κ is defined by

$$\kappa \equiv \frac{\sigma - 1}{\bar{\sigma} - 1}\frac{\sigma - \theta}{\bar{\sigma}}\frac{1}{N}$$

with $\bar{\sigma} \equiv \sigma - (\sigma - \theta)/N$, $s_h = N_h/N$ and $s_f = N_f/N$ and where variables with a hat denote log-deviation with respect to the steady-state.

4.1 Exchange-rate pass-through

Using the reduced form implied by equations (11) and (12) it is possible to study the conditions under which there is full pass-through of exchange-rate movements into foreign prices. Pass-through is defined as the response of the prices set by the foreign firms (selling in the market h) to movements in the exchange rate, i.e. $\partial \hat{P}_{f,t}/\hat{S}_t$. Pass-through is full when the response is unitary.

Proposition 1. *With flexible prices, the degree of pass-through is unitary when one of the following condition is met: 1)* $\sigma = \theta$; 2) $N \to \infty$; 3) $s_h = 0$.

Consider the first condition, $\sigma = \theta$. In this case the elasticity of demand, $\tilde{\sigma}_i$, is constant and independent of the market shares. Firms cannot affect sectorial aggregate prices and therefore a constant elasticity of demand implies full pass-through. The power of firms to affect sectorial aggregate prices is also nil under the second condition, $N \to \infty$. In this case, the market share of each firm becomes negligible like in a monopolistic-competitive market. Finally, in the third case ($s_h = 0$), foreign firms dominate completely the domestic market and so they can pass-through any exchange-rate movement into prices without losing market share.

To summarize, pass-through in the flexible-price equilibrium is high when foreign firms have larger market shares or are very small. In the intermediate cases, the pass-through is less than unitary because firms internalize the effects of their pricing choices on the market shares. Indeed firms foresee that too large price increases lead to significant losses in market share and thus to reductions in the mark-up. Therefore, they do not increase prices much when the exchange rate depreciates.

Figure 1 quantifies the exchange-rate pass-through as a function of the share of foreign products in the market, which is our measure of the dimension of globalization in the model. Calibration of baseline parameters is as follows: $\sigma = 6, \theta = 1.5$. We interpret the rise in the number of foreign products in the domestic market as an increase in globalization. Given a permanent shock to the exchange rate, the two panels in Figure 1 show the degree of pass-through as a function of the share of foreign products in the domestic market. The left panel shows how the degree of pass-through varies when the fraction of foreign products in the market changes on the $x-$axis and for different values of N. Along each line we keep the total numbers of products in the market constant. The right panel instead shows the degree of pass-through against the share of foreign products and for different values of N_h. In this case, along each line we keep N_h at a determined value and vary the number of foreign products, and therefore the total number of products. Both pictures show that the pass-through is increasing in the share of foreign products in the market. Consistent with the theoretical results, the pass-through is one when foreign firms dominate the market. Globalization, interpreted as an increase in the fraction of foreign products in the domestic market, leads to higher long-run pass-through and makes foreign prices more responsive to foreign marginal costs and the exchange rate. Moreover the pass-through is larger in sectors characterized by a low degree of concentration, which in our model can be proxied by the inverse of the total number of firms in the market, i.e. $1/N$. For large values of N, the degree of concentration in the sector is low and the pass-through is very close to one.

4.2 Response of domestic prices to domestic conditions

Over the recent years a large part of the debate on the costs and benefits of the globalization process has pointed toward the possibility that domestic prices could be disconnected from domestic conditions and more influenced by external factors. To the extent that domestic prices are largely driven by foreign marginal costs, the interventions of policy makers to constrain inflation by restraining domestic demand might become less effective. To study the link between domestic prices and marginal costs, we take the difference between equations (11) and (12) and solve for the equilibrium prices:

$$\hat{P}_{h,t} = \frac{\kappa s_f}{1+\kappa}(\hat{W}_t^* + \hat{S}_t - \hat{A}_t^*) + \frac{1+\kappa(1-s_f)}{1+\kappa}(\hat{W}_t - \hat{A}_t), \tag{13}$$

$$\hat{P}_{f,t} = \frac{\kappa s_h}{1+\kappa}(\hat{W}_t - \hat{A}_t) + \frac{1+\kappa(1-s_h)}{1+\kappa}(\hat{W}_t^* + \hat{S}_t - \hat{A}_t^*). \tag{14}$$

Equation (13) shows that prices of domestic firms selling in market h are a weighted average of domestic and foreign marginal costs. A standard model with monopolistic competition would instead imply prices to be just influenced by domestic marginal costs. Similarly, prices of foreign products sold in the market h are a weighted average of domestic and foreign marginal costs. The pricing competition between domestic and foreign firms creates a link through which movements in marginal costs spillover across firms competing in the same sector. The degree of marginal cost spillover is affected by the share of foreign firms operating in the market. An increase in the share of foreign products, s_f, tends to foster the link between domestic prices and foreign marginal costs. On reverse globalization in terms of higher penetration of foreign firms in the domestic market tends to weaken the link between domestic prices and domestic marginal costs. Our model would then be consistent with the 'global slack' hypothesis according to which the dynamic of domestic prices is more influenced by the foreign slack as a consequence of globalization.

Figure 2 plots the response of prices to a shock to domestic wages for the firms based in country h and selling products in country h. Once again two different cases are examined. The left-hand side panel of Figure 2 shows how the response of domestic prices to domestic wages varies with respect to changes in the fraction of foreign products (on the x/axis) and for different/given values of N. The right-hand side panel of Figure 2 shows how the response of domestic prices to domestic wages varies with respect to changes in the share of foreign products, this time for different/given values of N_h. In the first panel, the response of prices to wages is smaller as the share of foreign firms increases. The reduction is larger the higher is the degree of concentration in the sector captured by $1/N$. On the contrary, the right-hand side panel shows a bell-shaped response. When there are only domestic firms in the domestic market, h, the response of domestic prices to a wage shock is unitary. This is also the case when the share of foreign firms is large and, most important, when the degree of concentration in the market is very small, since N goes to infinity. For intermediate values, the response is less than unitary. Overall two main conclusions arise. Globalization reduces the response of domestic prices to movements in domestic marginal costs when foreign firms enter the market to replace domestic firms without changing the overall degree of concentration in the sector. When the entrance of foreign firms increases the total number of firms in the domestic market, hence increasing the degree of competition, things are more complex. When a small number of foreign firms enter the domestic market, domestic prices become less sensitive to domestic conditions. However as the number of foreign firms becomes large, domestic prices become again highly connected to domestic marginal costs, since domestic firms are small.

5 Sticky prices

In this section, we study the implications of adding price rigidities through a cost of adjusting prices as in the model of Rotemberg [33].[5] There are three main implications

[5] Alternative models of price-setting decisions, as for example Calvo [10], could have been considered.

of the new environment. It is now possible to study the interaction between sticky prices and pricing competition in characterizing the degree of exchange-rate pass-through, the sensitivity of prices to movements in the marginal costs and the deviations from the law-of-one-price.[6] Moreover, the presence of price rigidities allows to disentangle short-run versus long-run effects of marginal-cost shocks into prices, in line with the empirical evidence. Finally, it is possible to derive a New-Keynesian Phillips curve linking inflation, marginal costs and the additional elements implied by our model. The Phillips curve can be compared with the traditional one and those developed by Bilbiie et al. [5], Cecioni [13], Guerrieri et al. [25] and Sbordone [36] who also explore different aspects of globalization. Such a comparison highlights the different implications of our model of strategic pricing with respect to the ones present in previous literature.

In our model a generic firm i, based in country h, producing in a generic sector k of market h maximizes the present discounted value of profits:

$$E_t \sum_{\tau=t}^{\infty} R_{t,\tau} \left[P_{i,\tau} Y_{i,\tau} - \frac{W_\tau}{A_\tau} Y_{i,\tau} - \frac{\chi}{2} (\frac{P_{i,\tau}}{P_{i,\tau-1}} - 1)^2 P_{i,\tau} Y_{i,\tau} \right] \tag{15}$$

where χ, with $\chi \geq 0$, is a parameter measuring the cost of adjusting prices, while $R_{t,\tau}$ is a nominal stochastic discount factor through which units of wealth are appropriately evaluated across time and states of nature. The optimality condition requires prices to be set as a time-varying mark-up over nominal marginal costs:

$$P_{i,t} = \tilde{\mu}_{i,t} \frac{W_t}{A_t}. \tag{16}$$

However, in this case, the mark-up is a more complicated expression and in particular is a function of past and future expected variations in prices as shown by

$$\tilde{\mu}_{i,t} = \frac{\tilde{\sigma}_{i,t}}{(\tilde{\sigma}_{i,t} - 1) \left[1 - \frac{\chi}{2} (\pi_{i,t} - 1)^2 \right] + \chi \pi_{i,t} (\pi_{i,t} - 1) - \Gamma_t} \tag{17}$$

with:

$$\Gamma_t \equiv \chi E_t \left\{ R_{t,t+1} \pi_{i,t+1} (\pi_{i,t+1} - 1) \frac{Y_{i,t+1}}{Y_{i,t}} \right\}, \tag{18}$$

and $\pi_{i,t} \equiv P_{i,t}/P_{i,t-1} - 1$.

To get further insights, we take a first-order approximation of (16) which delivers the

[6] The interaction between sticky prices and pass-through has been emphasized by the recent empirical evidence of Gopinath and Rigobon [23] and Gopinath and Itskhoki [22].

following New-Keynesian Phillips curve:

$$\pi_{h,t} = \left[k \cdot mc_t + \frac{\sigma - \theta}{\chi \bar{\sigma}} \frac{1}{N} \cdot \hat{\xi}_{h,t} \right] + \beta E_t \pi_{h,t+1}, \tag{19}$$

where we have defined the domestic real marginal costs as $mc_t \equiv (\hat{W}_t - \hat{P}_{h,t} - \hat{A}_t)$ and the slope k is given by $k \equiv (\bar{\sigma} - 1)/\chi$.

Compared to the traditional New-Keynesian Phillips curve, the one derived above is characterized by an additional element represented by the second addendum in the square bracket. This element captures the novel aspect of strategic pricing featured by our model. When firms interact strategically, the aggregate supply equation shifts with the movements in the mark-up which are driven by variation in firms´ market share. When N approaches infinity, namely under a monopolistic-competitive market, or when $\sigma = \theta$, the equation nests the traditional New-Keynesian Phillips curve.

Two elements differentiate the Phillips curve of this model from the traditional one and describe the influence of globalization on the aggregate supply equation. The first element is the slope of the curve, i.e. the short-run relationship between inflation and domestic real marginal costs, which now depends on the number of products present in the market. Indeed $\bar{\sigma}$ is an increasing function of N. The higher the number of products, the higher is the steady-state elasticity of substitution and the higher is the response of inflation to movements in the real marginal costs. Hence, from this point of view higher competition steepens the Phillips curve and renders price more sensitive to domestic shocks. In a closed-economy model with Kimball's [30] preferences and monopolistic competition, Sbordone [36] also finds that the slope of the curve is influenced by the number of varieties in the market, however in her case such relation might change direction depending on parameters' calibration.

The second element that characterizes equation (19) with respect to the traditional New-Keynesian Phillips curve stems from the influence exerted by the fluctuations in market share over the mark-up of domestic firms. This influence is captured by the second term in the square bracket of equation (19). The canonical open-economy model, such as the one in Benigno and Benigno [3], features an AS equation which is isomorphic to the closed-economy equation:

$$\pi_{h,t} = \tilde{k} \cdot mc_t + \beta E_t \pi_{h,t+1} \tag{20}$$

for some parameter $\tilde{k}$. The open-economy dimension of the equation is hidden under the decomposition of the real marginal costs into a component given by the output gap and another given by the terms of trade. In particular, foreign prices influence the terms of trade and then the real marginal cost. Woodford [39] has noticed that in this model the 'global slack' hypothesis might be contradicted. Indeed, for realistic calibrations, a decrease in foreign prices, improving the terms of trade, would raise the real marginal costs and put upward pressure on prices instead of the downward pressure commonly thought.[7]

Our model features an additional channel on top of the real marginal costs of equation (20) which results from variations in the market share for the domestic firms, as shown in (19). Since the market share can be approximated by the relative prices

$$\hat{\xi}_{h,t} = (\sigma - 1)s_f(\hat{P}_{f,t} - \hat{P}_{h,t})$$

the Phillips curve can be written as follows:

$$\pi_{h,t} = k \cdot \left[mc_t + \kappa s_f(\hat{P}_{f,t} - \hat{P}_{h,t}) \right] + \beta E_t \pi_{h,t+1}.$$

This shows the direct influence of the relative prices on domestic inflation. This effect is akin to the channel studied by Guerrieri et al. [25], although in their model it arises assuming kinked demand as in Kimball [30]. On the contrary, in our model, it depends more genuinely on primitive foundations based on firms' strategic interaction. Those differences allow us to interpret the primitive parameters of our model in the light of the pro-competitive effects typical of the globalization process. In particular, the additional relative-price channel disappears under two circumstances. First, when all firms become small in size (N goes to infinity, implying κ goes to zero); this nests the case of a monopolistic-competitive market. Second, when the share of foreign firms is small (s_f goes to zero), or finally in the particular case in which $\sigma = \theta$, implying also κ that goes to zero.[8]

Equation (19) can now be used to discuss the impact of globalization on the price-behavior of firms, namely on the slope and the shift of the aggregate supply equation. Globalization, as captured by an increase in N_f, raises N and, for given N_h, implies an increase in the slope of the Phillips curve. Hence, on the one side, globalization makes prices more sensitive to variations in the marginal costs as $\bar{\sigma}$ increases. On the other side, in a globalized market domestic firms compete for market share with foreign firms, hence the relative market share, as proxied by the relative prices, shifts the AS

[7] In the models of Bilbiie et al. [21] and Cencioni [13] the real marginal costs expressed in units of the general price index is also a function of the total number of varieties produced in the economy.

[8] In Guerrieri et al. [25] the additional relative-price channel disappears only when foreign products disappear completely from the domestic market.

equation for given domestic marginal costs. For instance, a fall in the foreign prices with respect to the domestic prices reduces the market-share of domestic firms and induces a deflationary pressure on domestic prices. Holding constant the size of the market, N, an increase in the share of foreign products reinforces this channel. Hence we conclude that globalization, interpreted as an increase in competition from foreign firms, renders the AS equation more dependent upon foreign conditions, namely foreign prices and foreign marginal costs. Finally, let's consider the case in which N_f rises with N (keeping N_h constant). The effect of N_f on the strength of the relative-price channel is less obvious. At low values of N_f, a further rise in the number of foreign firms increases the importance of the relative-price channel, whereas in markets, characterized by high competition of foreign firms and low concentration, an increase in the number of foreign firms abates the relative-price channel. Eventually when N goes to infinity, the relative-price channel vanishes.

5.1 Exchange-rate pass-through

The degree of exchange rate pass-through depends now on the interaction between price stickiness and strategic pricing among firms. To analyze this issue, we investigate the form of the Phillips curve implied by the optimality condition of foreign firms selling in the domestic market:

$$\pi_{f,t} = \frac{1}{\chi^*}\left[(\bar{\sigma}-1)(\hat{W}_t^* + \hat{S}_t - \hat{P}_{f,t} - \hat{A}_t^*) + \frac{\sigma-\theta}{\bar{\sigma}}\frac{1}{N}\hat{\xi}_{f,t}\right] + \beta E_t \pi_{f,t+1} \tag{21}$$

where χ^* measures the cost of price adjustment for foreign firms and $\pi_{f,t} \equiv \ln P_{f,t}/P_{f,t-1}$. Equation (21) can be written as:

$$\hat{P}_{f,t} - \hat{P}_{f,t-1} = -\frac{(\bar{\sigma}-1)}{\chi^*}\hat{P}_{f,t} + \frac{(\bar{\sigma}-1)}{\chi^*}(\hat{W}_t^* + \hat{S}_t - \hat{A}_t^*) + \frac{\sigma-\theta}{\bar{\sigma}}\frac{1}{N}\frac{1}{\chi^*}\hat{\xi}_{f,t} + \beta E_t(\hat{P}_{f,t+1} - \hat{P}_{f,t}) \tag{22}$$

which is a difference equation in $\hat{P}_{f,t}$ that can be solved for $\hat{P}_{f,t}$ taking as given the path of wages, exchange rate and market share. The solution reads as follows:

$$\hat{P}_{f,t} = \lambda \hat{P}_{f,t-1} + \lambda E_t \sum_{j=0}^{\infty} (\beta\lambda)^j \left[\frac{(\bar{\sigma}-1)}{\chi^*}(\hat{W}_{t+j}^* + \hat{S}_{t+j}) + \frac{\sigma-\theta}{\bar{\sigma}}\frac{1}{N}\frac{1}{\chi^*}\hat{\xi}_{f,t+j}\right], \tag{23}$$

where λ is the stable root of the following polynomial:

$$P(\lambda) = \lambda^2 - \left[\frac{1}{\beta} + 1 + \frac{(\bar{\sigma}-1)}{\beta\chi^*}\right]\lambda + \frac{1}{\beta} \tag{24}$$

and in particular λ increases with the degree of price rigidity, χ^*. Moreover, an increase in the number of foreign firms, competing in the domestic market, increases $\bar{\sigma}$ and decreases λ.

Equation (23) shows that prices, set in country h by firms producing in country f, depend on two components. A backward-looking component, which becomes more important when the degree of rigidity is higher and competition is lower, and a forward-looking component. The latter depends on the present discounted value of the future marginal costs and on the current and future evolution of the market share $\hat{\xi}_{f,t}$.

Throughout we assume that the exchange rate follows a random walk. When holding constant the evolution of the market share, our model nests the *local-currency-pricing* model with sticky prices discussed by Benigno [2]. Indeed, in this case the short run pass-through is given by:

$$\frac{\partial \hat{P}_{f,t}}{\partial \hat{S}_t} = \frac{\lambda}{1-\beta\lambda}\frac{(\bar{\sigma}-1)}{\chi^*} = 1-\lambda,$$

whereas the long-run pass-through is given by:

$$\frac{\partial \hat{P}_{f,\infty}}{\partial \hat{S}_t} = 1.$$

The less than unitary short-run pass-through arises simply because prices are sticky, even in absence of strategic competition. In particular the short-run pass-through is smaller, the higher the degree of rigidity. In the long run instead the pass-through is unitary.

The classical local currency pricing market is only a limiting case of our model. In general, movements in the market share can influence pricing decisions. Expectations play an important role in this context. If firms expect large swings in market shares, their pricing strategy is adjusted so that prices become less sensitive to shocks both, in the long run and the short run. Recall, indeed, that the degree of market shares attains the following representation:

$$\hat{\xi}_{f,t} = (\sigma - 1)s_h(\hat{P}_{h,t} - \hat{P}_{f,t}). \tag{25}$$

Consider an exchange rate depreciation. Foreign firms do not change their prices, $\hat{P}_{f,t}$, one to one with the exchange rate as they incur in a reduction in their market share, $\hat{\xi}_{f,t}$, as shown by equation (25). The degree of price rigidity also plays an important role in this context. Indeed when stickiness of prices for their competitors is high, foreign firms will lose a larger fraction of market share when rising prices. This tends to dampen both, long run and short run pass-through. The analysis of the combined price dynamics in the same destination market provides a quantitative assessment of the above mentioned effect.

Let us start with a simple case, for which analytical solutions are possible. We assume that foreign firms, selling in the domestic market, do not face cost of adjusting prices, while domestic firms do so. The price rigidity faced by the competitors is sufficient to create a dynamic adjustment, also in the prices of foreign firms. Indeed, the price set by the foreign firm evolves according to equation (12), while the aggregate-supply equation of domestic firms can be written as follows:

$$\hat{P}_{h,t}-\hat{P}_{h,t-1}=-\frac{(\bar{\sigma}-1)}{\chi}\hat{P}_{h,t}+\frac{(\bar{\sigma}-1)}{\chi}(\hat{W}_t-\hat{A}_t)+\frac{(\bar{\sigma}-1)\kappa s_f}{\chi}(\hat{P}_{f,t}-\hat{P}_{h,t})+\beta E_t(\hat{P}_{h,t+1}-\hat{P}_{h,t}). \tag{26}$$

Substituting (12) into (26), it is possible to obtain:

$$\begin{aligned}\hat{P}_{h,t}-\hat{P}_{h,t-1} &= -\frac{(\bar{\sigma}-1)}{\chi}\frac{1+\kappa}{1+\kappa s_h}\hat{P}_{h,t}+\frac{(\bar{\sigma}-1)}{\chi}(\hat{W}_t-\hat{A}_t)\\ &\quad+\frac{(\bar{\sigma}-1)}{\chi}\frac{\kappa s_f}{1+\kappa s_h}(\hat{W}_t^*+\hat{S}_t-\hat{A}_t)+\beta E_t(\hat{P}_{h,t+1}-\hat{P}_{h,t}),\end{aligned}$$

which is a second-order difference equation whose solution takes the following form:

$$\hat{P}_{h,t}=\lambda_1\hat{P}_{h,t-1}+\lambda_1\frac{(\bar{\sigma}-1)}{\chi}E_t\sum_{j=0}^{\infty}(\beta\lambda_1)^j\left[(\hat{W}_{t+j}-\hat{A}_{t+j})+\frac{\kappa s_f}{1+\kappa s_h}(\hat{W}^*_{t+j}+\hat{S}_{t+j}-\hat{A}_{t+j})\right],$$

where λ_1 is the stable root of the following polynomial

$$P(\lambda_1)=\lambda_1^2-\left[\frac{1}{\beta}+1+\frac{(\bar{\sigma}-1)}{\beta\chi}\frac{1+\kappa}{1+\kappa s_h}\right]\lambda_1+\frac{1}{\beta}.$$

Once again the stable root, λ_1, is influenced by the degree of price rigidity. The higher the degree of price rigidity for the domestic firms, the higher is the root λ_1. Interestingly now λ_1 decreases when the shares of foreign firms in the domestic market increases. Indeed in this case s_h falls and reduces λ_1. Under the assumption that all exogenous processes follow a random-walk, the above equation can be simplified as follows:

$$\hat{P}_{h,t}=\lambda_1\hat{P}_{h,t-1}+(1-\lambda_1)\left[\frac{1+\kappa s_h}{1+\kappa}(\hat{W}_t-\hat{A}_t)+\frac{\kappa s_f}{1+\kappa}(\hat{W}^*_t+\hat{S}_t-\hat{A}_t)\right]. \tag{27}$$

Equation (27) shows that prices of the domestic firms depend upon past prices and on a weighted average of domestic and foreign marginal costs. Notice that the terms in the square brackets measure the prices that would prevail under flexible prices.

Using these results and equation (12), we can then get the short-run pass-through of exchange-rate movements into prices as:

$$\frac{\partial \hat{P}_{f,t}}{\partial \hat{S}_t} = \frac{1}{1+\kappa s_h} + (1-\lambda_1)\frac{\kappa s_h}{1+\kappa s_h}\frac{\kappa s_f}{1+\kappa}, \tag{28}$$

whereas the long-run pass-through coincides with the long-run pass-through under flexible prices:

$$\frac{\partial \hat{P}_{f,\infty}}{\partial \hat{S}_t} = \frac{1+\kappa s_f}{1+\kappa}. \tag{29}$$

Even if foreign firms have flexible prices, the short-run response of prices is below the long-run response since domestic competitors face price rigidity. Price stickiness of domestic firms dampens the short-run response of foreign prices to the exchange rate. The higher is the degree of price rigidity in the domestic market, the smaller is the exchange-rate pass-through. An increase in the number of foreign firms selling in the domestic market implies larger short-run and long-run pass-through.

Another case which allows us to obtain analytical solution and which deserves discussion is the one in which domestic and foreign firms, selling in market h, face the same degree of nominal rigidities, i.e. $\chi^* = \chi$. The aggregate supply equation (21) of firms based in country f and selling in country h can now be written as follows:

$$\hat{P}_{f,t}-\hat{P}_{f,t-1} = -\frac{(\bar{\sigma}-1)}{\chi^*}\hat{P}_{f,t}+\frac{(\bar{\sigma}-1)}{\chi^*}(\hat{W}_t^*+\hat{S}_t-\hat{A}_t^*)+\frac{(\bar{\sigma}-1)\kappa s_h}{\chi^*}(\hat{P}_{h,t}-\hat{P}_{f,t})+\beta E_t(\hat{P}_{f,t+1}-\hat{P}_{f,t}). \tag{30}$$

Combining equations (26) and (30) implies the following evolution for relative prices:

$$\omega_t - \omega_{t-1} = \frac{(1-\bar{\sigma})(1+\kappa)}{\chi}\omega_t - \frac{(\bar{\sigma}-1)}{\chi}(\hat{W}_t^* + \hat{S}_t - \hat{W}_t + \hat{A}_t - \hat{A}_t^*) + \beta E_t(\omega_{t+1} - \omega_t) \tag{31}$$

where we have defined:

$$\omega_t = (\hat{P}_{h,t} - \hat{P}_{f,t}).$$

A solution to the difference equation (31) delivers the evolution of the relative prices as a function of past relative prices and the current relative unit labor costs across countries:

$$\omega_t = \gamma\omega_{t-1} - \frac{(1-\gamma)}{(1+\kappa)}(\hat{W}_t^* + \hat{S}_t - \hat{W}_t + \hat{A}_t - \hat{A}_t^*), \tag{32}$$

where γ is the stable root associated with the equation (31).

Substituting equation (32) into (30) gives the equilibrium prices for foreign firms selling in the domestic market:

$$\begin{aligned}\hat{P}_{f,t} &= (\lambda+\gamma)\hat{P}_{f,t-1} - \lambda\gamma\hat{P}_{f,t-2} + (1-\lambda)(1-\gamma L)(\hat{W}_t^* + \hat{S}_t - \hat{A}_t^*) - \\ &\quad -(1-\lambda)(1-\gamma)\frac{\kappa s_h}{(1+\kappa)}(\hat{W}_t^* + \hat{S}_t - \hat{W}_t + \hat{A}_t - \hat{A}_t^*)\end{aligned} \tag{33}$$

Notice that the above equation captures the full effect of exchange rates into prices, as it also captures the indirect effects exerted through the movements in the market share. The short run response of prices, set by foreign firms in the domestic market, to exchange rate fluctuations (the short-run pass-through) is given by:

$$\frac{\partial \hat{P}_{f,t}}{\partial \hat{S}_t} = (1-\lambda)\left[1-(1-\gamma)\frac{\kappa s_h}{(1+\kappa)}\right] \tag{34}$$

while the long-run pass-through is:

$$\frac{\partial \hat{P}_{f,\infty}}{\partial \hat{S}_t} = \frac{1+\kappa s_f}{1+\kappa}.$$

Once again the short-run pass-through is smaller than the long-run pass-through and is dampened by the degree of price rigidity. Interestingly, when prices are sticky for both domestic and foreign firms, the exchange-rate pass-through does not necessarily increases monotonically as the horizon increases. Indeed the impact at medium horizons can be much smaller than the short-run impact.

In what follows we evaluate our results through some simulations. In particular we set the elasticity of substitution across sectors to be $\theta = 1.5$, while that across goods within a sector such that $\sigma = 6$ implying that the elasticity is higher within a sector than across sectors. The discount factor β is calibrated to imply, in a quarterly model, an average real rate of 4%. Therefore we set $\beta = 0.99$. The calibration of the price stickiness parameter, χ (or χ^*), is performed so as to map the slope of the Phillips curve to that of a standard model a´ la Calvo [10], in which α represents the probability of holding prices fixed and $1/(1-\alpha)$ is the average duration of prices. In particular we use the following relationships

$$k = \frac{(\bar{\sigma}-1)}{\chi} = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}. \tag{35}$$

We calibrate the degree of price rigidity for the firms based in the home country to imply a duration of prices equal to three quarters, so that $\alpha = 0.66$, and we derive the appropriate χ using the above formula. In Figure 3, we plot the degree of exchange-rate pass-through as a function of the degree of price rigidity for the foreign firms, α^*, which is connected to χ^* through a mapping similar to (35). On the left panel of the figure, we fix $s_f = 0.5$ and we present how the exchange-rate pass-through varies for different sizes of the sector, i.e. for different N. In the middle panel, instead we fix $N = 10$ and present results for different s_f. On the right panel, we fix the number of domestic firms $N_h = 5$ and present results for different s_f and so different N.

The degree of pass-through is decreasing when price rigidity of foreign firms increases. The left panel shows that, for a fixed level of rigidity, the higher the concentration in the industry the lower is the pass-through, but also that, when rigidity increases, the concentration in the industry has a smaller impact on the degree of pass-through. The middle and the right panels show similar pictures, although now the degree of pass-through is reduced when the share of foreign products is low. We conclude that globalization might increase the degree of pass-through, for given degree of nominal rigidity, the more so the lower the degree of rigidity.

Figure 4 shows the impulse response of foreign prices to an exchange-rate shock for different degrees of nominal rigidities (for the foreign firms). We set $\alpha = 0.66$, $N = 10$ and $s_f = 0.5$. The convergence to the long-run is faster the higher the degree of price flexibility. Interestingly, after 10 quarters, the pass-through is still far from the long-run pass-through for reasonable degrees of rigidity.

5.2 Response of domestic prices to domestic conditions

We now investigate how the interaction between price stickiness and strategic pricing affects the response of domestic prices to domestic marginal costs and how this relationship depends on globalization. We can get some insights on this issue by using some of the examples of the previous section. Recall that we have derived the price set by the domestic firms in market H as:

$$\hat{P}_{h,t} = \lambda_1 \hat{P}_{h,t-1} + (1-\lambda_1)\left[\frac{1+\kappa s_h}{1+\kappa}(\hat{W}_t - \hat{A}_t) + \frac{\kappa s_f}{1+\kappa}(\hat{W}_t^* + \hat{S}_t - \hat{A}_t)\right],$$

assuming that foreign firms face flexible prices. Domestic prices depend on the past domestic prices and on a weighted average on domestic and foreign marginal costs. The 'global slack' hypothesis is well formalized in the above equation. Foreign marginal costs affect domestic prices more when the share of foreign products in the market increases (for given size of the market). In this case, the short-run response of domestic prices to movements in wages is given by:

$$\frac{\partial \hat{P}_{h,t}}{\partial \hat{W}_t} = (1-\lambda_1)\frac{1+\kappa s_h}{1+\kappa}$$

which is, unambiguously, decreasing with the increase in the share of foreign firms in market H since:

$$(1-\lambda_1)\frac{1+\kappa s_h}{1+\kappa} = \frac{\lambda_1}{1-\beta\lambda_1}\frac{(\bar{\sigma}-1)}{\chi}$$

and since λ_1 decreases as s_f increases. Clearly, also the long-run response of domestic prices does not rise proportionally to the increase in domestic marginal cost due to the strategic competition with foreign firms. Indeed the long run pass-through is lower than one:

$$\frac{\partial \hat{P}_{h,\infty}}{\partial \hat{W}_t} = \frac{1+\kappa s_h}{1+\kappa} < 1$$

unless $s_h = 1$ or $\kappa = 0$ (when $N \to \infty$). The response of domestic prices to domestic marginal costs increases monotonically from the short to the long run. But, it is sufficient to introduce some rigidity in the prices of foreign firms to induce a non-monotonic adjustment across time. Actually, the response of prices to wages can be dampened for a long period of time because of the strategic interaction with foreign firms featuring sticky prices.

Figure 5 plots the response of prices to a wage shock, as a function of the degree of price rigidity faced by foreign firms, α^*. On the left panel of the figure, we fix $s_f = 0.5$ and show how the response of prices to a wage shock varies for different N. In the middle panel, instead we fix $N = 10$ and show results for different s_f. On the right panel, we fix the number of domestic firms, $N_h = 5$, and present results for different s_f, hence different N.

The left panel of figure 5 shows that the response of prices to movements in domestic marginal costs is smaller the higher the degree of price rigidity, but is relatively smaller in sectors characterized by higher concentration, since competition is stronger. The middle panel shows a similar picture, however now the response of prices to domestic conditions is reduced when the share of foreign products in the market increases. Globalization should therefore reduce the response of prices to domestic conditions, the more so the lower is the degree of rigidity. This is always true when we fix the total number of firms in the market. On the contrary, when we fix the number of domestic products in the market, and let the foreign products enter the market freely, we get an ambiguous result as for the flexible-price model. When starting from a small share of foreign products in the market, a further increase in the number of foreign products lowers the response of domestic price to domestic conditions. Instead, when starting from a large share of foreign products, an increase in foreign products reduces the degree of concentration in the industry up to the point that the response of domestic prices to domestic conditions becomes unitary.

6 Empirical analysis

Our empirical analysis is divided into two parts. In the first part, we explore the consequences of globalization on the degree of exchange rate pass-through by highlighting the role of international competition. In the second part, we stress the importance of globalization for the dynamic of domestic inflation.

6.1 Globalization and exchange rate pass-through

In our model globalization increases the degree of exchange rate pass-through. In particular the degree of exchange rate pass-through depends on the degree of concentration in the market and on the share of foreign products competing in the domestic market. Greater competition, due to an increase in the foreign products sold in a particular industry, rises the exchange rate pass-through both, in the short and the long run.

To test this channel we use data for five manufacturing sectors in the US: 1) vegetables and prepared food, 2) leather and footwear, 3) textiles and textile articles, 4) vehicles, vessels and associated transport equipment, and 5) base metals and machinery. Data are quarterly from 1993 to 2008. A more detailed description of the dataset can be found in Appendix A. We run several multiple regression analyses on both the entire sample and the sub-samples to identify the effects of the increased globalization.

Figure 6 shows industry-specific real exchange rates and nominal import prices for the five sectors and the period 1993-2008. Industry-specific real exchange rates are from Linda Goldberg's database while nominal import prices refer to the log of import prices, for each sector. Visual inspection shows that in the last part of the sample there are stronger co-movements between the two series, and this is particularly true for Sectors 1,2, 3 and 5. Some simple computations in Table 1 show, indeed, that in the first part of the sample prices vary in the opposite direction with respect to the real exchange rate, except for Sector 5. On the contrary, in the last eight years, the cumulative price change is more in line with the cumulative real exchange rate change.

To test the hypothesis of stronger co-movements over the most recent sample, we run seemingly unrelated regressions on a model with the following specification:

$$\Delta p_{k,t} = c_k + \sum_{j=0}^{m} \beta_{k,j} \Delta q_{k,t-j} + \varepsilon_{k,t} \tag{36}$$

where $\Delta p_{k,t}$ represents the change in log nominal import price of a generic sector k at time t and $\Delta q_{k,t}$ represents the change in the real exchange rate for sector k, c_k is a generic constant, and $\beta_{k,j}$ is the sector-specific coefficient measuring the response of prices to real exchange rate movements at lag j.[9] With the SURE estimator, we are allowing the unobserved shocks $\varepsilon_{k,t}$ to co-vary across the different sectors. The specification of equation (36) is similar to that of Gopinath and Itskhoki [23], who analyze data at the level of disaggregated US import prices. Contrary to us, Gopinath and Itskhoki [23] deflate the import price with the CPI inflation rate. We instead consider the sectorial real exchange rate as a good proxy for the sectorial nominal exchange rate and therefore analyze the pass-through into nominal import prices.

To make our measure of pass-through comparable to the one considered in the literature we define it as the sum of the coefficients $\sum_{j=0}^{m} \beta_{k,j}$, for each sector k. This measure also corresponds to the long run pass-through defined in our model. We also consider an alternative linear specification, which includes a dependence on lag prices changes, in line with the assumptions made in our theoretical model with sticky prices:

$$\Delta p_{k,t} = c_k + \gamma_k \Delta p_{k,t-1} + \sum_{j=0}^{m} \beta_{k,j} \Delta q_{k,t-j} + \varepsilon_{k,t}. \tag{37}$$

In the specification above the coefficient γ_k measures the persistence of import-price changes. In this second case we define pass-through with the term $\sum_{j=0}^{m} \beta_{k,j}/(1-\gamma_k)$. We have repeated estimation for the parameters in (36) and (37) over different sub-samples. In particular, we have chosen the first quarter of 2001 as the date for splitting our time sample into two sub-samples. Such choice is motivated by the observation of the evolution of an indicator of market competition and a proxy for globalization. We take the Herfindahl-Herschmann index as a proxy for the degree of market concentration (see Appendix A for details), while we take the share of import from China on total import in each sector as a proxy for the share of foreign products in the domestic markets. Table 3 presents the Herfindahl-Herschmann index for the sectors under consideration and shows that competition has increased (a fall in the HH index) significantly for Sectors 2 and 4 and decreased for the other sectors. Figure 9 shows that the share of imports from China

[9] We set $m = 3$, since longer lags are not significant.

has increased steadily in each of the sectors considered and at a faster pace after 2000. This observation is consistent with our choice of the year 2000 as the break point. We consider, indeed, the series of Chinese imports into the US as proxy for the degree of market penetration of foreign firms into the US market.[10]

Finally, we have considered the following alternative specifications for computing the price increments: quarterly difference indicated as $\Delta_q p_t$, yearly difference indicated as $\Delta_y p_t$ and two-year differences indicated as $\Delta_{2y} p_t$. In particular the regressions on one-year and two-year differences aim to give an alternative computation for the pass-through. Results are shown in Table 2.

For Model (A), which is based on equation (36), results in Table 2 show, almost consistently across all sectors, that the pass-through has increased over the second sub-sample (after 2001). In particular the pass-through has increased in all sectors except textile, for which however the degree of pass-through is quite small. All estimated coefficients are significant at 95% confidence interval. Finally notice that results are confirmed when considering model (B), represented by equation (37), and model (C) and (D) which use data based, respectively, on one- and two-year differences.

To further investigate how the degree of pass-through has changed over time, we have repeated the above regressions (for the quarterly difference) on a 8-year rolling window. Results are shown in Figure 7 for model (36) and in Figure 8 for model (37). Figure 7 shows clearly that the pass-through has increased for all sectors if the estimation window includes the last part of the sample. Figure 8 presents a similar pattern for Model (B).

Our results confirm some of the previous results in the literature on exchange rate pass-through, but also add some novel dimensions. Earlier papers find evidence of partial pass-through, hence rejecting both producer currency pricing and local currency pricing as characterizations of aggregate behavior (see Campa and Goldberg [11] for an empirical analysis on OECD countries and Bugamelli and Tedeschi [8] for evidence on euro area countries). More recent studies (see Campa and Goldberg [12]) have found that the pass-through has declined in the past decades for most countries except the United States. Our paper shows that the most recent years contribute to a significant increase in the pass-through for some sectors and that this effect can be attributed to the process of globalization.

[10] Bugamelli et al. [9] shows that the increase in the share of imports from China explains the dynamic of domestic prices for several countries.

6.2 Globalization and AS equation

The second empirical implication of our model refers to the AS equation, which is now augmented by the relative-price channel:

$$\pi_{h,t} = k \cdot \left[mc_t + \kappa s_f (\hat{P}_{f,t} - \hat{P}_{h,t}) \right] + \beta E_t \pi_{h,t+1}. \tag{38}$$

Two main features characterize the new AS equation. First, the global slack component, represented by the term $\kappa s_f (\hat{P}_{f,t} - \hat{P}_{h,t})$, plays a significant role. Second, the slope of the Phillips curve, represented by the parameter k, depends on the goods-market competition and therefore can change with the globalization process. By estimating equation (38), we aim to provide support for our theoretical results. There are several estimation methods to test the AS equation (38).[11] We follow the one in Sbordone [35]. We write the AS equation as follows:

$$\hat{P}_{h,t} - \hat{P}_{h,t-1} = k(ulc_t - \hat{P}_{h,t}) + k\kappa s_f \cdot pr_t + \beta E_t (\hat{P}_{h,t+1} - \hat{P}_{h,t})$$

where we define $mc_t \equiv (ulc_t - \hat{P}_{h,t})$, ulc_t as unit labor costs, and the relative prices pr_t as $pr_t \equiv (\hat{P}_{f,t} - \hat{P}_{h,t})$. The above equation is solved forward with respect to $\hat{P}_{h,t}$ to obtain:

$$\hat{P}_{h,t} = \phi_1 \hat{P}_{h,t-1} + (1 - \phi_1)(1 - \phi_2^{-1}) E_t \left\{ \sum_{T=t}^{\infty} \phi_2^{-(T-t)} [ulc_T + \kappa s_f \cdot pr_T] \right\} \tag{39}$$

where ϕ_1 is given by:

$$\phi_1 = \frac{1 + \beta^{-1} + k\beta^{-1} - \sqrt{(1 + \beta^{-1} + k\beta^{-1})^2 - 4\beta^{-1}}}{2}$$

and $\phi_2 = (\phi_1 \beta)^{-1}$. The next step is to rearrange equation (39) as follows:

$$(\hat{P}_{h,t} - ulc_t) = \phi_1 (\hat{P}_{h,t-1} - ulc_{t-1}) - \Delta ulc_t + (1 - \phi_1) E_t \left\{ \sum_{T=t}^{\infty} (\beta\phi_1)^{(T-t)} [\Delta ulc_T + \omega \cdot pr_T] \right\}, \tag{40}$$

where $\omega \equiv \kappa s_f$.

Equation (40) allows to test the relation between the log difference of domestic prices on one side and unit labor costs, their lags, their future expectations and relative prices on the other. This relation depends on the parameters ϕ_1 and ω, which are in turn related to the deep parameters of the model. In particular the parameter ϕ_1 depends upon k,

[11] For an alternative strategy in terms of GMM estimation see Galí and Gertler ([20]).

the slope of the Phillips curve, and β, the discount factor, while the parameter ω depends upon κ and s_f, which are proxies for the market share. Since it is not possible to identify separately the parameters κ and s_f, as well as the parameters β and k, we focus on identifying the slope of the AS equation, k, and the parameter, ω. The latter is a crucial parameter as it captures the importance of the relative-price channel as emphasized by our model. Moreover assuming that $\beta = 0.99$, as it is standard in a quarterly model, we can identify k.

To evaluate the right-hand-side of (40), we need to compute expectations of future changes in the unit labor costs and future relative prices. To this end, we use a VAR model with two lags involving the following vector of variables $X_t = [(\hat{P}_{h,t} - ulc_t)\ \Delta ulc_t\ pr_t]$. Therefore for a combination of parameters k and ω we can get the model implied log-difference between prices and unit-labor costs. To estimate k and ω, we search for the values that minimize the criterion $\sum_{t=1}^{T} \varepsilon_t^2/T$, where ε_t measures the distance between the model implied $(\hat{P}_{h,t} - ulc_t)$ and the data. In particular we run a grid-search analysis for the parameters k and ω under the non-negative constraints.

We estimate equation (38) on two different datasets and different samples. On the one side, we use data on prices and unit labor costs for the non-farm business sector which has been traditionally the focus of analysis to test closed-economy New-Keynesian AS curves. On the other side, we use data on prices and unit-labor cost for the manufacturing sector. Data for the latter sector have never been used before in tests of the New-Keynesian Phillips curve, although they are particularly relevant for our experiment as this sector has been heavily exposed to the globalization process in the last decade.

Figure (10) plots the log of prices and unit labor costs for the two sectors analyzed together with the appropriate relative price, defined as the log of the price of import with respect to the domestic price. The import-price index is constructed by aggregating sectorial manufacturing import-price indexes, as discussed in the appendix. Such aggregation is possible only for the period 1993-2008. To appreciate the difference between the two sectors in terms of their exposure to globalization, Figure (10) is illustrative. In the non-farm business sector there is a strong relationship between prices and unit labor costs. This is not the case in the manufacturing sector, where unit labor costs have decreased in the past decades but the prices have instead increased. However, in this sector, prices are positively correlated with the relative price, therefore with the import prices, suggesting that international competition might be an important aspect influencing the dynamic of domestic prices.

When computing Phillips curve estimations we perform the following comparison: for both sectors we compare estimation of the traditional Phillips-curve equation, in which the parameter ω is set to 0 to shut off the relative-price channel, with the estimation of the specification implied by our model. Table (4) summarizes the results of the estimation of equation (38) for the full sample 1993-2008, the first part of the sample 1993-2000 and the last part of the sample 2001-2008. Focusing first on the full sample and on the benchmark case of the traditional AS equation ($\omega = 0$), we obtain an estimate of k equal to 0.01 for the non-farm business sector, which implies a high value of price rigidity, close to 10 quarters, in a model with a common labor market, but a value consistent with other estimates of the literature when we considered firm-specific labor market, around 4 quarters.[12] These results are in line with those of Sbordone ([35]), which covers a different sample, however the estimated coefficient is not significantly different from zero. This is not surprising as it is in line with the comments made in Fuhrer ([19]) on the difficulties of identifying the New-Keynesian Phillips curve. We then repeat the same restricted ($\omega = 0$) estimation for the manufacturing sector on the full sample. Here we get the following estimates: $k = 0$ and then $\phi_1 = 1$. This result confirms the visual inspection obtained through Figure (10). A value for k equal to zero in (40) implies that the lagged price performs better, based on our estimation criterion, in fitting the current price. Moreover this shows that equation (38) cannot be longer interpreted as the appropriate Phillips curve, as discussed also in Fuhrer ([19]). Therefore the traditional AS equation does not fit well data for the manufacturing sector.

We then move to the unrestricted estimation on the full sample and allow for the relative-price channel ($\omega \neq 0$). We find that such channel is important for both sectors and in particular for the manufacturing sector. Now, the slope of the AS equation increases to 0.015 for the manufacturing sector and to 0.078 for the non-farm business sector. Most important the point estimate of ω is positive in both sectors and greater in the manufacturing sector. In the latter case it is also significant. Interestingly, in the second part of the sample, after the 2001, significance increases for both the manufacturing sector and the non-farm business sector, while in the first part of the sample all the coefficients perform poorly for both sectors.

These results support the importance of the relative-price channel in explaining the dynamic of prices. This is true mostly for the second part of the sample when globalization plays a major role. Moreover such results explain why estimations of the traditional New-Keynesian AS equation performs poorly so often. Notice, indeed, that we find a 55% reduction in the criterion $\sum_{t=1}^{T} \varepsilon_t^2/T$ when we allow for a non-zero ω in the estimation of the AS equation, for both sectors.

[12] With a firm-specific labor market k in (35) should be multiplied by the factor $(1+\eta\bar{\sigma})$ where η is the inverse of the Frisch elasticity of labor supply.

Our results are in line with the ones obtained by Guerrieri et al. [25] which, by comparing an unrestricted and a restricted specification for the AS, also find evidence that foreign competition plays an important role in accounting for the behavior of inflation in the traded-goods sector. However, besides some differences in the estimation strategy, our results differ critically both in terms of the micro-foundations chosen to explain the globalization phenomenon and in terms of the dataset chosen for the estimation. We believe indeed that trade globalization is better captured by a model of oligopolistic competition between domestic and foreign firms and that the manufacturing sector is the more exposed to this phenomenon.

7 Conclusions

Much discussion has been devoted in recent years over the effects of globalization. While the globalization process takes different forms, we focus on one particular aspect which is the surge in the fraction of firms selling abroad. Competition in international market renders the pricing decision of firms more dependent upon foreign factors, hence reduces the dependence of inflation on the domestic slack. Such increased link between domestic inflation and global factors occurs through two main channels: first, an increase in the impact of import prices on the overall price index due to an increase in the number of foreign products in domestic markets; second, an increase in the dependence of the pricing strategies of domestic firms on foreign components, due to the increase in competition with foreign firms. Interestingly the reduced form of the Phillips curve changes by shifting with relative-price movements and the sensitivity of inflation to marginal costs changes with globalization. Moreover, as far as firms' pricing decisions are affected by the relative market shares between domestic and foreign firms competing in the same destination market, the degree of exchange rate pass-through rises with an increase in the number of foreign competitors. Our theoretical results are confirmed through an empirical analysis based on manufacturing sectors in the US. Indeed there is evidence of an increase in the degrees of pass-through in most of the sectors considered. Moreover, estimation of the AS equation for the manufacturing sector provides evidence for the importance of the relative-price channel in accounting for the dynamic of inflation as emphasized by our model.

The dependence of inflation upon global factors might have important implications for the conduct of monetary policy as it might reduce the leverage that central bankers have in controlling prices, a topic, the latter, that we leave for future research.

8 Appendix: Data

Pass-through analysis

The data used have quarterly frequency on the sample 1993q1-2008q4.

Industry-specific real exchange rate data are taken from Linda Goldberg web site. They correspond to the series "merman" of the Industry-specific exchange rate database. The index used is a multilateral exchange rate index elaborated by Linda Goldberg from United States International Trade Commission (USITC) import data.

Sectorial import prices data are taken from Bureau of Labor Statistics (BLS) web site and correspond to the Harmonize System Import Index. The index is an industry-specific multilateral import price following the one digit Harmonized System classification (HS). The original series have monthly frequency, hence, in order to obtain a quarterly series the average value of three months for each quarter has been considered.

Data on sectorial import prices and sectorial import exchange rate have been aggregated into 5 sectors using the Relative Importance Index of Table 3 and 5 from the historical tables of U.S. Import and Export Price Indexes of BLS . The following sectors are considered:

Sectors	HS sectors	NAICS sectors
Vegetables and prepared food	II – IV	311 – 312
Leather and footwear	VIII – XII	316
Textiles and textile articles	XI	313 – 314
Vehicles, vessels and transport equipment	XVII	336
Base metals and machinery	XV – XVI	331 – 332 – 333 – 334 – 335

In this way the variables q_t and p_t were obtained. While the variables Δq_t and Δp_t are the log-difference of the respective series.

Sectorial index of concentration data are taken from Economic Census: Concentration ratios, years 1997 and 2002 . In particular the Herfindahl-Herschmann index for 50 largest companies from the Economic Census has been used. Data are available, for each three digits NAICS sector, only for years 1997 and 2002.

Data on sectorial import share from China are taken from United States International Trade Commission (USITC) web site. For each sector, to obtain Chinese import share, sectorial imports from China were divided by sectorial total imports. Sectorial imports correspond to "custom-value" series.

Aggregate-Supply analysis

The data for prices and unit labor costs for the manufacturing sector and non-farm business sector are from BLS and available on a quarterly basis. Sectorial import prices data are taken from Bureau of Labor Statistics (BLS) web site and correspond to the Harmonize System Import Index. The index is an industry-specific multilateral import price following the one digit Harmonized System classification (HS). The original series have monthly frequency, hence, in order to obtain a quarterly series the average value of three months for each quarter has been considered. Data on sectorial import prices have been aggregated into a single import price using the Relative Importance Index of Table 3 and 5 from the historical tables of U.S. Import and Export Price Indexes of BLS .

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	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5
1993 – 2000	-0.30	-0.19	-0.10	-0.59	0.77
2001 – 2008	2.35	0.57	0.26	1.05	0.59

Table 1: Ratio between the log-change in import price and the log-change in the real exchange rate ($\Delta p/\Delta q$) computed on the intervals 1993-2000 and 2001-2008 for the five sectors considered: 1) vegetables and prepared food, 2) leather and footwear, 3) textiles and textile articles, 4) vehicles, vessels and associated transport equipment, and 5) base metals and machinery.

	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5
Model (A)	0.497^{***}	0.192^{***}	0.081^{**}	0.130^{***}	0.669^{***}
Until 2001 Q1	0.259	0.158^{***}	0.124^{**}	0.153**	0.631^{***}
After 2001 Q1	0.483**	0.290^{***}	0.059	0.159^{***}	0.645^{***}
Model (B)	0.540^{**}	0.201^{***}	0.083^{*}	0.080^{**}	0.711^{***}
Until 2001 Q1	0.168	0.147^{***}	0.115	0.108*	0.840*
After 2001 Q1	0.560	0.288^{***}	0.042	0.103***	0.699^{***}
Model (C)	0.409^{***}	0.154^{***}	0.076^{***}	0.086^{***}	0.439^{***}
Model (D)	0.554^{***}	0.164^{***}	0.095^{***}	0.087^{***}	0.630^{***}

Table 2: Estimated pass-through coefficients for Sector 1 (vegetables and prepared food), Sector 2 (leather and footwear), Sector 3 (textiles and textile articles). Model (A) corresponds to equation (36), Model (B) corresponds to equation (37). Model (C) to the following equation $\Delta_y p_t = c + \beta_0 \Delta_y s_t + \varepsilon_t$ where Δ_y represents the one-year difference operator. Model (D) corresponds to the following equation $\Delta_{2y} p_t = c + \beta_0 \Delta_{2y} s_t + \varepsilon_t$ where Δ_{2y} represents the two-year difference operator. Stars denote significance level, ***=1%, **=5%, *=10%.

	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5
1997	219.28	167.2	115.13	797.6	85.41
2002	229.22	163.6	185.48	526.9	92.15

Table 3: Herfindahl-Herschmann index of market concentration for the five sectors considered: 1) vegetables and prepared food, 2) leather and footwear, 3) textiles and textile articles, 4) vehicles, vessels and associated transport equipment, and 5) base metals and machinery.

	Manufacturing sector (1)	(2)	Non-farm business sector (3)	(4)
	Full Sample 1993-2008			
k	0.000 (0.024)	0.025 (0.069)	0.010 (0.048)	0.057 (0.131)
ω	0	0.32* (0.19)	0	0.04 (0.032)
	Sample 1993-2000			
k	0.001 (0.0116)	0.001 (0.0202)	0.024 (0.0471)	0.019 (0.0523)
ω	0	0.25 (4.21)	0	0.05 (0.148)
	Sample 2001-2008			
k	0.002 (0.0275)	0.1 (0.2429)	0.02 (0.1098)	0.087 (0.2969)
ω	0	0.37** (0.1507)	0	0.05* (0.0295)

Table 4: Estimates of k and ω in equation (38) for the manufacturing and non-farm business sector. In columns (1) and (3) ω is restricted to be equal to zero. Data are quarterly. Three different samples are considered: 1993-2008, 1993-2000, 2001-2008.

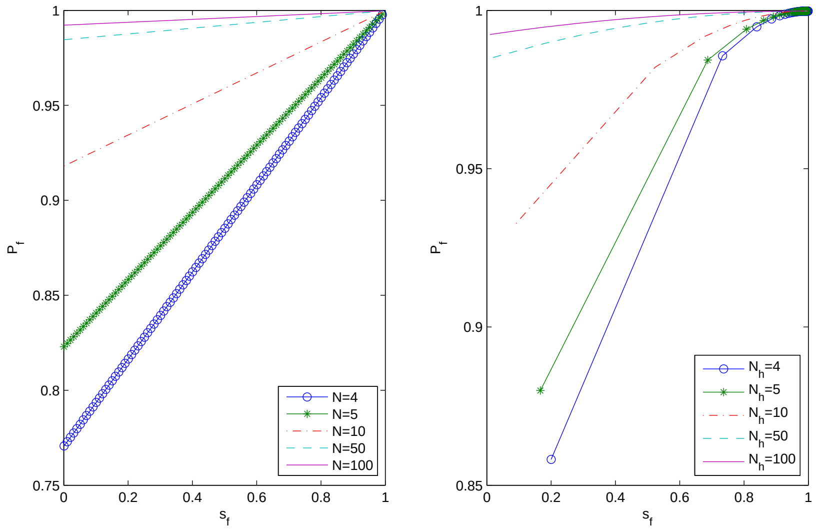

Figure 1: Long-run pass-through ($\partial\hat{P}_{f,t}/\partial\hat{S}_t$) as a function of the share of foreign products in the domestic market, s_f. On the left panel, N is fixed (at different levels) and s_f is varied from 0 to 1. On the right panel, N_h is fixed (at different levels) and N_f varies from 0 to infinity to imply variation in s_f.

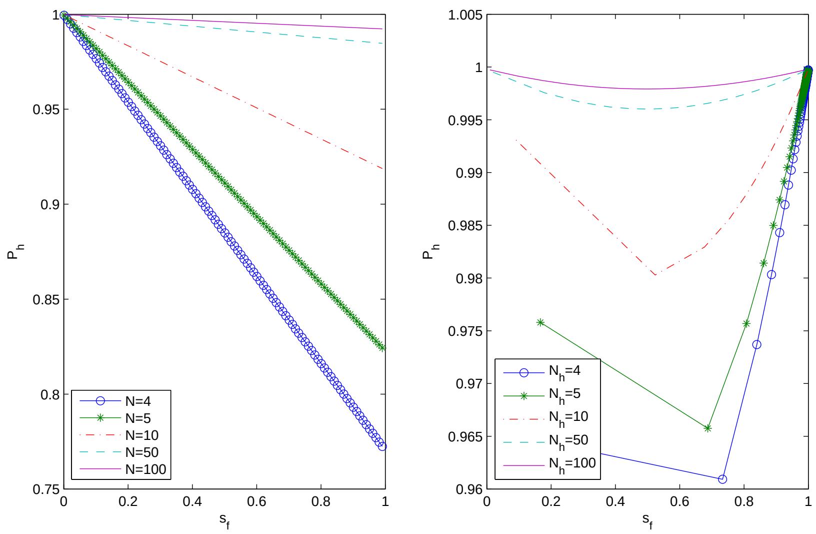

Figure 2: Long-run response of domestic prices to domestic wages ($\partial\hat{P}_{h,t}/\partial\hat{W}_t$) as a function of the share of foreign products in the domestic market, s_f. On the left panel, N is fixed (at different levels) and s_f is varied from 0 to 1. On the right panel, N_h is fixed (at different levels) and N_f varies from 0 to infinity to imply variation in s_f.

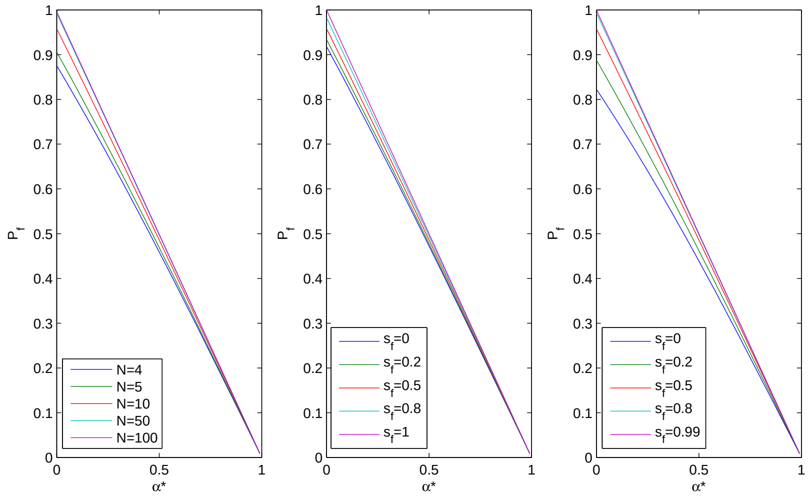

Figure 3: Short-run exchange-rate pass-through $(\partial \hat{P}_{f,t}/\partial \hat{S}_t)$ as a function of α^*, measuring the degree of nominal rigidity of foreign firms. On the left panel N is fixed at different levels and $s_f = 0.5$. In the middle panel s_f is set at different levels and $N = 10$. On the right panel, s_f is also set at different levels while $N_h = 5$.

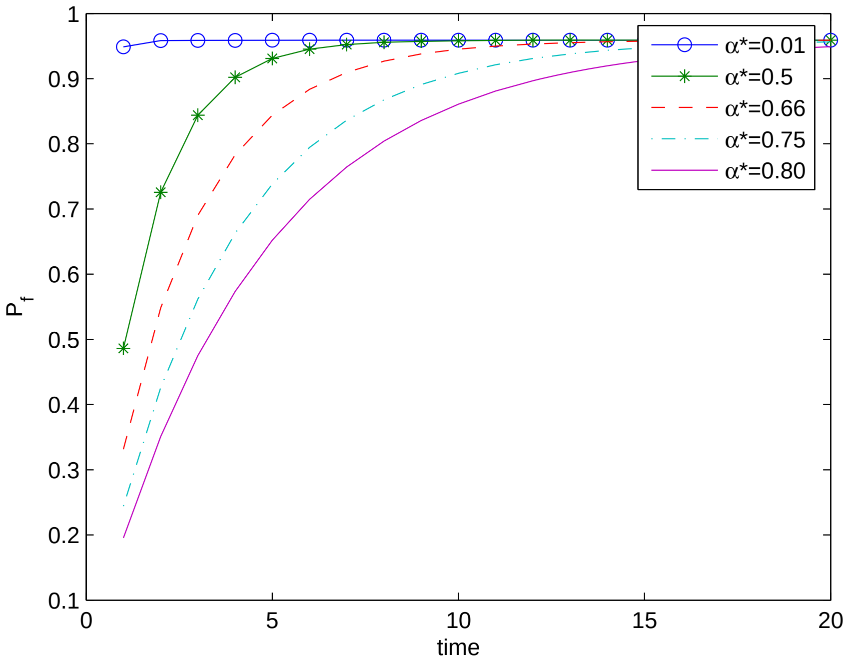

Figure 4: Impulse response function of foreign prices, $P_{f,t}$, to an unitary shock to the nominal exchange rate for different degress of nominal rigidities in the foreign economy, α^*.

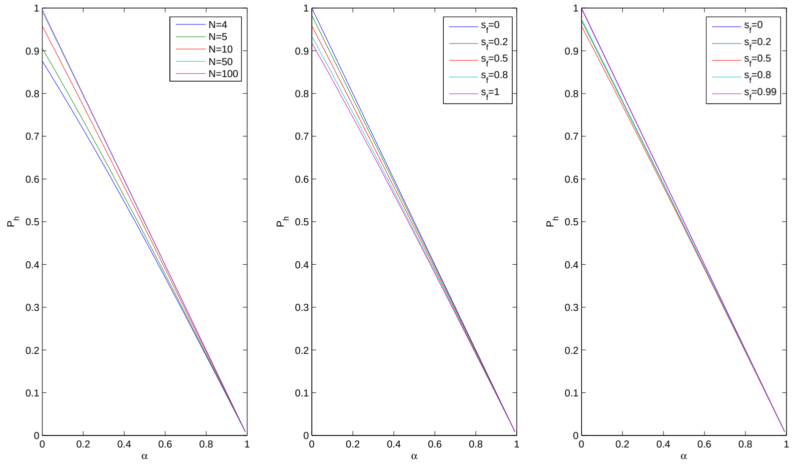

Figure 5: Short-run sensitivity of domestic prices to domestic wages ($\partial\hat{P}_t/\partial\hat{W}_t$) as a function of α, measuring the degree of nominal rigidity of firms based in country h. On the left panel N is fixed at different levels and $s_f = 0.5$. In the middle panel s_f is set at different levels and $N = 10$. On the right panel, s_f is also set at different levels while $N_h = 5$.

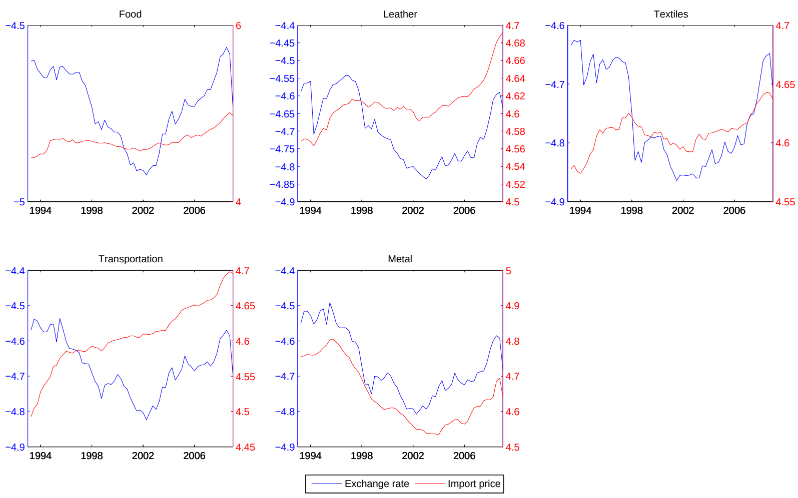

Figure 6: Plot of the logs of the real exchange rate and of the nominal import price for the five sectors considered.

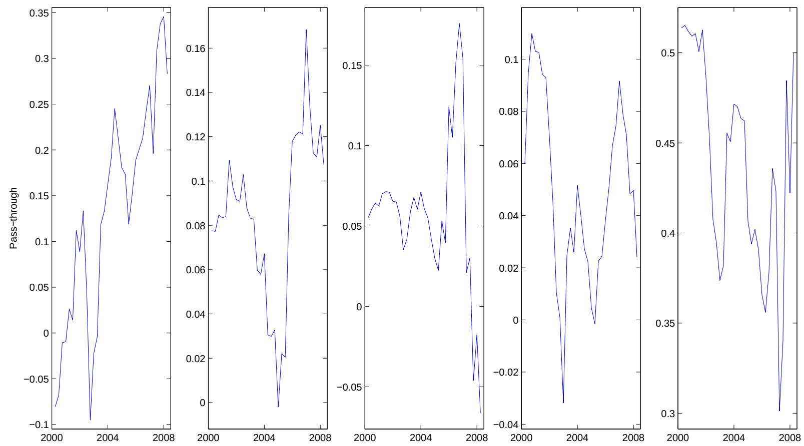

Figure 7: Pass-through for each of the five sectors considered, estimated using the model (36) on 8-year rolling window. For example, the values obtain in the year 2002 at the first quarter corresponds to the estimation window 1994.Q1-2002.Q1.

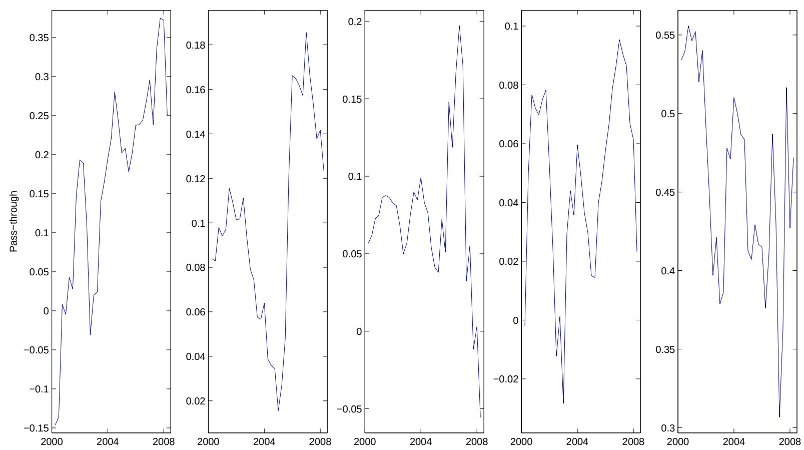

Figure 8: Pass-through for each of the five sectors considered, estimated using the model (37) on 8-year rolling window. For example, the values obtain in the year 2002 at the first quarter corresponds to the estimation window 1994.Q1-2002.Q1.

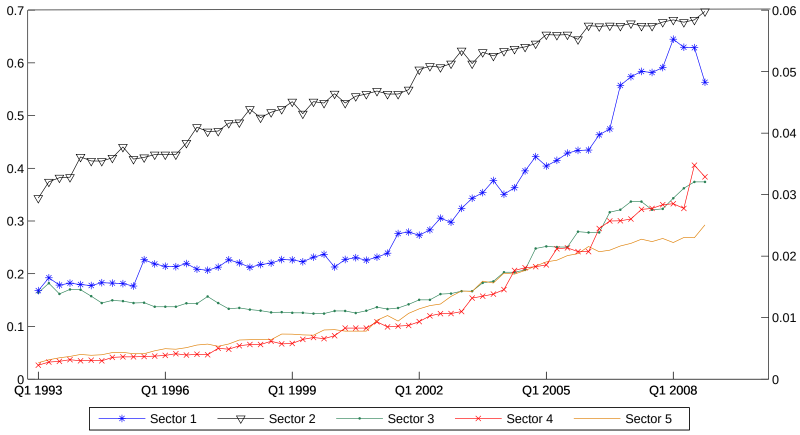

Figure 9: Import share from China for the five sectors considered: 1) vegetables and prepared food, 2) leather and footwear, 3) textiles and textile articles, 4) vehicles, vessels and associated transport equipment, and 5) base metals and machinery. Sector 1 and 4 plotted on a secondary axis.

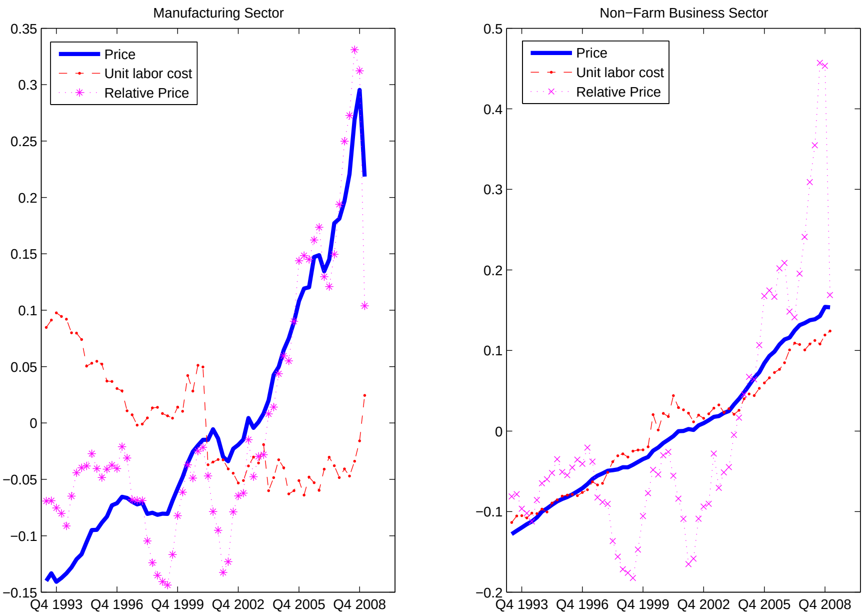

Figure 10: Plot of the price, unit labor cost and relative price for the manufacturing sector (left panel) and the non-farm business sector (right panel). All variables in logs and demeaned.