Globalization, Pass-Through, and Inflation Dynamics*

Pierpaolo Benigno[a] and Ester Faia[b]
[a]LUISS Guido Carli and EIEF
[b]Goethe University Frankfurt and CEPR

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's (1987) 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 supporting the implications of our model.

JEL Codes: F40, F60.

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 policymakers. One important theme, which has been the subject of considerable discussion, has been the "global slack"

*We are grateful to the Fondation Banque de France for a grant sponsoring this project. We thank Matteo Bugamelli, Linda Goldberg, Luca Guerrieri, Argia Sbordone, Stephanie Schmitt-Grohe, Etsuro Shioji, Yuki Teranishi, and Mark Wynne for helpful suggestions and comments, two anonymous referees, and seminar participants at the Banque de France, ESSIM and at the conferences on "Globalization and Monetary Policy" organized by the Bank of Korea and Bank of Canada and on "Future of Central Banking under Globalization" organized by the Bank of Japan and at the Sveriges Riksbank. Dirk Bursian, Eleni Iliopulos, Hermes Morgavi, Natasha Rovo, and Federica Romei have provided excellent research assistance.

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 firms' globalization affects inflation dynamics. First, we ask how globalization, interpreted as an increase in the share of goods sold by foreign firms in the domestic market, affects the dynamic of imported inflation through its influence on the pass-through of exchange rate into import prices. The second channel through which globalization influences the dynamic of inflation occurs, indirectly, through its effect on the pricing strategies and the degree of competition of domestic firms selling in the domestic market. We show that this channel changes the slope and the position of the New Keynesian aggregate supply equation.

To address these issues we extend Dornbusch's (1987) model to a dynamic context with price stickiness. Domestic and foreign firms compete in a strategic way to increase their market shares via their pricing decisions. In this context, the price markup becomes a function of each 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 markups.

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 upon the share of foreign products in the market and upon the degree of market concentration. Greater competition, due to the increase in the share of foreign products sold in a specific industry—a phenomenon strongly connected with globalization—raises the degree of exchange rate pass-through, both in the short and in the long run. Through this channel, globalization amplifies the dependence of imported good inflation upon external conditions. Our theoretical results are confirmed through an empirical analysis based on sectors belonging to the harmonized system (HS) classification. Changes in import prices for a number of sectors are regressed on past changes in the same prices and on current and past changes

[1] See, among others, Bernanke (2007), Borio and Filardo (2006), Fisher (2006), and Rogoff (2003).

of the effective exchange rate. By using alternative tests to identify the intensification of the globalization process, we repeat estimations on the data samples before and after the break points, showing an increase of pass-through in at least half of the sectors considered. To deepen the assessment of the role of competition and foreign firm penetration, we regress the pass-through coefficient, estimated via rolling-window samples, over an index of foreign firms' market penetration, which we proxy with the share of imports from China over total imports. Further robustness of the penetration index is assessed by subsequently adding the Herfindhal concentration index in the regression. We find that an increase in the penetration index increases pass-through and the relation is statistically significant.

Our framework also 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 in 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 2008), which can shift the Phillips curve for a given domestic output gap. This channel runs as follows. When foreign prices decrease and terms of trade improve, there are inflationary pressures on domestic prices. This shifts the Phillips curve upward. Woodford (2007) pointed out that such a shift is actually at odds with the conventional view regarding the effects of globalization on inflation dynamics. The *relative price* channel emphasized by our model can rationalize common wisdom, as an increase in the share of imports moves 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 the reduced-form Phillips curve implied by our model. We use U.S. data for the non-farm business sector and the manufacturing sector and compare the estimation's results across the two sectors. There are two main results. First, the relative price channel is crucial in improving the fit and the estimates of the traditional aggregate supply (AS) curve. The literature has already discussed the difficulties for the estimates of the traditional Phillips curve to deliver robust and significant results (most notably Fuhrer 2009): our relative price channel can provide one of the missing links. Second, and consistently with the model, we find that the relative price channel is stronger in the second part of the sample, after 1999, which coincides with the pickup of trade globalization.

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 estimation of the New Keynesian AS equation with our new channel. Section 7 concludes.

2. Comparison with the Literature

Our paper is related to an extensive literature which has assessed the degree of exchange rate pass-through (see Goldberg and Knetter 1997 for a seminal contribution) and to a more recent literature studying the impact of globalization on inflation dynamics.

We base our analysis on a model presented by Dornbusch (1987) which, to our knowledge, is the first example of a Dixit-Stiglitz model of imperfect competition extended to include strategic interaction among firms. Dornbusch (1987) already derives a relationship between prices and marginal costs based on a non-constant markup, showing that it depends on the strategic interaction between firms. He also discusses the possibility that exchange rate pass-through can be imperfect. In this respect, our contribution is to analyze more deeply, using log-linear approximations, the relationship between industry prices and exchange rates and relate it to the market size, the share of competing foreign firms, and to the elasticities of substitution across goods within and across industries. Of course, our model shares similar features with other models of imperfect competition built on Dornbusch (1987), like Atkeson and Burstein (2008), who study fluctuations in relative purchasing power parity. However, in the latter work, firms compete on quantities rather than on prices, unlike our model.[2] In a contemporaneous work, Auer and Schoenle (2012) have also used strategic pricing in a model à la Dornbusch (1987) and derived a similar relationship between pass-through and firms' market share.[3] Their focus is not on the impact of globalization on the exchange rate pass-through. However, they investigate more deeply the empirical implications of the theory along several dimensions that we do not explore in our work, including the cross-sectional price distribution among firms. The competitive effect of globalization discussed in our model resembles that explored by Chen, Imbs, and Scott (2009), who follow Melitz and Ottaviano (2008). The latter work shows that greater competition by foreign firms and an increased share of imports induce a fall in profit margins and markups. The important difference is that firms' heterogeneity is not essential in our framework, as the competitive effect is determined by the strategic interaction among firms. The role of market competition is also considered from a different angle in Bodnar, Dumas, and Marston (2002), who focus on the relationship between the exposure of firms' profits to exchange rate fluctuations and the exchange rate pass-through. Finally, there is a related extensive literature which has studied alternative ways to capture imperfect pass-through of marginal costs to prices. Rotemberg and Woodford (1992) also adopt a collusive oligopolistic market structure to derive a non-constant markup model showing that in this case the markup can be a function of the industry's expected profits. Ravn, Schmitt-Grohe, and Uribe (2010, 2012) exploit preferences displaying deep habits to build a dynamic demand function, which also features an imperfect pass-through of costs into prices. Gopinath and

[2]Soto and Selaive (2003) develop a general equilibrium model of oligopolistic competition in which firms compete on quantities rather than on prices.

[3]The link between exchange rate pass-through and market share has originally been discussed and tested by Feenstra, Gagnon, and Knetter (1996), who show that pass-through should be high for exporters with large market shares.

Itskhoki (2007) and Gust, Leduc, and Vigfusson (2010) use instead a non-isoelastic demand function in line with Kimball's (1995) preferences. In contrast to our findings, Gust, Leduc, and Vigfusson (2010) argue that trade integration has led to a decline in exchange rate pass-through. As proxies of trade integration, they use the fall of an iceberg trading cost faced by foreign firms and the increase in their productivity. However, market size and shares remain invariant in their model. Instead, our focus is on how changes in the market composition and size directly affect pass-through without tracing them back to their determinants.

One further contribution of our paper is to extend the imperfect-competition model of Dornbusch (1987) to a dynamic context with price frictions. Our model delivers a New Keynesian AS equation suitable to analyze the impact of globalization on inflation dynamics. In this respect, our approach competes with a recent literature addressing the same theme but using different features. Sbordone (2007) exploits Kimball's (1995) preferences to introduce time-varying demand elasticities into a closed-economy model with a standard Calvo (1983) pricing mechanism. She finds that the relation between trade globalization (modeled as an increase in the number of varieties) and the slope of the Phillips curve changes depending on the parameters' configuration. Guerrieri, Gust, and Lopez-Salido (2010) apply Kimball's (1995) preferences to an open-economy model and derive a reduced New Keynesian Phillips curve, in which domestic inflation (but not the slope of the Phillips curve) also depends on the ratio between prices of imported goods and domestic prices. Our model delivers a similar New Keynesian Phillips curve but based on specific microfoundations which capture firms' strategic behavior and therefore imply different relationships between the parameters of the curve and indexes of international competition.

We use our theoretical model to derive two sets of empirical implications that we test. Globalization, which is proxied by a higher share of foreign firms in the domestic market, should imply an increase in the degree of exchange rate pass-through and shifts of the domestic AS equations mainly driven by movements in the relative price of foreign with respect to domestic goods.

To test the first implication, we use U.S. sectoral import prices taken from the Bureau of Labor Statistics (BLS) and corresponding to the one-digit harmonized system classification. Results on the direction of pass-through are mixed but show, for a significant number of sectors, evidence supporting our theoretical results. The extensive empirical literature on the argument shares the ambiguity of our results. Campa and Goldberg (2005) find a weak tendency toward a decline in exchange rate pass-through rates which is statistically significant for only four out of twenty-three OECD countries, albeit not for the United States. Campa and Goldberg (2008) also find mixed evidence: by examining pass-through of exchange rate movements into import prices of manufacturing sectors of OECD countries, they indeed uncover cases in which it has increased and cases in which it has decreased.[4] Marazzi and Sheets (2007) instead find compelling evidence for a declining exchange rate pass-through to an aggregate index of U.S. import prices.[5] In comparison with Campa and Goldberg (2005, 2008), they argue that the inclusion in the regression of a control for movements in oil and other commodity prices is critical for the result. We work with relatively more disaggregated data than Marazzi and Sheets (2007) and also test our implications by including a measure of commodity prices in line with their suggestion. In this case, the number of sectors in which we find an increased pass-through is lower, but we still find an overall balance between increasing and decreasing cases.

Finally, the analysis of the impact of globalization on the AS equation confirms the findings of Guerrieri, Gust, and Lopez-Salido (2010) showing that the relative price of foreign with respect to domestic goods is a significant variable to include in order to explain inflation dynamics. As a price index, we use BLS data on the non-farm business sector and the manufacturing sector, while they use a tradable goods price index. Moreover, in line with our theoretical implications, we show that the additional open-economy variable is more relevant in the last part of our sample, therefore capturing the effects of globalization on domestic inflation dynamic.

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

[4]Their data set covers the period 1976–2004. The break is placed in 1995.

[5]Gust, Leduc, and Vigfusson (2010) also discuss some evidence for a decline in pass-through in a data set that includes forty finished goods industries.

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 of a generic good i, produced in country h and belonging to a sector k, is given by

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

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

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

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

Following Dornbusch (1987), 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 sectoral price. 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

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

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 occurs 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 sectoral aggregate prices. The empirically relevant case is the one in which the elasticity across different varieties, within a single sector, is higher than that across sectors, implying a $\tilde{\sigma}_i$ which is a decreasing function of firm's i market share. In the limiting case where 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, and Y_f are prices and output in country h for firms resident in country h and f, respectively.

Our model implies that variation in the market share causes changes in the markup. 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 the pro-competitive effect since it echoes the ones analyzed in Chen, Imbs, and Scott (2009), Ghironi and Melitz (2005), and Melitz and Ottaviano (2008) in models that allow for firm heterogeneity. Notice that this pro-competitive channel survives in our model even in the 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, and 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. Later, we introduce sticky prices.

It is useful to question why the possibility of rent extraction is not caught by domestic firms prior to the entrance of foreign firms. The fundamental explanation would rest on comparative advantage and efficiencies of foreign firms. It might well be that wages in the foreign country are too low or technological innovations spanning the whole range of tastes in the constant elasticity of substitution (CES) aggregator only happen to realize through foreign firms. We do not model these comparative advantages, but rather take them as granted within the framework of our partial equilibrium analysis.

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 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:

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

showing that prices are set as a time-varying markup 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 read 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 labor market (denominated in foreign currency), and A_t^* is the common productivity shifter for firms based in country f. Prices in (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

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

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

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-deviations 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., $\partial \hat{P}_{f,t} / \partial \hat{S}_t$. Pass-through is full when the response is unitary.

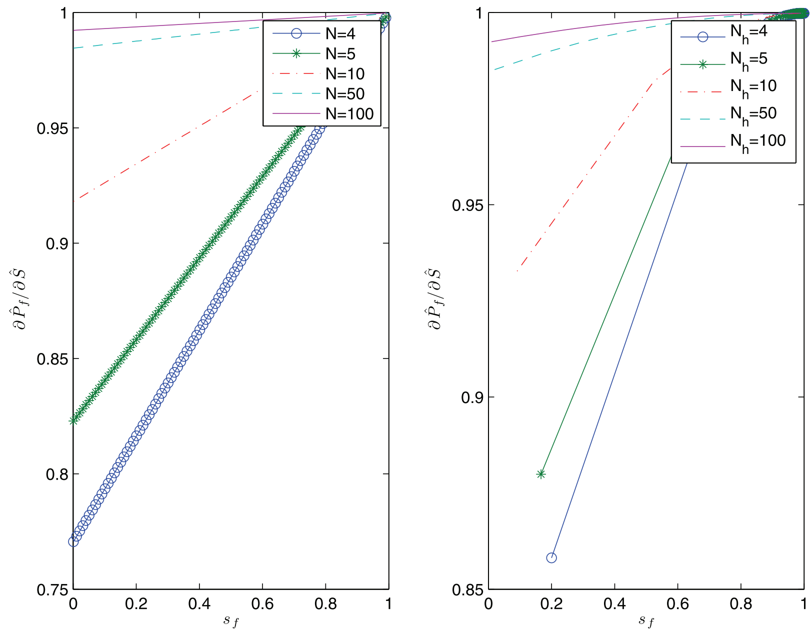
Proposition 1. *With flexible prices, the degree of pass-through is unitary when one of the following conditions is met: (i)* $\sigma = \theta$; *(ii)* $N \rightarrow \infty$; *(iii)* $s_h = 0$.

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 sectoral aggregate prices and therefore a constant elasticity of demand implies full pass-through. The power of firms to affect sectoral aggregate prices is also nil under the second condition, $N \rightarrow \infty$. In this case, the market share of each firm becomes negligible like in a monopolistically competitive market. Finally, in the third case ($s_h = 0$), foreign firms dominate completely the domestic market and therefore 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 markup. 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 number 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

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



Notes: In the left panel, N is fixed (at different levels) and s_f is varied from 0 to 1. In the right panel, N_h is fixed (at different levels) and N_f varies from 0 to infinity to imply variation in s_f.

market. Consistent with the theoretical results, the pass-through is 1 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 1.

4.2 Response of Domestic Prices to Domestic Conditions

In 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 policymakers 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:

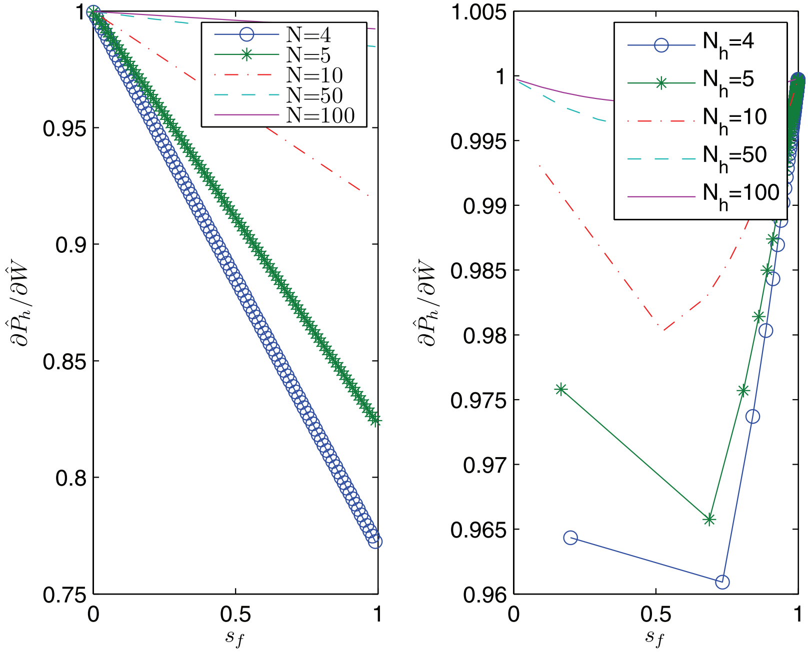
$$\hat{P}_{h,t} = \frac{\kappa s_f}{1+\kappa}(\hat{W}_t^* + \hat{S}_t - \hat{A}_t^*) + \frac{1+\kappa(1-s_f)}{1+\kappa}(\hat{W}_t - \hat{A}_t), \qquad (13)$$

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

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 have spillover effects 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. Conversely, 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 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

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



Notes: In the left panel, N is fixed (at different levels) and s_f is varied from 0 to 1. In the right panel, N_h is fixed (at different levels) and N_f varies from 0 to infinity to imply variation in s_f.

x-axis) and for different (given) values of N. The right 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 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 raises 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 enters 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 (1982).[6] There are three main implications 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 and the sensitivity of prices to movements in the marginal costs. Moreover, the presence of price rigidities allows one 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.

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:

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

[6] Alternative models of price-setting decisions—as, for example, Calvo (1983)—could have been considered.

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 markup over nominal marginal costs:

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

However, in this case, the markup 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 $\pi_{i,t} \equiv P_{i,t}/P_{i,t-1} - 1$.[7]

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

[7] We focus on a symmetric equilibrium in which all firms within a sector set the same price. However, it might be possible that there are multiple equilibria given the non-linearity of the right side of (17). In what follows, we abstract from them.

by variation in firms' market share. When N approaches infinity, namely under a monopolistically 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 firms' 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 upon 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 (1995) preferences and monopolistic competition, Sbordone (2007) also finds that the slope of the curve is influenced by the number of varieties in the market; however, in her case such relation changes direction depending on parameters' calibration.[8]

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 markup of domestic firms. This influence is captured by the second term in the square bracket of equation (19). In the canonical open-economy model (see Benigno and Benigno 2008), the AS equation 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 $\tilde{k}$. In particular, the open-economy channels influencing the inflation dynamics are hidden under the decomposition of the real marginal costs, which is the sum of the output gap and terms of trade. In particular, foreign prices influence the terms of trade and then the real marginal cost. Woodford (2007) has noticed that in this model the "global slack" hypothesis might be

[8]Sbordone (2007) uses a Calvo model which implies a different and opposite relationship than the Rotemberg model between the slope of the AS equation and the parameter $\bar{\sigma}$.

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.

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, Gust, and Lopez-Salido (2010), although in their model it arises assuming kinked demand as in Kimball (1995). On the contrary, in our model, it depends on primitive foundations based on firms' strategic interaction. Those differences allow us to interpret the primitive parameters of our model in light of the pro-competitive effects typical of the globalization process. In particular, the additional relative price channel disappears under two circumstances. The first is when all firms become small in size (N goes to infinity, implying that κ goes to zero); this nests the case of a monopolistically competitive market. The second circumstance is 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 that κ goes to zero. To appreciate the contribution of our more microfounded model, note the difference with Guerrieri, Gust, and Lopez-Salido (2010) in which the additional relative price channel disappears only when there are no foreign products in the domestic market.

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. This channel is not present in Guerrieri, Gust, and Lopez-Salido (2010). 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 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. We leave to the working paper version, Benigno and Faia (2010), the detailed solution of the model. Here we briefly summarize the main implications. The degree of pass-through is decreasing when price rigidity of foreign firms increases. Moreover, for a fixed level of rigidity, the higher the concentration in the industry, the lower is the pass-through, but also, when rigidity increases, the concentration in the industry has a smaller impact on the degree of pass-through. In general, globalization might increase the degree of pass-through, for a given degree of nominal rigidity—the more so the lower the degree of rigidity. Concerning domestic prices, their response 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. Globalization should therefore reduce the response of prices to domestic conditions—the more so the lower 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 raises the degree of exchange rate pass-through. In particular, this depends on the share of foreign products competing in the domestic market and on the degree of concentration in the reference market. Greater competition, due to an increase in the foreign products sold in a particular industry, raises the exchange rate pass-through both in the short and in the long run.

To test this channel we proceed in various steps using data at an aggregate level corresponding to the one-digit harmonized system (HS) classifications. The appendix discusses in detail the sectors analyzed. Data are monthly and the sample goes from 1993 (M12) to 2012 (M2). Sections III, XIX, and XXI in the HS classifications are excluded because data are available on a shorter sample or missing. We shall note that our data sample is rather short, an unavoidable constraint for us. This plays against the statistical significance of the results, at least for some sectors. But precisely for this reason, we read the results reported below as reasonably good given the constraints.

To study exchange rate pass-through, we run seemingly unrelated regressions on a model with the following benchmark specification:

$$\Delta p_{k,t} = c_k + \sum_{j=1}^{n} \gamma_{k,j} \Delta p_{k,t-j} + \sum_{j=0}^{m} \beta_{k,j} \Delta s_{t-j} + \varepsilon_{k,t}, \tag{21}$$

where $\Delta p_{k,t}$ represents the change in log nominal import price of a generic sector k at time t and Δs_t represents the change in the U.S. effective nominal exchange rate, c_k is a generic constant, $\gamma_{k,i}$ measures the dependence of price changes to its lag values at time $t-i$, and $\beta_{k,j}$ is the sector-specific coefficient measuring the response of prices to nominal exchange rate movements at lag $t-j$.[9] With Stein's unbiased risk estimator (the SURE estimator), we are allowing the unobserved shocks $\varepsilon_{k,t}$ to co-vary across the different sectors. We define the long-run pass-through as $\sum_{j=0}^{m} \beta_{k,j}/(1 - \sum_{i=1}^{n} \gamma_{k,i})$.

We also consider the following alternative specifications for computing the price increments: yearly differences, $\Delta_y p_t$, and two-year differences, $\Delta_{2y} p_t$. We regress them on the corresponding time differences of the nominal exchange rate as follows:

$$\Delta_y p_{k,t} = c_k + \beta_k \Delta_y s_t + \varepsilon_{k,t}, \tag{22}$$

$$\Delta_{2y} p_{k,t} = c_k + \beta_k \Delta_{2y} s_t + \varepsilon_{k,t}. \tag{23}$$

Results on the long-run degree of pass-through are shown in table 1, where model A corresponds to (21), model B to (22), and model C to (23). The table shows that for all the sectors, except for sector I, the pass-through coefficients are positive and significantly different from zero across all the specifications. Large values are found in sectors V, XIV, and XV, which correspond to mineral products, stone and precious metals, and base metals, respectively.

To study the effect of globalization on the degree of pass-through, we investigate whether it has changed in recent years and, in particular, if there has been a noticeable increase in the last decade. We run the regression on model (21) by splitting the sample into two parts. We do this according to two different criteria. First, we use the share of import from China in the United States as a proxy of the

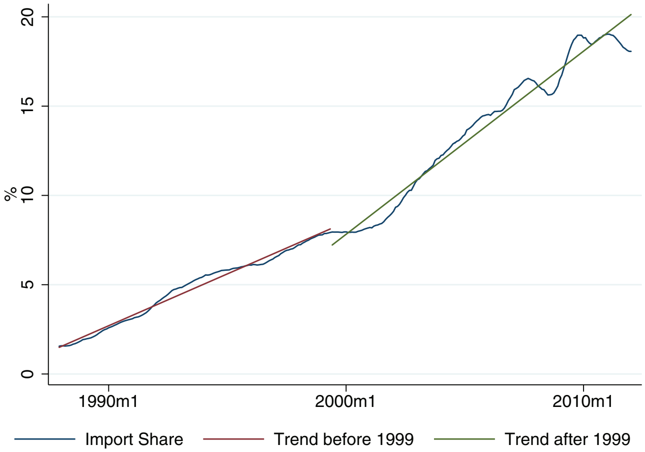
[9] Lags are chosen according to the Akaike information; therefore n is set to 2 and m to 2.

Table 1. Estimated Pass-Through Coefficients for Sectors in the HS Classifications

Sector	Model A	Model B	Model C
I	−0.17	−0.04	0.17**
	(0.16)	(0.07)	(0.06)
II	0.56**	0.78***	0.96***
	(0.23)	(0.11)	(0.09)
IV	0.27***	0.34***	0.44***
	(0.05)	(0.03)	(0.03)
V	1.77***	3.2***	2.56***
	(0.60)	(0.27)	(0.23)
VI	0.39***	0.45***	0.56***
	(0.08)	(0.04)	(0.04)
VII	0.34***	0.52***	0.67***
	(0.07)	(0.04)	(0.03)
VIII	0.08***	0.13***	0.16***
	(0.02)	(0.02)	(0.02)
IX	0.25	0.45***	0.47***
	(0.24)	(0.11)	(0.08)
X	0.34	0.34***	0.49***
	(0.21)	(0.1)	(0.07)
XI	0.09**	0.12***	0.11***
	(0.04)	(0.02)	(0.02)
XII	0.01	0.03**	0.06***
	(0.02)	(0.01)	(0.01)
XIII	0.04	0.07***	0.17***
	(0.03)	(0.02)	(0.03)
XIV	0.63***	0.83***	0.84***
	(0.16)	(0.1)	(0.09)
XV	1.18***	1.11***	1.36***
	(0.21)	(0.1)	(0.07)
XVI	0.16***	0.21***	0.28***
	(0.03)	(0.02)	(0.02)
XVII	0.08***	0.08***	0.07***
	(0.02)	0.01	(0.009)
XVIII	0.16***	0.17***	0.022***
	(0.03)	(0.02)	(0.01)
XX	0.08***	0.09***	0.16***
	(0.02)	(0.02)	(0.02)

Notes: Full sample 1993:M12–2012:M2. Model A corresponds to equation (21), model B corresponds to equation (22), and model C corresponds to equation (23). Standard errors are in parentheses. ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively.

Figure 3. Import Share from China in the United States, Break Point at 1999:M6.



Note: Trends before and after are shown.

trend in globalization. As shown in figure 3, there is a change in the trend identifiable in June 1999 through an Andrews (1993) test. We split the sample around this month and estimate the pass-through before and after this break. Results are shown in table 2.[10]

Evidence shows an increase in pass-through for ten out of eighteen sectors considered: sectors I (Live Animals and Animal Products), IV (Prepared Foods), V (Mineral Products), VI (Products of Chemical Industries), VII (Plastics and Related Articles), IX (Wood, etc.), XI (Textiles), XIV (Pearl, Stones, etc.), XV (Precious Metals), and XX (Miscellaneous Manufactured Articles). For the remaining sectors the pass-through decreased: specifically, this holds for sectors II (Vegetable Products), VIII (Raw Hides, etc.), X (Wood Pulp, etc.), XII (Headgear, Umbrellas, etc.), XIII (Stone, Cement), XVI (Machinery, Electrical Equipment, etc.), XVII (Vehicles, etc.), and XVIII (Optical, Photo, etc.).[11]

[10] In the table, the "stars" close to the roman numerals of the HS sectors refer to the significance of the break point through a Chow test.

[11] The table also shows when the difference between the coefficients of the two samples is statistically significant.

Table 2. Estimated Pass-Through Coefficients Using Model (21) for Sectors in the HS Classifications

Sector	Before 1996:M6	After 1999:M6
I	−0.28*	−0.11
	(0.16)	(0.22)
II	0.84	0.5**
	(0.63)	(0.24)
IV	0.07	0.32***
	(0.09)	(0.07)
V	−0.04	2.31***
	(1.2)	(0.73)
VI	0.22**	0.41***
	(0.1)	(0.1)
VII	0.03	0.38***
	(0.21)	(0.07)
VIII***	0.2***	0.05
	(0.06)	(0.03)
IX	−0.16	0.4
	(0.3)	(0.31)
X	0.88	0.15
	(1.17)	(0.12)
XI	0.03	0.12**
	(0.05)	(0.05)
XII*	0.05*	−0.01
	(0.02)	(0.03)
XIII	0.15**	0.00
	(0.07)	(0.04)
XIV	0.17	0.73***
	(0.12)	(0.22)
XV***	0.13	1.45***
	(0.33)	(0.26)
XVI**	0.29***	0.1***
	(0.07)	(0.02)
XVII	0.13***	0.07***
	0.04	(0.02)
XVIII***	0.33***	0.1***
	(0.07)	(0.03)
XX**	0.07*	0.09**
	(0.04)	(0.04)

Notes: The sample is split into two parts: 1993:M12–1999:M6 and 1999:M7–2012:M2. Standard errors are in parentheses. ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively. The "stars" next to the sector's roman numeral refer to a Chow test on the significance of the break date.

Table 3. Andrews Test for the Estimates (with Eight-Year Rolling Window) of Long-Run Pass-Through Coefficient Using Model (21)

Sector	Test	Break
I	1.17	2001:M5
II	0.71	2005:M11
IV	10.23**	2006:M1
V	8.73**	2006:M6
VI	2.79	2003:M8
VII	2.8	2000:M12
VIII	5.44	1998:M11
IX	3.8	2001:M11
X	2	2003:M5
XI	3.58	2003:M7
XII	3.9	1998:M11
XIII	12.9***	2007:M6
XIV	5	1999:M4
XV	12.98***	2003:M11
XVI	6.59*	2002:M5
XVII	1.56	1999:M8
XVIII	12***	1998:M11
XX	0.2	1998:M12

Notes: The table reports the sector, the value of the test, and the break point. ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively.

To gauge a second criterion for splitting the sample, we estimate (21) on a rolling-window basis of eight years and test for a break in the rolling estimates of the pass-through, separately for each sector, using again the Andrews (1993) test. Results of the tests are presented in table 3. There is a significant break only for a few sectors, IV, V, XIII, XV, and XVIII with different break dates. For all sectors, we divide the sample according to the break points identified by the Andrews test, even if not significant, and report estimates before and after the break. Results are presented in table 4: although the split is different, the results are in line with our previous analysis.

To deepen the assessment of the role of foreign firms' penetration on pass-through, we regress the pass-through coefficients

Table 4. Estimated Pass-Through Coefficients Using Model (21) for Sectors in the HS Classifications, Using Andrews Test to Split Sample

Sector	First Sample	Second Sample
I	−0.4**	−0.06
	(0.17)	(0.25)
II	0.73**	0.34
	(0.36)	(0.28)
IV	0.07	0.41***
	(0.07)	(0.07)
V	0.29	3.63***
	(0.73)	(0.86)
VI	0.2**	0.47***
	(0.08)	(0.13)
VII	0.06	0.39***
	(0.17)	(0.08)
VIII	0.23***	0.05
	(0.06)	(0.03)
IX	−0.44	0.52*
	(0.4)	(0.3)
X	1.09	0.07
	(0.7)	(0.09)
XI	0.01	0.2**
	(0.03)	(0.08)
XII	0.08**	−0.01
	(0.03)	(0.03)
XIII	0.15***	−0.07*
	(0.04)	(0.04)
XIV	0.17	0.74***
	(0.13)	(0.22)
XV	0.24	1.6***
	(0.19)	(0.33)
XVI	0.27***	0.09***
	(0.06)	(0.02)
XVII	0.13***	0.07***
	(0.04)	(0.02)
XVIII	0.38***	0.1***
	(0.07)	(0.02)
XX	0.06	0.09**
	(0.04)	(0.04)

Notes: The sample is split into two parts according to the break points identified using the Andrews test as shown in table 3. Standard errors are in parentheses. ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively.

(from model A), estimated via (eight years) rolling-window samples, on a foreign firm penetration index which is proxied by the share of imports from China over total sectoral imports. The index was taken from the U.S. Census Bureau and was available at yearly frequency.[12] We focus on analyzing the relationship between pass-through and the above-mentioned indexes for the sectors in which pass-through went up after the breakup date (sectors I, IV, V, VI, VII, IX, XI, XIV, XV, and XX). Table 5 shows the results. For all sectors (except sectors V and XX) we find a positive and significant (up to 95 percent confidence interval) relation between the pass-through and the penetration index. Note, in particular, that sector V behaves as an outlier given that the estimated coefficient appears strangely high and it is not significant at 95 percent.

To further assess the robustness of the results on the penetration index, we regress the estimated pass-through coefficients on both the China penetration index and a concentration/competition index, which we proxy with the Herfindhal index (also taken from the U.S. Census Bureau).[13] Results, not reported, show that while the coefficient on the China index remains mostly significant and positive, turning out positive also for sector V, the coefficients of the Herfindhal index are actually insignificant in all cases (except positive coefficients for sectors V and IX). There are two obstacles, both unavoidable, for which this regression might not work properly. The first relates to the classification of the sectors considered. Indeed the Herfindhal index follows a different classification, namely the North American Industry Classification System (NAICS). For this reason we had to match the sectors of NAICS classification with the sectors in the HS classification: the matching, although accurate, might be far from perfect, and at the end we had to disregard sectors I and XIV.[14] Furthermore, the Herfindhal index is not available on a regular basis throughout our sample. Second, the two indexes might be correlated with each other, as they both refer to market shares.

[12]In order to harmonize the data samples in terms of their frequencies, we have taken the end-of-year observation of the monthly pass-through estimated coefficients. See the appendix for details.

[13]We also considered two alternative indexes given by the share of value added of the fourth and eighth largest firms.

[14]See the appendix for a description of the matching.

Table 5. Linear Regression of Estimated Pass-Through Coefficients Using Model (21)

Var.	I	IV	V	VI	VII	IX	XI	XIV	XV	XX
China	0.36***	0.26***	−1.35	0.43***	0.42***	0.44***	0.15***	0.26***	1.28***	−0.03
	(0.06)	(0.03)	(0.92)	(0.10)	(0.10)	(0.13)	(0.04)	(0.08)	(0.18)	(0.05)
Const.	0.78***	1.16***	−5.50	1.78***	1.15***	1.29***	0.32***	1.34***	3.82***	0.07*
	(0.20)	(0.11)	(4.44)	(0.35)	(0.20)	(0.33)	(0.08)	(0.28)	(0.43)	(0.03)

Notes: The table shows linear regression of estimated pass-through coefficients using model (21) against a penetration index of foreign firms represented by the share of imports from China over total imports (index_China). Sectors selected are the ones for which pass-through went up in the latest samples. Newey-West standard errors are in parentheses (lag = 1). ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively.

To further evaluate the robustness of our results, we modify the benchmark regression by adding two additional variables as follows:

$$\Delta p_{k,t} = c_k + \sum_{j=1}^{n} \gamma_{k,j} \Delta p_{k,t-j} + \sum_{j=0}^{m} \beta_{k,j} \Delta s_{k,t-j} + \sum_{j=0}^{l} \varsigma_{k,j} \Delta p^c_{t-j} + \sum_{j=0}^{p} \delta_{k,j} i_{t-j} + \varepsilon_{k,t}, \quad (24)$$

where p^c_t is a price index of all commodities and i_t is the U.S. short-term interest rate. Variations in the commodity price index can capture important determinants of price changes besides exchange rate movements. Marazzi and Sheets (2007) have emphasized that the inclusion of this variable can be critical to determine a decline in pass-through during the period 1996–2004, while its omission can imply higher and quite volatile pass-through coefficients. The short-term interest rate, instead, captures aggregate determinants of prices which depend on the transmission mechanism of monetary policy directed toward the control of aggregate inflation. If the exchange rate depreciates or if the commodity price increases, monetary policy can react by raising nominal interest rate to curb the inflationary pressure and therefore to contain the variations of sectoral prices. Without the inclusion of an index of monetary policy stance, our pass-through coefficients could be biased toward low or even negative values.

We repeat our previous analysis by first estimating equation (24) and setting $\delta_{k,j} = 0$ for all k and j. Then we include also the nominal interest rate. Here, to save space, we only report the new results in a format equivalent to that of table 2. In particular, table 6 is the equivalent of table 2 when the model estimated is the one in (24) and in which $\delta_{k,j} = 0$ for all k and j. Table 7 considers the general unrestricted case.[15]

Looking at the specification which includes only the commodity price index, our results on the increase of pass-through are weakened but not overturned. The number of sectors in which pass-through increases is lower, seven instead of ten. However, the increase in

[15] In the regression of table 6, $m = n = l = 2$, while in that of table 7, $m = 1$ and $l = p = n = 2$.

Table 6. Estimated Pass-Through Coefficients Using Model (24), Assuming $\delta_{kj} = 0$ for All k and j for Sectors in the HS Classifications

Sector	Before 1996:M6	After 1999:M6
I	−0.27	−0.48*
	(0.17)	(0.28)
II*	0.34	0.66**
	(0.58)	(0.29)
IV	0.02	0.23***
	(0.09)	(0.09)
V	0.01	0.16
	(0.85)	(0.46)
VI	0.14	0.12
	(0.09)	(0.11)
VII	−0.06	0.17**
	(0.21)	(0.08)
VIII*	0.19***	0.05
	(0.07)	(0.04)
IX	−0.18	−0.15
	(0.31)	(0.36)
X	0.72	−0.005
	(1.17)	(0.15)
XI	0.006	0.10
	(0.05)	(0.07)
XII	0.05	−0.009
	(0.03)	(0.05)
XIII	0.11	0.03
	(0.07)	(0.05)
XIV	0.25**	0.24
	(0.12)	(0.25)
XV	0.005	0.58**
	(0.30)	(0.25)
XVI	0.29***	0.11***
	(0.08)	(0.03)
XVII	0.14***	0.05*
	(0.04)	(0.03)
XVIII*	0.33***	0.12***
	(0.07)	(0.04)
XX	0.07*	0.10*
	(0.04)	(0.05)

Notes: The sample is split into two parts: 1993:M12–1999:M6 and 1999:M7–2012:M2. Standard errors are in parentheses. ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively. The "stars" next to the sector's Roman numeral refer to a Chow test on the significance of the break date.

Table 7. Estimated Pass-Through Coefficients Using Model (24) for Sectors in the HS Classifications

Sector	Before 1996:M6	After 1999:M6
I	0.09	−0.45**
	(0.12)	(0.22)
II*	−0.01	0.55**
	(0.44)	(0.23)
IV	0.05	0.17**
	(0.08)	(0.07)
V	0.35	0.12
	(0.79)	(0.35)
VI	0.17**	0.11
	(0.07)	(0.08)
VII	0.05	0.15**
	(0.16)	(0.07)
VIII**	0.15***	0.04
	(0.05)	(0.03)
IX	−0.00002	−0.40
	(0.26)	(0.27)
X*	1.12	−0.06
	(0.88)	(0.11)
XI	0.03	0.08
	(0.04)	(0.05)
XII	0.03	0.03
	(0.03)	(0.03)
XIII	0.11*	0.06
	(0.06)	(0.04)
XIV	0.35***	0.44**
	(0.10)	(0.19)
XV	0.08	0.84***
	(0.23)	(0.21)
XVI	0.33***	0.12***
	(0.06)	(0.03)
XVII***	0.15***	0.08***
	(0.03)	(0.02)
XVIII*	0.34***	0.12***
	(0.06)	(0.03)
XX	0.06*	0.06
	(0.03)	(0.04)

Notes: The sample is split into two parts: 1993:M12–1999:M6 and 1999:M7–2012:M2. Standard errors are in parentheses. ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively. The "stars" next to the sector's Roman numeral refer to a Chow test on the significance of the break date.

pass-through is now strong also for sector II (Vegetable Products). Results are confirmed for sectors IV, V, VII, XI, XV, and XX. Looking at the specification in which we also control for the monetary policy stance, we lose supportive evidence for sectors V and XIV, but gain it for sector XIV (Pearl, Stones, etc.). On the contrary, it should be noted that for the sectors XVI (Machinery, Electrical Equipment, etc.), XVII (Vehicles, etc.), and XVIII (Optical, Photo, etc.), the evidence of a declining pass-through is robust across all specifications.

Overall our findings confirm some of the previous results in the literature on partial exchange rate pass-through, but also add some novel dimensions.[16] We find mixed evidence that globalization has increased the degree of pass-through. For the sectors supporting our results, an index of market penetration of foreign firms has an explanatory power in line with the theoretical implications of the model.

6.2 Globalization and the AS Equation

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

$$\pi_{h,t} = k \cdot \left[mc_t + \kappa s_f (\hat{P}_{f,t} - \hat{P}_{h,t}) \right] + \beta E_t \pi_{h,t+1}. \qquad (25)$$

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. We estimate equation (25) to see to what extent our channels are confirmed by the data. There are several estimation methods to test the AS equation (25). We follow the one in Sbordone (2002). We write the AS equation as follows:

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

[16] 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 2005 for an empirical analysis on OECD countries and Bugamelli and Tedeschi 2008 for evidence on euro-area countries).

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

$$\hat{P}_{h,t} = \phi_1 \hat{P}_{h,t-1} + (1-\phi_1)(1-\phi_2^{-1})E_t \times \left\{ \sum_{T=t}^{\infty} \phi_2^{-(T-t)} [ulc_T + \kappa s_f \cdot pr_T] \right\}, \tag{26}$$

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 (26) as follows:

$$(\hat{P}_{h,t} - ulc_t) = \phi_1(\hat{P}_{h,t-1} - ulc_{t-1}) - \Delta ulc_t + (1-\phi_1)E_t \times \left\{ \sum_{T=t}^{\infty} (\beta\phi_1)^{(T-t)} [\Delta ulc_T + \omega \cdot pr_T] \right\}, \tag{27}$$

where $\omega \equiv \kappa s_f$.

Equation (27) allows to us 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, the slope of the Phillips curve, and β, the discount factor, while the parameter ω depends upon κ and s_f, which are proxies of 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 is standard in a quarterly model, we can identify k.

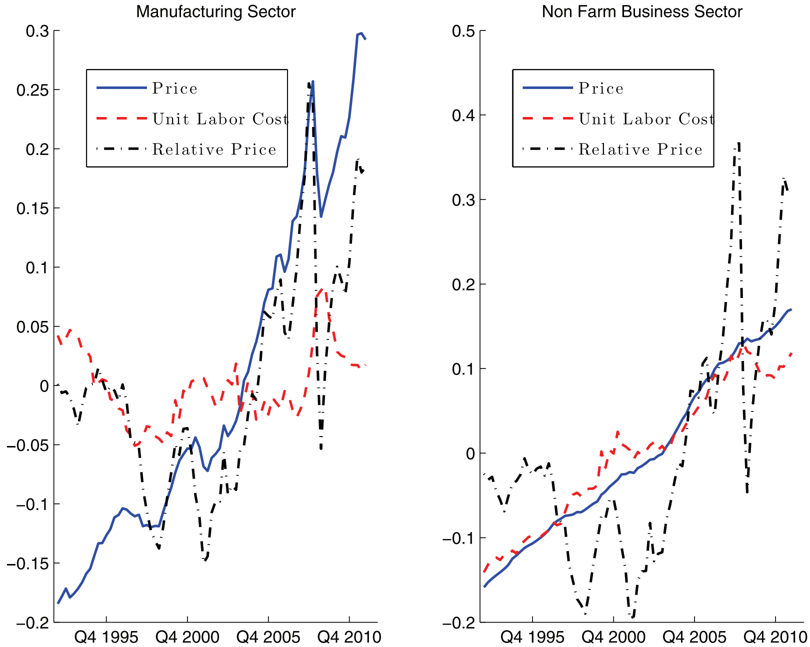
To evaluate the right side of (27), we need to compute expectations of future changes in the unit labor costs and future relative prices. To this end, we use a vector autoregression (VAR) model with four lags involving the following vector of variables: $X_t = [(\hat{P}_{h,t} - ulc_t)\ \Delta ulc_t\ pr_t]$. 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 constraint.

We estimate equation (25) on two different data sets and using different time samples. On the one side, we use data on prices and unit labor costs for the non-farm business sector, which has been traditionally used 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 testing the New Keynesian Phillips curve, although they are particularly relevant for our experiment, as this sector has been heavily exposed to the trade and firms' globalization process in the last decade.

Figure 4 plots the log of prices and unit labor costs for the two sectors analyzed together with the appropriate relative price, defined as the log in the price of import with respect to the domestic price. The import price index is constructed by aggregating sectoral import price indexes belonging to the HS classifications, as discussed in the appendix. Such aggregation is possible only for the period 1993–2012. To appreciate the difference between the two sectors in terms of their exposure to globalization, figure 4 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 prices have instead increased. However, in this sector, prices are positively correlated with the relative price, and 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 8 summarizes the results of the equation (25) estimation for the full sample 1993–2012, for the

Figure 4. Plot of Price, Unit Labor Cost, and Relative Price for the Manufacturing Sector and the Non-farm Business Sector



Note: All variables are in logs and demeaned.

first part of the sample 1993–99, and for the last part of the sample 1999–2012. The split is again chosen consistent with the break identified in figure 3. 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 0.007 for the non-farm business sector, which implies a high degree of price rigidity—close to twelve quarters for a model with a common labor market and a moderate value, and close to six quarters for a model with firm-specific labor market.[17] These results suggest a higher degree of price rigidity than that found

[17] With a firm-specific labor market, the definition of k should also include a factor $(1 + \eta\bar{\sigma})$, where η is the inverse of the Frisch elasticity of labor supply.

Table 8. Estimates of k and ω in Equation (25) for the Manufacturing and Non-farm Business Sector

	Manufacturing Sector		**Non-farm Business Sector**	
	(1)	**(2)**	**(3)**	**(4)**
Full Sample 1993–2012				
k	0.000	0.015	0.007	0.034
	(0.0016)	(0.0567)	(0.034)	(0.056)
ω	0	0.21	0	0.04**
		(0.30)		(0.020)
Sample 1993–99				
k	0.000	0.001	0.001	0.021
	(0.0014)	(0.0268)	(0.0069)	(0.1707)
ω	0	−0.08	0	0.04
		(0.468)		(0.111)
Sample 1999–2012				
k	0.000	0.1	0.008	0.035
	(0.0029)	(0.2622)	(0.0385)	(0.0602)
ω	0	0.34	0	0.04**
		(0.306)		(0.0207)

Notes: In columns 1 and 3, ω is restricted to be equal to zero. Data are quarterly. Three different samples are considered: 1993–2012, 1993–99, and 1999–2012. Standard errors are in parentheses. The "stars" next to the sector's Roman numeral refer to a Chow test on the significance of the break date.

by Sbordone (2002), which covers a different sample. However, the estimated coefficient is not significantly different from zero. This is not surprising and is in line with the arguments of Fuhrer (2009) related to 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 4. A value of k equal to zero in (27) implies that the lagged price performs better, based on our estimation criterion, in fitting the current price. Moreover, this shows that equation (25) can no longer be interpreted as the appropriate Phillips curve, as discussed also in Fuhrer (2009). Therefore, the traditional AS equation does not fit well data for the manufacturing sector.

We then perform the unrestricted estimation on the full sample and include the relative price channel ($\omega \neq 0$). We find that this channel is important for both sectors and, in particular, for the non-farm business sector. Now, the slope of the AS equation increases to 0.015 for the manufacturing sector and to 0.034 for the non-farm business sector. The latter value is now consistent with the results of the literature and with a degree of rigidity around three quarters as found in micro studies. Most important, the point estimate of ω is positive in both sectors and greater in the manufacturing sector. However, it is significant only for the non-farm business sector. Interestingly, when we look at the non-farm business sector, the positive sign becomes significant on the second part of the sample. 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. Our results indeed shed light on the possible reasons for which traditional New Keynesian AS equations often provide erratic and insignificant results. We find a reduction of more than 70 percent 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. Relative prices as well as firms' market shares might therefore provide the missing link.

Guerrieri, Gust, and Lopez-Salido (2010), by comparing GMM estimations for an unrestricted—including relative prices—and a restricted specification of the AS, also find evidence that foreign competition plays an important role in accounting for the behavior of inflation in the traded goods sector. Their model, however, neglects any possible role that globalization might have on the slope of the Phillips curve. Our results confirm the importance of the relative price channel, even though we use different data and estimation techniques. In our case the combination of the model analysis, which carries sound microfoundations of the firms' strategic behavior, and of the estimation results adds crucial insights in interpreting the role of the relative price. The role of external factors is not limited to deflationary shifts of the AS curve but is crucial also for the sensitivity of prices to external conditions.

7. Conclusions

Much discussion has been devoted in recent years to 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 markets renders the pricing decision of firms more dependent upon foreign factors and hence reduces the dependence of inflation on the domestic slack. This increased link between domestic inflation and global factors occurs through two main channels. First, there is 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, there is an increase in the dependence of the pricing strategies of domestic firms upon foreign components, due to the increase in competition with foreign firms. Interestingly the reduced form of the Phillips curve changes. Indeed it shifts with respect to relative price movements. Moreover, the sensitivity of inflation to marginal costs changes with respect to foreign firms' penetration. Finally, 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. We test the model results with an empirical analysis based on U.S. sectors belonging to HS classification. We find evidence of an increase in the degree of pass-through in the majority of the sectors considered. Moreover, estimation of the AS equation 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. Recent studies based on DSGE analysis (see Bouakez and Rebei 2008) have also emphasized the role of monetary policy in explaining changes in pass-through. We leave these topics for future research.

Appendix. Data

Pass-Through Analysis

Sectoral import prices data are taken from the Bureau of Labor Statistics (BLS). The indexes are industry-specific multilateral import prices following the one-digit harmonized system (HS) classification. The data used have monthly frequency on the sample 1993:M12–2012:M2.

Table 9 shows the sectors that are considered.

The nominal effective exchange rate, the commodity price index, and the three-month U.S. Treasury bill rate are taken from Datastream with the respective codes 741111577, WDI76ACDF, and USGBILL3.

Table 9. Sectors and Their HS Classifications

Sectors	**HS Sectors**
Live Animals and Animal Products	I
Vegetable Products	II
Prepared Foodstuffs, Beverage, and Tobacco	IV
Mineral Products	V
Products of the Chemical or Allied Industries	VI
Plastics and Articles Thereof	VII
Raw Hides, Skins, Leather, Furskins, etc.	VIII
Wood, Wood Charcoal, Cork, etc.	IX
Wood Pulp, Recovered Paper, and Paper Products	X
Textiles and Textile Articles	XI
Headgear, Umbrellas, Artificial Flowers, etc.	XII
Stone, Plaster, Cement, etc.	XIII
Pearls, Stones, Precious Metals, Imitation Jewelry, and Coins	XIV
Base Metals and Articles of Base Metal	XV
Machinery, Electrical Equipment, etc.	XVI
Vehicles, Aircraft, Vessels, and Associated Transport Equipment	XVII
Optical, Photo, Measuring, Medical and Musical Instruments and Timepieces	XVIII
Miscellaneous Manufactured Articles	XX

Data on sectoral import share from China are taken from the U.S. International Trade Commission (USITC) website. Yearly data on sectoral imports by the HS system for the period 1992–2012 (through February) are taken from the U.S. Census Bureau. The penetration index is calculated as the ratio between Chinese sectoral imports to the United States and total sectoral imports to the United States. The yearly penetration index is then matched with the pass-through coefficients obtained through the rolling-window estimates. The average of the starting point and the end point of the rolling window was used in order to assign a year and a month to the estimate. Then an annual time series was constructed using the end-of-year data.

Sectoral index of concentration data are taken from the Economic Census: concentration ratios are available for the years 1997, 2002, and 2007. In particular, the Herfindahl-Hirschman Index for the fifty largest companies from the Economic Census has been used. The available data for the three years mentioned above are assumed to be valid also in the years following the respective census if no new data has arrived. Data are available for each three-digit NAICS sector. Since the rest of the data sample follows the HS classification, we had to match the sectors of the NAICS classification with the rest. The matching was chosen as follows: sector IV matched with 311/312, V with 324, VI with 325, VII with 326, VIII with 316, IX with 321, X with 322, XI with 313/314/315, XIII with 327, XV with 331/332, XVI with 333/335, XVII with 336, XVIII with 324, and XX with 337/339. Sectors I and XIV were dropped since they could not be matched with the NAICS classification.

Aggregate Supply Analysis

The data for prices and unit labor costs for the manufacturing sector and non-farm business sector are from BLS and are available on a quarterly basis. The series for import prices is constructed from the HS import indexes at one digit, excluding sectors III and XIX for missing data. 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 sectoral import prices have been aggregated into a single import price using the Relative Importance Index of tables 3 and 5 from the historical tables of U.S. Import and Export Price Indexes of the BLS of April 2012.

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