

A Structural Approach to Explaining Incomplete Exchange-Rate Pass-through and
Pricing-To-Market

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The continuing depreciation of the dollar against other major currencies, coupled with concerns about the impact of China's exchange-rate policy on domestic prices, has spurred new interest in the exchange-rate pass-through literature. A recent study by economists at the Board of Governors attracted wide attention by documenting a steady decline over the past decade in the pass-through of exchange rates into U.S. import prices. This finding was later challenged by a study published by the Federal Reserve Bank of New York (see Mario Marazzi et al (2005) versus Rebecca Hellerstein, Deirdre Daly, and Christina Marsh (2006)), which demonstrated that the finding of such a decline depends crucially on the specification of the pass-through regression, and in particular the inclusion of commodity prices. This exchange highlights the need to understand the structural determinants of exchange rate pass-through, not only because such understanding is important when trying to forecast future pass-through patterns, but also because it provides guidance regarding the specification of the appropriate reduced-form regression, and more generally, measurement of pass-through.

The increased availability of micro data on prices and quantities means that research uncovering these determinants is more promising than ever. This paper lays out a structural approach that can be used to identify the determinants of incomplete exchange rate pass-through. We argue that despite the use of parametric assumptions, our identification method that relies on exploiting exchange rate variability is general, and can be applied to a variety of markets and data. We show that existing micro studies yield surprisingly robust results regarding the sources of incomplete pass-through, with non-traded local costs emerging as the primary cause, in spite of differences in industries and countries investigated, modelling assumptions and data. We conclude by noting limitations of this approach and suggesting directions for future research.

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1 The Empirical Framework

1.1 The Problem

Consider the example of a German firm exporting to the U.S. To keep things simple, suppose it is a single-product firm. The price of the product, expressed in U.S. dollars (\$) and euros (€), respectively, is given by the following two identities:

$$(1) \quad P_{jt}^{\$} = M_{jt} * MC_{jt}^e * E_t$$

$$(2) \quad P_{jt}^e = M_{jt} * MC_{jt}^e$$

P_{jt}^e denotes the price this firm charges in the U.S. market, when it is converted to euros, and *not* the price of this product in the domestic German market. M_{jt} denotes the proportional markup, MC_{jt}^e is the marginal cost, denominated in the producer currency (€), and E_t is the bilateral exchange rate (\$/€). When exchange rate pass-through is complete, changes in E_t lead to proportional changes in the local currency (€) price of the good $P_{jt}^{\$}$. Hence the variability in $P_{jt}^{\$}$ tracks the variability in E_t . In contrast, the product's price expressed in the producer currency (euro) P_{jt}^e should remain constant. However, there is overwhelming empirical evidence pointing to precisely the opposite pattern: The variability in exchange rates closely tracks the variability in P_{jt}^e , while the product's local-currency price remains fairly stable over time. Hence, the data imply incomplete, and in fact very low, pass-through. This is the phenomenon we are trying to understand. As evident from (2), for P_{jt}^e to co-vary with exchange rates, it must be true that exchange rates lead to either a change in markups M_{jt} , or a change in euro-denominated marginal cost MC_{jt}^e , or both. An additional explanation is that because of nominal price rigidities (e.g., menu costs), prices do not respond to changes in the economic environment at all, so that $P_{jt}^{\$}$ remains literally fixed in the short run. In the data this would show as a “no change” in the local-currency price of the product, as opposed to a small, incomplete change implied by the markup or marginal-cost change channels. In the following we investigate how micro data can help us identify the relative contributions of the markup, marginal cost, and nominal-rigidity channels respectively, in generating incomplete pass-through. For expositional purposes we focus mainly on the case of a single destination market (in our example above, the U.S.), but the framework can easily accommodate extensions to a multi-destination framework. In fact, we argue that the multi-destination framework allows one to obtain sharper results and further refine the hypotheses investigated. Following the

literature, we use the term “incomplete pass-through” to refer to a single-destination market and “pricing-to-market” to refer to multiple destination markets, where the incomplete pass-through also generates deviations from the Law of One Price.

1.2 A Reduced-Form Approach

Before describing the structural approach, it is instructive to consider what can be learned from a reduced-form approach to the problem. To this end, let us focus on the case of a (let’s say German) firm that exports to *multiple* destinations. Consider the following reduced form regression relating the price the firm charges in each destination (converted to euros) to the bilateral exchange rate:

$$(3) \quad \ln P_{mt}^e = \theta_t + \lambda_m + \beta_m \ln E_{mt} + u_{mt}$$

where the subscript m denotes destination market, θ_t is a set of time effects, λ_m is a set of destination market fixed effects, and E_{mt} is the bilateral exchange rate between the destination market and Germany. This is the standard pricing-to-market (PTM) equation estimated in the literature, where β_m denotes the PTM coefficient. The market fixed effects λ_m proxy for both quality and markup differences across markets that do not vary over time, while the time fixed effects θ_t capture the common-across-markets changes in marginal costs and markups. Given this setup, the finding of a β_m that is significantly different from zero convincingly establishes that exchange-rate changes are associated with markup variation and that this variation is specific to each destination market (a more detailed discussion is provided in Pinelopi K. Goldberg and Michael Knetter (1997), pp. 1254-55). The reduced-form approach has several advantages: it is easy to implement, it does not rest on any functional-form assumptions, and the data requirements are modest. Apart from exchange rates, one needs *only data on prices* to estimate (3), though for the approach to be informative, the data must cover multiple destinations. On the negative side, the inferences one can draw from price data alone are limited. Specifically, while the reduced-form approach reveals that the “variable-markup” channel is at work, it cannot tell us how large the markup variation is, or how this mechanism compares to the other potential channels. More importantly, an implicit assumption underlying this approach is that the marginal cost of selling to each destination is not affected by exchange rates. This assumption is plausible when the data used are f.o.b. export prices, as in Michael Knetter’s (1989) original work; however, it is much more controversial if one employs consumer-level data with a large portion of local, destination-market-specific, non-traded costs.

1.3 A Structural Approach

Consider equation (2) again. Let us abstract from nominal rigidities for now. Our objective is to decompose the variability in P_{jt}^e into the variability in marginal costs, and the variability in markups. The challenge is that neither marginal costs nor markups are observable. The problem looks remarkably similar to the one faced in empirical work in Industrial Organization. Accordingly, the approach we propose is informed by recent advances in that field. While the techniques are not new, we note that the application of Industrial Organization methods to the question of exchange rate pass-through has a particular appeal that is rarely found in domestic market applications: exchange rates provide a source of large and plausibly exogenous price variation in the data. It is this variation that we exploit to identify marginal costs and markups. Hence, exchange rates play a double role in this framework: they are the object of investigation; at the same time, they help us identify the parameters of interest in the underlying structural model. We next explain how the data can help us identify the relative contributions of markups, marginal costs, and nominal rigidities respectively. We base most of our discussion on a static model, but consider dynamic extensions at the end.

Variable Markups: A common misconception is that incomplete pass-through reflects the intensity of competition in the destination market. This is only partially true. The intensity of competition is relevant, but only to the extent that it produces variable markups. To see that, consider the case of a monopolist who faces a CES demand. If demand is elastic, the markup will be low. Nevertheless, given the CES structure, the markup will not change in response to an exchange rate change, so that - absent any changes in the marginal costs - pass-through will be complete! For a model to be able to generate incomplete pass-through, it is thus important to allow for functional forms that do not - by construction - imply constant markups. In the static, period-by-period profit maximization problem, a firm's markup M_{jt} is linked to the price elasticity facing the firm by the firm's first order condition:

$$(4) \quad M_{jt} = \frac{\eta_{jt}(P_{jt}, \bar{P}_t, Z_t)}{\eta_{jt}(P_{jt}, \bar{P}_t, Z_t) - 1}$$

where η_{jt} denotes the price elasticity facing the firm. The notation is chosen to reflect the fact the price elasticity facing the firm will in general be a function of the firm's price P_{jt} (and hence *not* constant), as well as a function of a vector of competitor prices \bar{P}_t , and a set of exogenous variables Z_t . The markup can be inferred from the first order conditions once the price elasticity facing the firm has been estimated. This suggests the following approach for estimating markups: 1. Assume a particular utility (or demand) function and estimate the

relevant parameters using data on prices and market shares; 2. Assume a particular market structure and behavior; 3. Infer the markups implied by 1. and 2. using the first order condition (4). As we noted above, the advantage of international data is that exchange rate variation provides a plausible source of identification of the demand side parameters - at least in the partial equilibrium setting. Hence, while this approach is parametric, identification is not driven by functional form assumptions alone. Perhaps the most unsettling aspect of this approach is the dependence of the derived markups on the functional form assumptions inherent in the first step. In practice, a variety of approaches have been adopted in the literature to estimate the price elasticity facing the firm. One common approach, especially in the macro literature, is to assume a CES market demand together with Cournot competition. The Cournot assumption leads to a price elasticity facing the firm that depends on the market share: the larger the market share, the lower the elasticity of demand facing the firm. One can easily see how this generates incomplete pass-through; as the local currency price starts rising in response to an exchange rate depreciation, the market share of the firm under consideration declines, raising the price elasticity of demand facing the firm. While this approach can generate incomplete pass-through, the assumptions of CES demand and Cournot are hard to defend, especially when applied to a wide set of sectors across the economy. At the other end of the spectrum, one can assume a linear demand function, which generates - by construction - a pass-through of less than 50%. This particular functional form assumption can generate a significant degree of price inertia that matches what is observed in the data; however, the linear demand structure does not match other features of the data (e.g., does not produce plausible demand elasticities).

An alternative approach that has been pursued in a series of recent papers is to adopt flexible functional forms that have been shown to match cross-sectional patterns in the data well and produced plausible substitution patterns, and examine what these functional forms imply for pass-through. Examples of this approach include the estimation of nested logit (Pinelopi K. Goldberg (1995), Pinelopi K. Goldberg and Frank Verboven (2001)), and random-coefficient models (Rebecca Hellerstein (2006), Pinelopi K. Goldberg and Rebecca Hellerstein (2007), and Emi Nakamura (2007)). As with earlier work, the markup estimation in these papers relies on particular functional form assumptions, so that the markup estimates are ultimately only as credible as the underlying assumptions. Having said that, the assumptions are not adopted with the particular goal of matching the pass-through patterns, so that the implications of these models for pass-through remain an open empirical question. An interesting feature of all studies mentioned above is the modelling of consumer heterogeneity. While this increases the realism of the models and contributes to more plausible substitution patterns, it tends

to produce a pattern of markup adjustment that implies too much pass-through. The reason is a selection effect. As the price increases, the market gets increasingly dominated by high income consumers who tend to have lower price elasticities of demand. Hence, the aggregate price elasticity of demand tends to fall as the price rises. As a result, these models generate incomplete pass-through, but the markup variation is not sufficient to explain the magnitude of price adjustment observed in the data. In the context of identity (2), the models we just described do generate variation in M_{jt} , but this variation accounts for only a small part of the variation in P_{jt}^e . Hence, marginal costs MC_{jt}^e must also be affected by the exchange rate.

Marginal Costs: Why would the marginal cost of the producer, expressed in producer currency (euro), be affected by the exchange rate? Three possibilities come to mind: 1. Decreasing Returns to Scale implying an upward sloping MC curve; 2. Imported Inputs used in the production of the export good; 3. Local, non-traded costs in the destination market. We note however that these three explanations have different implications for pass-through versus pricing-to-market. In particular, the first two explanations imply incomplete pass-through in any particular destination market, but do not generate deviations from the Law of One Price across destinations. In contrast, the third explanation (non-traded costs) also implies pricing-to-market. This is a case where data from multiple destinations can help distinguish between alternative hypotheses.

To fix ideas, consider -without loss of generality - the following Cobb-Douglas specification for marginal cost:

$$(5) \quad MC_{jt}^e = Q_{jt}^\gamma * (W_t^e)^\delta * (E_t W_t^\$)^{1-\delta} * e^{\omega_{jt}}$$

The dependence of the marginal cost on the quantity produced Q_{jt} allows for the exchange rate to affect the producer's marginal cost, even when the latter is expressed in producer currency. As the exchange rate rises, the domestic price starts to rise and quantity goes down. If the MC curve is upward sloping ($\gamma > 0$), MC will *decrease* as the price rises, so that pass-through will be incomplete. This mechanism implies that we should see large changes in quantities when the local currency price does not respond to exchange rate changes. Moreover, as noted above, this mechanism implies that the decrease in MC would affect all destination markets, so that it cannot generate pricing-to-market, at least not without an additional markup channel in effect. The variables W_t^e and $W_t^\$$ denote factor prices in the producer country and destination market respectively. Their coefficients are restricted to sum up to 1 to guarantee homogeneity of degree 1 in input prices. The dependence of the marginal cost on the destination market input prices

$W_t^{\$}$ captures both the presence of non-traded costs and the potential importance of imported inputs (the implicit assumption being that imported inputs are priced in U.S. dollars). The main coefficient of interest here is $(1 - \delta)$. If $(1 - \delta)$ is estimated to be significantly different from zero, marginal costs are affected by input prices in the U.S. In our particular example of a German firm selling to the U.S., we cannot distinguish between the hypotheses of imported inputs versus non-traded costs, but in more general settings it should be possible to make the inference more precise. For example, if the prices employed in the estimation are consumer prices in the U.S., it is likely that the dependence of the marginal costs on U.S. input prices reflects non-traded costs; in contrast, if the prices are prices at the dock, the estimate is more likely to reflect imported inputs. More importantly, data from multiple destinations would help distinguish between the two explanations. How can (5) be estimated? Once the markups have been derived based on the approach outlined above, identity (1) (or (2)) allows one to back-out the marginal costs. The main challenge in estimating (5) is the identification of the coefficient γ that provides a measure of decreasing returns to scale. Good instruments for Q_{jt} are hard to find.

Nominal Price Rigidities: So far we have abstracted from the role of nominal price rigidities, assuming that prices can readily adjust, so that firms' behavior is captured by the first order condition (4). Recent papers by Goldberg and Hellerstein (2007) and Nakamura (2007) relax this assumption exploring the implications of nominal price rigidities. The main implication of the presence of these rigidities in the static framework adopted by Goldberg and Hellerstein (2007) is that they generate a wedge between the profits the firms would realize if they adjusted their price and the profits they realize when they keep the price unchanged from the previous period. This wedge can be exploited to derive upper and lower bounds of the fixed costs of price adjustment. Implementation of this approach requires in practice high frequency, highly disaggregate data, so that the spells of non-adjustment are visible to the researcher. The approach outlined above is still useful in assessing the role of variable markups, non-traded costs and imported inputs in generating incomplete pass-through, as long as estimation is confined to those periods during which firms adjust prices (the premise being that once firms decide to adjust, they will adjust in accordance with the first order conditions). But assessing the significance of price rigidities is complicated by the presence of strategic complementarities. Even if the fixed costs of price adjustment facing a particular firm are small so that this firm adjusts its price, nominal price rigidities can have an indirect effect on the size of price adjustment; if the firm believes that other firms in the market are unlikely to change their prices, it may change its price by a lesser amount compared to the case of fully flexible

prices. A rough idea about the significance of nominal price rigidities can be obtained through simulations that compare the flexible price equilibrium with the price adjustment that a model with price rigidities *can* generate. However, given the existence of multiple equilibria, such simulation results need to be interpreted with caution.

So far our discussion has concentrated on a static model. Extension of the framework to a dynamic model is far from trivial. To see why, consider equation (4). It is this first order condition based on the solution of a firm's static profit maximization problem that allows one to derive a simple relationship between estimable price elasticities of demand and markups. In the presence of dynamics, this simple relationship breaks down and one needs to add substantially more structure to the problem to estimate the parameters of interest. In principle dynamics can enter the demand side, the supply side, or both. In all cases, identification is a challenge. Coming up with plausible identification conditions has always been difficult in this literature, even in the context of static models; the problem is naturally amplified when one considers dynamic extensions. The simplest (and perhaps only feasible) way to introduce dynamics in the empirical analysis is by keeping the basic structure (demand and costs) static, while analyzing the implications of fixed costs of price adjustment in a multi-period framework. This approach is taken in a recent paper by Nakamura (2007). Even in this framework, the model is sufficiently complex that it cannot be solved analytically (at least not for reasonable functional forms), so that one needs to employ computational methods to characterize the equilibrium. The results indicate that the extension to the dynamic model is important if one tries to understand the sluggish adjustment of prices over time - a feature a static model naturally cannot produce.

2 What Have We Learned So Far

Existing studies have applied the approach described above to a variety of industries (autos, beer, coffee) tailoring the particular modeling assumptions to the institutional details of these industries, and using different data sets. Despite these differences, some general patterns regarding pass-through robustly emerge from the empirical analyses. The most striking one is that all studies find a large role for non-traded costs/imported inputs. These factors are estimated to contribute 50% to 78% to incomplete pass-through. What is surprising is that these estimates are in line with those provided in other work that has used very different methods (e.g., Linda Goldberg and Jose Campa (2007) and Ariel Burstein, Joao Neves, and Sergio Rebelo (2003)). What drives these estimates of high non-traded costs in structural models? Inspection of identity (2) provides the answer. The demand models estimated in the papers cited above generate markup variation that is consistent with incomplete pass-through. How-

ever, this variation is too small to explain the variation in product prices, when the latter are expressed in producer currency. The residual variation is attributed to marginal cost variation. In other words, marginal costs (expressed in producer currency) are found to strongly co-vary with exchange rates. This suggests that these marginal costs contain either imported inputs (denominated in a currency other than the producer currency) or non-traded costs. Given this pattern, it is natural to ask whether the popular demand models estimated in the literature are appropriate in this context. Interestingly, the more realistic the models are, and the closer they match cross-sectional patterns in demand, the harder time they have to generate incomplete pass-through. The issue of consumer heterogeneity is important here. As noted above, consumer heterogeneity by itself tends to *increase* pass-through. The better consumer heterogeneity is captured in the model, the harder it is for it to generate incomplete pass-through. The most striking example is Pinelopi K. Goldberg (1995), whose use of consumer level data allows for a very flexible set of interactions between product and consumer characteristics. When the model is simulated, pass-through for luxury German cars that are bought primarily by high-income consumers is almost complete; in contrast, pass-through for Japanese cars is substantially smaller. To explain the pass-through behavior of German car prices, one must appeal to other factors, non-traded costs being an obvious candidate.

So far we interpreted the high correlation between exchange rates and marginal costs as indicative of the importance of non-traded costs. As noted above, this correlation is in the one market case equally consistent with the existence of imported inputs. Without multi-destination data we cannot distinguish between the two. We should point out however that recent work by Gita Gopinath, Oleg Itskhoki, and Roberto Rigobon (2007) documents low exchange rate pass-through *at the dock* in the U.S. Given that prices at the dock do not contain non-traded costs, this finding can be explained only by variable markups or imported inputs. The data used by Gopinath, Itskhoki, and Rigobon (2007) do not allow one to distinguish between the two explanations, but given the relatively small role attributed to markup adjustment in the structural studies, the descriptive results are strongly suggestive of the importance of imported inputs. Finally, the correlation between marginal costs and exchange rates could also be driven by an upward sloping MC curve. The only study that has explicitly looked at this possibility is Pinelopi K. Goldberg and Frank Verboven (2001), which however did not find any evidence that this channel was important.

Another common finding of recent studies regards the role of nominal price rigidities. In both Goldberg and Hellerstein (2007) and Nakamura (2007), nominal rigidities are found to contribute little to explaining incomplete pass-through, though in Nakamura's work such rigidi-

ties are important in generating sluggish adjustment. Overall, non-traded local costs emerge as the most important source of incomplete pass-through, followed by markup adjustment. Nominal rigidities are needed to fully account for the incomplete price response, but their role has been estimated to be rather small.

3 Directions for Future Research

We conclude by indicating some directions for future research. First, the low variability in markups generated by currently popular models of demand suggests that one should be open towards alternate models. But one should proceed with caution. For example, one would not want to sacrifice the realism of these models by abstracting from consumer heterogeneity to generate higher pass-through. More importantly, the approach described so far is for the most part static. Modelling dynamics would be an important step towards extending and generalizing this framework. A structural treatment of dynamics would require one to be specific about how dynamics enter the demand or supply side. Recent papers by Morten Ravn, Stephanie Schmitt-Grohe, and Martin Uribe (2007) and George Alessandria, Joseph Kaboski, and Virgiliu Midrigan (2007) present important steps in this direction. The first paper introduces dynamics on the demand side by considering habit formation, while the second one considers the implications of inventories for incomplete pass-through. In both cases, the specifications are substantially more complex than the ones discussed here, so that it is hard to take the models to the data. Third, while the existing literature suggests that non-traded costs and imported inputs are important, there is still ambiguity regarding the relative contributions of these two factors. As noted above, a re-focus of the empirical work from exchange rate pass-through to pricing-to-market and use of data from multiple export destinations can shed light on this question. It is possible that the globalization of the production structure has made firms less vulnerable to exchange rate fluctuations, so that an exchange rate “shock” is hardly a “cost shock” anymore for a firm that invoices its imported inputs in dollars. Finally, the framework described in this paper is partial-equilibrium; wages, input prices and exchange rates were all taken as exogenous. It would be desirable to eventually integrate insights from the partial-equilibrium literature to general equilibrium models that would inform monetary policy. This is an ambitious task that would require collaboration between economists in the fields of Macroeconomics, Industrial Organization, and International Economics.

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