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Exchange Rates and Producer Prices: Evidence From Micro-Data*

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Abstract

We use a unique data set that matches survey data on domestic and export prices to plant census information to address the following questions. Are desired markups constant or variable? How are markups adjusted in response to demand shocks? Does the probability that prices change respond to demand shocks? Our identification strategy is based on matched observations for the price charged for a given product by a given plant in two markets that are segmented by variable exchange rates. Changes in exchange rates shift perceived relative demand across the two markets while potentially also affecting costs. We use fixed effects to control for changes in marginal cost and focus on markup responses to demand shocks. Our findings suggest that desired markups are not constant. In particular, it appears that desired markups increase in response to increases in demand and fall in response to reductions in demand. Our findings on the state-dependence of price setting are equivocal. We are unable to distinguish between the case of no state dependence and the case of state dependence combined with a unit elasticity of desired markups with respect to exchange rate-driven demand shocks.

JEL Classification: F31, F41, L11, L16

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1 Introduction

We use a unique data set that matches survey data on domestic and export prices to plant census information to address the following questions. Are desired markups constant or variable? How are markups adjusted in response to demand shocks? Does the probability that prices change respond to demand shocks? The answers to these questions are of interest to both the international macroeconomics literature on pricing-to-market and exchange rate pass-through, and the macroeconomics literature on sticky prices and on pricing behavior and the business cycle. Our findings suggest that desired markups are not constant. In particular, it appears that desired markups increase in response to increases in demand and fall in response to reductions in demand. As regards state-dependence of price setting, our baseline results are equivocal. We are unable to distinguish between the case of no state dependence and the case of state dependence combined with a unit elasticity of desired markups with respect to exchange-rate driven demand shocks.

The data that we exploit is based on merging the Irish Census of Industrial Production (CIP) with the micro data used to construct the Irish Producer Price Index (PPI). The producer price data is drawn from a sub-sample of the plants covered by the CIP. The two data sets can be linked through a unique plant identifier. The plant-level data is annual, while the price data is monthly. Our sample period covers 1995-2004. The openness of the Irish manufacturing sector, both on the output and the input side means that nominal exchange rate changes are an important source of both demand and cost shocks. Over half of plants are exporters, and between 60 and 80% of total sales are export sales. Over 70% of plants for which data is available report importing intermediates, and between 45 and 65% of total expenditure on intermediates is on imports. The largest single trading partner is the UK, with which Ireland has a floating exchange rate throughout the sample period.

Using this data, we document that producer prices in Ireland behave much as producer prices in other European countries along the dimensions of frequency of price adjustment, prevalance of both increases and decreases, and the size of price changes. We show that prices are sticky in invoice currency rather than domestic currency, and that once measured in invoice currency, the behavior of prices is roughly similar for domestic sales and exports.

The data set has a crucial feature that allow us to identify price responses to demand shocks driven by exchange rate changes as distinct from cost shocks. We observe prices for the same product being sold by the same plant in both home and export markets. Movements in exchange rates between the home currency and the currency of the export market are perceived by the Irish producer as movements in relative demand. Under the assumption that over a given time interval, changes in marginal costs are the same across different markets for a given product produced by a given plant, this allows us to identify the effect of demand shocks. Since we document that prices for most products are not continually adjusted, we consider separately the effect of demand shocks on the intensive margin (how prices respond conditional on adjustment) and on the extensive margin (whether or not prices are changed).

On the intensive margin, we assume that conditioning on prices changing allows us to observe desired changes in prices, and from this, we estimate the elasticity of the desired markup with respect to demand shocks driven by exchange rates. We find a unit elasticity of markups with respect to exchange rate changes, implying that desired markups increase in response to increases in demand, and fall in response to reductions in demand. On the extensive margin, our results cannot distinguish between the case of no state dependence in pricing behavior and the case of state dependence with a unit elasticity of the desired markup with respect to exchange rate-driven demand shocks.

Our contribution to the macro literature on variable markups is to show fairly conclusively that it is not unusual for firms to tolerate big variations in markups across different markets. Why and how they do so, and whether this behavior is optimal are very interesting questions that we are not at this stage able to answer definitively. We present some results that are consistent with the possibility that this behavior is driven by a desire to keep prices in line with those of competitors (with the caveat that our data on competitors' prices is imperfect). We suspect that there may be an entry-exit dimension to the story, with shocks that push markups below a certain level leading to exit rather than price adjustment, but since we do not observe the level of profits in different markets, we have not been able to explore this possibility further.

As regards the implications of our findings for exchange rate passthrough, we find that even conditional on price adjustment, the relative price of the same good produced by the same firm sold in two different markets moves one-for-one with exchange rate changes. The broad applicability of this finding is tempered by the fact that in our data, we can only identify destination markets precisely if exports are invoiced in destination currency. We suspect that we would find rather different results for exports invoiced in domestic currency. Our best guess is that our result pushes the burden of explanation of real exchange rate behavior onto the choice of invoice currency. In respect to that decision, we provide evidence of some systematic patterns, but simultaneously a good deal of heterogeneity within plants as well as across plants in invoicing behavior. It is common to see plants simultaneously invoicing a substantial fraction of sales to the UK market in home currency, and a substantial fraction in Sterling. This suggests to us that the relative bargaining power in bilateral relations may be an important factor in explaining the choice of invoice currency.

This paper is related to the recent literature that uses micro data to explore price stickiness in producer and trade prices. It is most closely related to Gopinath and Rigobon (2007), Gopinath, Itskhoki and Rigobon (2007) and especially Gopinath and Itskhoki (2008) who explore the responses of import and export prices to exchange rates using US data. It is also related to Nakamura and Steinsson (2007) and the work of the European Inflation Persistence Network on producer prices in the US and Europe respectively [see Vermeulen et al. (2007) for a summary of the latter].

Our fixed effects approach to the identification of markup variation in response to shocks to relative demand driven by exchange rates is methodologically closest to Knetter (1989) and Knetter (1993), though these papers do not make use of micro data. It is also related to Chevalier, Kashyap and Rossi (2003) and Eichenbaum, Jaimovich and Rebelo (2007) where markups are calculated directly from micro data on prices and costs, and to Goldberg and Hellerstein (2008), Goldberg and Verboven (2001), Hellerstein (2008) and Nakamura (2007), where markups are backed out of the structural estimation of firm first order conditions. The paper is also related to the literature that aims to identify whether firms engage in state-dependent pricing, for example, Klenow and Kryvtsov (2007) and Midrigan (2007). In contrast with this work, we apply a direct test of state-dependence rather than trying to infer it from the behavior of aggregate moments. [More lit review].

The next section of the paper describes our data set. The third section presents summary statistics on pricing behavior in our sample along various dimensions. The fourth section briefly outlines a partial equilibrium model of pricing behavior to motivate our empirical strategy. The fifth section describes our empirical strategy in detail. The sixth section presents and discusses our results on markup variation and state-dependence. The final section concludes.

2 Our data

Our data comes from two sources. The first source is the Irish Census of Industrial Production (CIP). This census of manufacturing and mining sectors takes place annually, and is applied at both the firm and plant level (about 90% of plants are single-plant firms). All plants with 3 or more employees are required to fill in a return. The industries covered are NACE Revision 1.1 (the harmonized European industrial classification system) classes 10 to 41. The data available to us covers the period 1991 to 2004. Of the variables collected, those relevant for our purposes are the industrial classification, country of ownership, value of sales, value of export sales (with some destination and currency invoicing information), employment, wage bill, materials costs (with share of materials imported, and some origin and invoicing information) and plant invoice currency. There is some information on investment, but we do not make use of it in this work. Further details on this data are provided in the Appendix.[1]

The second source is the micro data collected for the purpose of constructing the Producer Price Index (PPI). The sampling frame for this data is the population of plants in the CIP. Participation in the PPI is long-term, though there is periodic resampling from the CIP to maintain coverage following attrition in the original sample and entry of new plants into the CIP. On average, 14% of CIP plants are included in the PPI sub-sample in any given year. Plants in this subsample are asked to provide transactions prices for a representative subset of their product range on a monthly basis. The explicit request is for a price drawn from an invoice dated on the 15th of the month in question. The definition of a product is usually very detailed, both in terms of the description of the item, and in terms of "price-determining variables" such as destination market, terms of sale and unit information. Participants are asked to discontinue a price series and replace it with another if there has been a change in any of these variables.

The price data is available for the period January 1995 to November 2006. The relevant variables for our purposes include prices, the currency in which the price is quoted, whether the good is sold domestically or exported, and for a limited subset of export observations, information about the destination market. Unfortunately, most of the "price-determining

[1] To maintain confidentiality, we exclude from our analysis plants whose share of total sales in any given year is greater than 4%. We also exclude NACE 2-digit secctor 37 (recycling) and sectors 4030 and above (heat, hot water and water).

variables," including destination market, are available only for price quotes present in the last cross-section (November 2006), so we make use of this information only for robustness checks. Within plants, we generally observe price quotes for multiple products, where products are defined at a sub-NACE 4-digit level of aggregation (somewhere between a 4-digit and an 8-digit PRODCOM classification, though the classification system does not exactly match PRODCOM). In addition, we often observe multiple quotes per product within a plant. This is both because we observe quotes for multiple markets (home and export) and multiple quotes within the same market. Products can be matched across plants using the product classification particular to this data. The monthly price data can be linked to the CIP plant data using a unique plant identifier. The empirical work in the remainder of the paper is based on this matched sample.

The matched sample

On average, over 1995-2004, 14% of the universe of plants accounting for 32% of sales are included in the matched subsample. On the PPI side, 95% of price observations are matched to a plant in the CIP. We describe here summary statistics for the CIP as a whole, for the subsample of plants that are matched with the PPI data, and for the matched PPI data. Table 1 shows year-by-year coverage of the matched sample in terms of number of plants, total sales, export sales and employees. Clearly, plants in the matched sample are bigger and more export-intensive than average. This is confirmed by Tables 2 and 3, which report statistics on size ownership, export status and import status for all plants and for plants in the matched sample in 1995 and 2004. In addition to being more export-intensive, plants in the matched sample are also more imported-intermediate intensive, and more likely to be foreign-owned. In an absolute sense, both matched and unmatched plants are very open on both the input and the output side. As such, they may not be representative of firms in very closed economies, but they provide an ideal laboratory for examining the effects of exchange rate changes on pricing behavior. Table 4 reports the sectoral composition of the matched and unmatched samples. The matched sample is broadly representative of Irish industry.

Table 5 provides some summary statistics on the hierarchical structure of the price data. Between 550 and 900 plants are present in each annual cross-section. They provide between 4,200 and 5,900 price quotes per month, for between 900 and 1,400 products. The plants in our sample are multi-product producers, selling individual products in multiple different markets, both domestic and foreign. To use the terminology of Klenow and Kryvtsov (2007), quote-lines are observed over long periods of time. Figure 1 illustrates this by showing the evolution over the sample period of the 25th, 50th and 75th percentiles of the distribution of the duration of the quote-lines in the sample at a particular point in time. One notable feature of these spells is that for all spells a price is recorded for *every* month between the first time and the last time a particular quote-line is observed. Since it is implausible that all products in the sample are traded in every month, we are forced to conclude that at least some of the prices we observe are not transactions prices. Hence, we will be somewhat cautious about making statements about the absolute level of price stickiness. However we hope that where there are price changes, for those observations at least, we do observe something that relates to actual transactions.

3 Features of pricing behavior in our data

Before exploring markup variation and state dependence, we lay out some summary statistics on the frequency and size of price changes, synchronization of price changes within plants, and on the invoice currency choice of exporters with different characteristics.

3.1 Frequency and size of price adjustment

Table 6 reports the mean frequency of price adjustment overall, for home sales and exports, and for exports, by currency of denomination. The first column reports the relevant number of observations. The next three columns report frequencies of adjustment in invoice currency, unweighted, weighted by turnover share, and weighted with an additional adjustment to treat product exit as a price change. The fifth and sixth columns report separately the weighted frequencies of price increases and price decreases in invoice currency. The last two columns report the frequency of price changes in domestic currency, unweighted and weighted. We leave out a window of 12 months around the Euro changeover (July 2001-June 2002) in case price setting behavior is special during this episode, though the reported frequencies are not in fact sensitive to this.

From the perspective of pricing behavior, the columns in Table 6 showing frequency of adjustment measured in invoice currency are of greatest interest. Prices are sticky in invoice currency. The weighted mean frequency of price adjustment of 0.14 implies a weighted mean duration of prices of 7.1 months, calculated as $1/f$. The overall frequency of price changes is somewhat lower than that reported by Vermeulen et al. (2007) for six Euro zone countries, and by Nakamura and Steinsson (2007) for the US. This may be partly due to the fact that we are measuring stickiness in invoice currency rather than home currency, or to the difference between our weighting scheme and theirs. The weighted mean frequency of adjustment in invoice currency is roughly comparable across domestic sales and exports. For both, the frequency is similar to that found by Gopinath and Rigobon (2007) for US export prices. Within exports, the weighted mean frequency of adjustment is lower for prices invoiced in domestic currency than it is for prices invoiced in foreign currency.

The price changes actually used to construct producer price inflation are those measured in domestic currency (Irish pounds or Euros), i.e. the final two columns. The currency breakdown illustrates that the high frequency of adjustment when measured in domestic currency is due to a combination of foreign currency invoicing, stickiness in invoice currency, and floating exchange rates.

Since we cut the data in similar ways in presenting the results on the intensive and extensive margin, it is worth saying something here about the breakdown of different goods that we use. The first breakdown of goods into different types is a classification of NACE 4-digit sectors used by Vermeulen et al. (2007). NACE sectors 10-41 are divided into consumer food products, consumer non-food non-durables, consumer durables, intermediates, energy or capital goods. Consumer food products, intermediates and capital goods are the most important sectors in our data. The other breakdown we use is based on the Rauch (1999) classification of 4-digit SITC sectors as traded on an organized exchange, reference-priced or differentiated. The match between our 4-digit NACE (production) sectors and 4-digit SITC (trade) sectors is imperfect, and many NACE sectors in our data do not have a Rauch classification. More details of these classifications are provided in the Appendix. We also report frequencies by plant size. Because of the transfer pricing issue, we use an employee-based rather than a sales-based measure of size. Plants are allocated to size classes on the basis of their median number of employees over the sample period.

Table 7 reports the frequency of price adjustment for these two different classifications and by plant size. There is considerable heterogeneity in the degree of price stickiness. The ordering of relative frequency of adjustment for goods of different types is roughly similar to that found by Vermeulen et al. (2007) for 6 Euro zone countries. The ranking of frequency of adjustment by Rauch classification is a little different to that found by Gopinath and Rigobon (2007) for US import and export prices. They find that prices for reference-priced goods are considerably more flexible than differentiated goods.

As others have found [Vermeulen et al. (2007), Nakamura and Steinsson (2007)] we observe simultaneous price increases and decreases, not only across, but within sectors. Like Vermeulen et al. (2007), we find that the frequency of price increases is marginally higher than the frequency of price decreases. Nakamura and Steinsson (2007) find a much bigger gap in the frequency of price increases and decreases in US data. The contrast between the large gap we find for home sales and the almost equal frequency of increases and decreases for export sales implies that a bigger role for exports in Europe may explain the US-Europe differences. We have not explored the possibility that different inflation rates may account for some of these differences.

Table 8 reports summary statistics on the size distribution of price changes. Weighted mean price increases and decreases are somewhat bigger than those reported by Vermeulen et al. (2007) though the weighted medians are not too dissimilar. We find weighted median changes that are considerably smaller than those reported by Nakamura and Steinsson (2007) for the US. Unlike the sign of price changes, this does not appear to be accounted for by the prevalence of exports.

To summarize, we find that the behavior of producer prices in Ireland is not too dissimilar from that in six Euro zone countries and the US along the dimensions of weighted mean frequency and size of price adjustment. This gives us some confidence moving forward that our results on the intensive and extensive margins of price adjustment will have general applicability.

3.2 Synchronization of price changes

The degree of synchronization of price changes across multiple quotes for the same product sold by the same plant is crucial for our strategy for identifying the effects of demand shocks, as well as being of independent interest [see for example Lach and Tsiddon (1996) and Midrigan (2007)]. In some cases of multiple quotes, a single quote per market is reported (i.e. home and export market, or home and several different export destinations). However many plants report multiple quotes per market. Summary statistics on this type of synchronization are reported in Table 9. The first column of the table reports the fraction of plant-product-months with more than one quote (i.e. the relevant population) where at least one price changes. The second column reports the fraction of this group for which there is exactly one price change. The third column reports the fraction of these plant-product-months for which at least two, but not all price quotes change (this applies only to cases with three or more price quotes). The fourth column reports the fraction of these plant-product-months for which all relevant quotes change. There is substantial, but not perfect synchronization of price changes across quotes for the same product produced by a particular plant. The next rows of the table illustrate that this is true when we restrict the sample only to quotes in home currency in the home market and quotes in Sterling in the export market (the sample we use to identify the effect of demand shocks). We have also checked that the proportions are roughly similar when the period of the Euro changeover is excluded.

3.3 Invoice currency choice

While we cannot match our price quotes (for which we know the invoice currency) with precise destination information, we do have some information at the firm level about choice of invoice currency for exports to the UK market. In the CIP, firms are asked what fraction of their exports to the UK is invoiced in Sterling, what fraction in domestic currency (Irish pounds or Euros, as appropriate) and what fraction in other currency. There are some issues with the quality of this variable, so we do not perform a formal analysis of the invoice currency choice decision. But given the importance of this choice for pricing behavior, we report some summary statistics here.

[To be completed]

4 A framework to examine price setting

To motivate our empirical work, we present a simple framework for analyzing price setting behavior. First, it is useful to consider the case of instantaneous adjustment.

4.1 No price stickiness

Our framework simplifies along a number of dimensions. In particular, we do not model the entry/exit decision, we assume that multi-product firms maximize profits separately for different products, and we condition on invoice currency choice. These simplifications are driven by the limitations of the data.[2]

Consider a single-product firm i selling to K different destination markets, indexed by k. Demand in each market is assumed to take the form:

$$q^i_{kt} = f^i_k\left(p^{i*}_{kt}, p^{-i*}_{kt}\right) y_{kt} = f^i_k\left(p^i_{kt}/e_{kt}, p^{-i*}_{kt}\right) y_{kt} \tag{1}$$

Here, q^i_{kt} is the quantity of i's good demanded by market k at time t, p^{i*}_{kt} is its price in terms of the currency of the destination market, p^{-i*}_{kt} (possibly a vector) represents competitors' prices in the destination market, p^i_{kt} is the price of the good in producer currency, e_{kt} is the exchange rate (producer's currency per unit of destination market currency) and y_{kt} is a random variable (possibly a vector) that may shift demand. If market k uses the producer's currency, $e_{kt} = 1$ and $p^{i*}_{kt} = p^i_{kt}$ (e.g. the home market). We assume that the price in market k does not depend on i's price in any other market (i.e. there is effective market segmentation).

Let firm i's costs be given by

$$c^i_t = c^i\left(\sum_k q^i_{kt}\right) z^i_t \tag{2}$$

where c^i_t measures costs in units of the producer's currency, and z^i_t is a random variable that may shift the cost function. Implicitly, this specification assumes that delivery costs are paid by the buyer, not the seller, and are not included in the price (We will be able to relax this assumption to some degree in most of what we do). The firm's profit in period t is then:

$$\pi^i_t = \sum_k p^i_{kt} q^i_{kt} - c^i\left(\sum_k q^i_{kt}\right) z^i_t \tag{3}$$

Maximizing with respect to the producer currency price for each market yields a set of first order conditions:

$$p^i_{kt} = mc^i_t\left[\frac{\eta^i_{kt}}{\eta^i_{kt} - 1}\right] = mc^i_t \mu^i_{kt} \ \forall k, t \tag{4}$$

If the firm sets prices in the currency of the destination market rather than the home currency, the markup equation would be effectively unchanged:

$$p^{i*}_{kt} = mc^i_t\left[\frac{1}{e_{kt}}\frac{\eta^i_{kt}}{\eta^i_{kt} - 1}\right] = mc^i_t \frac{\mu^i_{kt}}{e_{kt}} \tag{5}$$

[2]Although we observe extensive product entry and exit in our data, we have only a sample, not the universe of products, so it is not clear what we can infer from this. Plant participation in the home and UK markets (the two we focus on most closely) is highly persistent.

Here, mc_t^i equals $\partial c^i / \partial q_{kt}^i \cdot z_t^i$, the marginal cost of production in period t. The assumption that marginal cost is equal across all markets k (or, more precisely, that changes in marginal cost are the same across markets) is crucial to our identification strategy. The desired markup over marginal cost, μ_{kt}^i, depends on η_{kt}^i, the elasticity of demand with respect to the destination currency price in market k:

$$\eta_{kt}^i = \frac{\partial \ln q_{kt}^i}{\partial \ln p_{kt}^{i*}}$$

For general demand functions, η_{kt}^i depends on both the destination currency price, p_{kt}^{i*}, and on the behavior of competitors through p_{kt}^{-i*}.

Exchange rate changes affect the desired price through two channels, a demand channel and a cost channel. On the demand side, there is a direct effect and an indirect effect, both of which rely on the price elasticity of demand not being constant. The direct effect is that for a given producer currency price in market k (p_{kt}^i) the price elasticity of demand (η_{kt}^i) may vary with the exchange rate because $p_{kt}^{i*} = p_{kt}^i / e_{kt}$. Or, to put it a different way, when the exchange rate changes, this affects the firm's domestic currency revenues from the foreign market even if the destination currency price and quantity sold remain unchanged. This is perceived by the firm as a relative demand shift. The indirect effect works through the impact of changes in the exchange rate on competitors prices, p_{kt}^{-i*}. Again, this relies on the price elasticity of demand not being constant and depending on competitors' prices. We assume that the net effect of a depreciation (an increase in e_{kt}) through both direct and indirect channels is perceived by the firm as an increase in demand in market k relative to the home market.[3]

On the cost side, changes in exchange rates may affect the price of imported intermediate inputs. We expect depreciations to increase costs through this channel, and appreciations to reduce costs. In the results we present in this paper, we use a fixed effects strategy to control for changes in costs, so we can isolate the demand-side effects of exchange rate changes. We are particularly interested in whether firms respond to demand shocks with some degree of adjustment of desired markups. We refer to this as the intensive margin of price adjustment. But before digging deeper, we must take account of the fact that prices may not be changed every period.

[3]Because we do not observe the full set of competitors' prices in any market, we do not control for the two effects separately in our baseline results, though we show some robustness results where we try to do this with imperfect data.

4.2 State-dependent pricing

We follow the literature[4] in assuming that if there is state-dependence it takes the form of an (S,s) rule. Firms re-optimize prices only if the desired change in invoice currency prices is sufficiently large. We also assume that when they re-set prices, they set them such that the price equivalent in home currency equals (4).[5] This rule is optimal if desired prices are a random walk and there are fixed costs of changing prices. Given that we cannot reject the random walk null for nominal exchange rates, this is a reasonable assumption if the only shocks that face firms are driven by floating exchange rates. It is less reasonable in the presence of shocks (for example, to competitors' prices, wages etc.) that may be persistent, but not a random walk.

Suppose we are at date t. Let $s_k^i(t) < t$ be the last date on which firm i changed its price in market k. Then let

$$\Delta_{t-s_k^i(t)} x_t = x_t - x_{s_k^i(t)}$$

Define:

$$g^i_{kt,s_k^i(t)} = \Delta_{t-s_k^i(t)} \ln mc_t^i + \Delta_{t-s_k^i(t)} \ln \mu_{kt}^i \tag{6}$$

This is the desired change in the producer currency price. Since $p_{kt}^{i*} = p_{kt}^i / e_{kt}$, for prices invoiced in destination currency, the desired change in destination currency price is equal to $g^i_{kt,s_k^i(t)}$ less the relevant exchange rate change. We call this $d^i_{kt,s_k^i(t)}$:

$$d^i_{kt,s_k^i(t)} = \begin{array}{ll} g^i_{kt,s_k^i(t)} & \text{if invoiced in home currency} \\ g^i_{kt,s_k^i(t)} - \Delta_{t-s_k^i(t)} \ln e_{kt} & \text{if invoiced in destination currency} \end{array} \tag{7}$$

If firms follow an (S,s) rule, large positive and negative values of $d^i_{kt,s_k^i(t)}$ will result in prices being re-set. In between, there is a band of inaction. We allow for the possibility that the (S,s) band is not symmetric:

$$\begin{array}{lll} \text{Increase invoice currency price} & \text{if} & d^i_{kt,s_k^i(t)} > \bar{\rho} > 0 \\ \text{Keep invoice currency price unchanged} & \text{if} & \underline{\rho} \leq d^i_{kt,s_k^i(t)} \leq \bar{\rho} \\ \text{Reduce invoice currency price} & \text{if} & d^i_{kt,s_k^i(t)} < \underline{\rho} < 0 \end{array} \tag{8}$$

In general, if desired prices depend on exchange rates, the likelihood of a price change under state-dependent pricing depends on exchange rates, though as we will see, parameter

[4] See Barro (1972), Caplin and Spulber (1987), Caballero and Engel (1993) among many others.

[5] We do not allow for the possibility of "sticky information."

values matter crucially. Following the literature, we call this the extensive margin of price adjustment, in contrast to the intensive margin which captures how prices change conditional on adjustment.

4.3 Time-dependent pricing

There is a long tradition of assuming that firms price in a time-dependent fashion. If firms strictly follow time-dependent rules, there is no extensive margin of price adjustment in response to shocks. If firms follow a mixture rule with both state and time-dependent components, there will be some extensive margin response to shocks. Our empirical strategy is designed to test for the presence of an extensive margin. It controls for, but cannot test for the presence of a time-dependent component to pricing. We do observe seasonal patterns in the frequency of price adjustment that suggest that some firms may systematically reset prices at a quarterly or annual frequency. We also present some evidence on the length of price spells suggesting that few firms engage in purely time-dependent pricing of this type.

5 Empirical strategy

We first describe a simple exercise designed to test the null hypothesis that desired markups are constant, making use of as much of the sample information as possible. We then lay out a more formal strategy for identifying price responses to demand shocks driven by exchange rate shocks on both the intensive and extensive margin. This strategy allows us to estimate the direction of the effects of shocks on markups, with the tradeoff that identification is driven by a small subset of the data.

5.1 Markup variation in the broad sample

Suppose that desired markups are constant over time within a quote-line. In addition, suppose that at any point in time, marginal cost is the same across all markets k served by plant-product pair i up to the order of a time-invariant constant. Then we can write the price of plant-product pair i in market k at time t as:

$$p_{kt}^{i} = mc_{t}^{i}\lambda_{k}^{i}\mu_{k}^{i}\left(1+\varepsilon_{kt}^{i}\right) \tag{9}$$

Here, $mc_t^i \lambda_k^i$ is the marginal cost of sales to market k at time t, μ_k^i is the (constant) desired markup, which may vary across markets, and ε_{kt}^i is the deviation of the markup from the desired markup at time t. For plant-product pairs with more than one price quote, we can back out an estimate of ε_{kt}^i as the residual from regressing $\ln p_{kt}^i$ on an appropriate set of dummy variables:

$$\ln p_{kt}^i \simeq \theta_t^i + \phi_k^i + \varepsilon_{kt}^i \tag{10}$$

If desired markups are indeed constant, and firms choose prices optimally when they change them, should find the distribution of $\hat{\varepsilon}_{kt}^i$ more tightly centered on zero when we condition on plant-product-market-months where invoice currency prices are changed than when we condition on plant-product-market-months where prices are not changed. On the other hand, if desired markups are variable, the behavior of $\hat{\varepsilon}_{kt}^i$ conditional on price changes versus the behavior of $\hat{\varepsilon}_{kt}^i$ conditional on no price change depends on how desired markups move, and there is no clear prediction about the relationship between the two distributions.

For reasons we describe below, in estimating (10), we restrict attention to home sales invoiced in home currency and export sales invoiced in Sterling. The exercise is meaningful only for plant-product pairs for which there is more than one quote, so we additionally restrict our estimation to such pairs and require that at least one price change be observed over the duration of each quote-line.

5.2 Identifying responses to demand shocks

Our strategy for identifying the nature of price adjustment to demand shocks driven by exchange rate changes is based on the idea that comparing matched observations for plants selling the same product in different markets that are segmented by variable exchange rates allows us to control for changes in marginal cost without actually observing them.[6] This approach is valid if *changes* in marginal cost for a particular product produced by a particular plant are the same across all destination markets over a given time interval. We maintain this assumption in what follows.

Consider the following specification for $g^i_{kt,s_k^i(t)}$, the latent desired percent change in the producer currency price for the plant-product pair i in market k given that the previous

[6] We have some information on total cost, but it is at an annual frequency and observed at the level of the plant, not the product.

price change was at $s_k^i(t)$:

$$g^i_{kt,s^i_k(t)} = \alpha + \theta^i_{t,s^i_k(t)} + \beta_k \Delta_{t-s^i_k(t)} \ln e_{kt} + \varepsilon^i_{kt} \tag{11}$$

In this expression, $\theta^i_{t,s^i_k(t)}$ is a plant-product-month-age of price fixed effect, $\Delta_{t-s^i_k(t)} \ln e_{kt}$ is the change in bilateral exchange rates between the home market and market k since the last time the price of product i in market k was changed and ε^i_{kt} is an error term. Under the identifying assumptions, the plant-product-month-age of price fixed effect captures the percent change in marginal cost between t and the last time the price was changed (as well as any shifts in desired markups that are the same across markets). As long as delivery costs are fixed, it does not matter whether prices are measured inclusive or exclusive of these costs.

The coefficient of interest, β_k, can be identified when we observe a plant-product pair in two markets that are segmented by variable exchange rates. Specification (11) imposes that β_k is the same for all plants selling to market k, but this can easily be relaxed to allow it to vary by sector, plant size or other characteristics. β_k is the elasticity of the desired relative markup (between the home market and market k) with respect to shifts in relative demand that are correlated with nominal exchange rate changes between the two markets.

As already mentioned, we believe it is plausible to assume that a depreciation (an increase in e_{kt}) is perceived by the firm as an increase in demand in market k compared to the home market. Under this assumption, a positive value of β_k implies that desired relative markups are increasing in relative demand. A negative value implies that desired relative markups are decreasing in relative demand. A value of zero is consistent with constant desired markups.

Since our strategy depends on observing the same good sold by the same plant in at least two markets segmented by variable exchange rates, we must be able to identify export destinations. In identifying markets other than the home market, we are constrained by the fact that our destination information for exports is poor. However for all export observations, we have information on the currency in which prices are set. When prices are set in currencies such as the dollar, this is not informative about the precise destination market. But for some currencies, we are fairly sure that we can identify a product with a particular market based on the invoice currency. In particular, we assume that Sterling-invoiced exports are sold in the UK market and in our baseline estimation, we restrict the sample to home market quotes invoiced in domestic currency and export quotes invoiced in Sterling. Since the UK is the largest single destination market for Irish exports, this yields a relatively large sample size. We recognize that this approach is not ideal: The choice of invoice currency is endogenous, and there is evidence that pricing behavior differs systematically with the choice of invoice currency [Gopinath, Itskhoki and Rigobon (2007)]. But given the constraints of the available data, this is the best we can do.

5.2.1 Intensive margin

We observe $g^i_{kt,s^i_k(t)}$ only when invoice currency prices are reset. By conditioning on invoice currency price changes at t, we can use (11) to test whether relative markups vary in response to relative demand shocks:

$$\Delta_{t-s^i_k(t)} \ln p^i_{kt} = \alpha + \theta^i_{t,s^i_k(t)} + \beta_k \Delta_{t-s^i_k(t)} \ln e_{kt} + \varepsilon^i_{kt} \tag{12}$$

We can identify β_k if price changes are synchronized across the Irish and UK markets at t, conditional on the previous price changes in those two markets also being synchronized. As we will see, synchronization of price changes within plant-product pairs is relatively common. However, the requirement that two consecutive sets of price changes be synchronized restricts the size of the sample we can use to estimate equation (12) and raises the possibility that the results may be driven by sample selection. We return to this issue later.

We restrict our baseline sample to plant-product pairs with at least one quote for a home sale invoiced in domestic currency and at least one quote for an export sale invoiced in Sterling. In estimating (12) and (15) we weight by turnover shares as described below and cluster standard errors at the plant level.

5.2.2 Extensive margin

We can use equation (11) to write the the desired change in destination currency price, $d^i_{kt,s^i_k(t)}$, as

$$d^i_{kt,s^i_k(t)} = \begin{array}{ll} \alpha + \theta^i_{t,s^i_k(t)} + \varepsilon^i_{kt} & \{ \begin{array}{l}\text{for home sales invoiced}\\ \text{in home currency}\end{array} \\ \alpha + \theta^i_{t,s^i_k(t)} + (\beta_k - 1)\, \Delta_{t-s^i_k(t)} \ln e_{kt} + \varepsilon^i_{kt} & \{ \begin{array}{l}\text{for UK sales invoiced}\\ \text{in Sterling}\end{array} \end{array}$$

Now, assume that ε_{kt}^{i} has a logistic distribution. Then, making use of (8), we can write:

$$\Pr\left[\text{Increase in inv. curr. price}\right] = \Lambda\left(\alpha - \bar{\rho} + \theta_{t,s_k^i(t)}^{i} + (\beta_k - 1)\,\Delta_{t-s_k^i(t)} \ln e_{kt}\right) \tag{13}$$

$$\Pr\left[\text{Reduction in inv. curr. price}\right] = \Lambda\left(-\alpha + \underline{\rho} - \theta_{t,s_k^i(t)}^{i} - (\beta_k - 1)\,\Delta_{t-s_k^i(t)} \ln e_{kt}\right) \tag{14}$$

where $\Lambda(z) = \exp(z)/1+\exp(z)$. As in the case of the intensive margin, in order to identify $(\beta_k - 1)$, we rely on matching observations for the same product sold by the same plant in the Irish and UK markets. Conditional on the last price change having been synchronized across the two markets, changes in marginal cost are picked up by plant-product-month-age of price fixed effects.

Expressions (13) and (14) allow us to test the joint null hypothesis of no state dependence, or state-dependence and $\beta_k = 1$, against the alternative of state-dependence and $\beta_k \neq 1$. Though the scale of the latent variable $(d_{kt,s_k^i(t)}^{i})$ is not identified, if there is state-dependence in price setting and $\beta_k > 1$, the coefficient on the exchange rate change is positive for the case of increases and negative for the case of decreases. If β_k is exactly one, firms will not want to change prices in response to exchange rate changes that are pure demand shocks, even if pricing is in general state-dependent. If there is state-dependence and $\beta_k < 1$, the coefficient on the exchange rate change is negative for the case of increases and positive for the case of decreases.

Ideally, we would have liked to be able to test the null of no state-dependence against the alternative of state-dependence irrespective of the value of β_k. Given our estimates of β_k from the intensive margin, this formulation will turn out to be particularly unfortunate. But because we can only identify UK sales if they are invoiced in Sterling rather than home currency, this is the best we can do.

The potential asymmetry across increases and decreases in (8) implies that (13) and (14) should be estimated separately.[7] For (13), we code increases in invoice currency price as a one, while observations where the price is not reset and observations where the invoice currency price is decreased are both coded zero. Similarly, for (14), we code as a one observations where the invoice currency decreases, while cases where the price is not reset or the invoice currency price increases are both coded zero. We use fixed effects logit estimation. The conditioning procedure that eliminates the fixed effects $(\theta_{t,s_k^i(t)}^{i})$ makes use only of cases

[7] Estimating separate equations is more straightforward and transparent than combining fixed-effects with ordered dependent variables .

where the dependent variable is a one in one market but not the other. The thresholds for price adjustment, $\bar{\rho}$ and $\underline{\rho}$ are controlled for by this procedure, implicitly allowing for plant and time-interval specific cutoffs. As in the case of the intensive margin, we restrict our baseline sample to plant-product pairs with at least one quote for home sales invoiced in domestic currency and at least one quote for export sales invoiced in Sterling. We weight by turnover shares and cluster standard errors at the plant level.

5.3 Weighting procedure

The fact that we can match price information with plant census data means that we can weight observations at a much greater level of disaggregation than is usual in studies that use micro price data. Across destination market categories and plants, weights are given by plant-level turnover broken down by domestic and export sales as a share of total within-sample turnover for the relevant year. For a given year, within a plant and destination market category (home price quote or export price quote), we know nothing about the breakdown of sales, so we assign all quotes equal weight.

For example, suppose plant i reports J_{ht}^{i} price quotes in the home market at time t and total home sales of $SALES_{ht}^{i}$ in that year. Then the weight for a price quote for a given product j sold by this plant in the home market at time t is given by:

$$w_{ht}^{ij} = \frac{\frac{1}{J_{ht}^{i}} SALES_{ht}^{i}}{\sum_{i=1}^{N_t} \sum_{k=h,e} SALES_{kt}^{i}}$$

If this plant reports J_{et}^{i} price quotes in the export market, the analogous weight for an export price quote is:

$$w_{et}^{ij} = \frac{\frac{1}{J_{et}^{i}} SALES_{et}^{i}}{\sum_{i=1}^{N_t} \sum_{k=h,e} SALES_{kt}^{i}}$$

One problem with this weighting scheme is that because of the possibility of transfer pricing, the weights for some foreign multinationals may misrepresent true sales. Some of the most likely cases have been dropped from our sample for confidentiality reasons, but this may still be a problem, so we check the robustness of our main results to alternative weighting schemes.

6 Markup variation and state-dependence

6.1 Markup variation in the broad sample

Table 10 reports summary statistics of the distribution of the residuals from estimating (10). Under the null hypothesis that the desired markup is constant (and subject to our assumptions on costs), these are the percent deviations of the markup from the desired markup. When we condition on invoice currency prices changing, the distribution is in fact less tightly concentrated around zero than when we condition on invoice currency prices not changing. This is illustrated in Figure 2. The evidence from this exercise suggests that, desired markups vary over time. This is based on using 60% of our full sample of 520,000 price quotes to estimate (10), so it seems unlikely that this result is driven by selection.

We now proceed to the results from our more formal test of the null hypothesis of constant desired markups.

6.2 Intensive margin

Tables 11 and 12 report the results from estimating (12), conditioning on synchronized price changes at t and $t - s_k^i(t)$.[8] The first row of Table 11 gives the baseline estimates. It is worth pointing out that these estimates are based on a small fraction of the full sample of price quotes available to us. This is because the requirement of double-synchronization of price changes is a demanding one. The coefficient β_k on $\Delta_{t-s_k^i(t)} \ln e_{kt}$ is the coefficient of interest. It is positive and significantly different from zero, but not significantly different from one. As already discussed, a positive coefficient indicates that desired markups increase in response to positive demand shocks and fall in response to negative demand shocks. A coefficient equal to one implies a unitary elasticity of the desired relative markup with respect to the exchange rate.

Subsequent rows of Table 11 and Table 12 estimate equation (12) on various subsets of the data. In all but two cases the coefficient of interest is significantly different from zero. In all but two cases it is not significantly different from one. One might have expected heterogeneity across firms of different sizes, industries with different market structure and

[8] It is only necessary to condition on synchronization at t, but since only those observations for which there is double synchronization identify the parameter of interest, we restrict the sample so as to be clear about the number of observations that drive our results.

so on, but we find no systematic vidence of such heterogeneity. We now discuss possible interpretations of these results.

6.2.1 Interpretation

Since we identify sales to the UK through the choice of Sterling as the invoice currency, our estimate of $\beta_k \simeq 1$ is exactly what we would find if we were to condition on *no* changes in invoice currency prices rather than on invoice currency prices changing. On average, firms do not appear to take advantage of the fact that they are changing prices in both markets to readjust relative markups in response to the accumulated exchange rate changes since the last time both prices were changed.

One interpretation of the estimate of $\beta_k \simeq 1$ is that it is capturing "rule-of-thumb" pricing behavior, where firms apply the same percentage increase to invoice currency prices in both markets, irrespective of the shock to relative demand coming through exchange rates. To investigate this possibility, Figure 3 plots the difference between the log change in the Sterling price and the log change in the home currency price in Ireland against the log change in the exchange rate, for all the observations included in the estimation.[9] The 45 degree line is also added to the figure (this is approximately equal to the regression line since $\beta_k \simeq 1$). Clearly, we do not have strict equality between the log change in invoice currency price in both markets, since the data does not lie exactly on the 45 degree line. So while there may be some pure "rule-of-thumb" pricing behavior, this alone is not what drives the estimate of β_k.

Another possibility is that our coefficient estimate is driven by selection: only a very narrow set of observations fulfil the double-synchronization requirement that allows us to identify β_k. One point to note here is that synchronized price changes within plants are common - of the relevant population (plant-product pairs with more than one price quote in months where there is at least one price change) 50% are fully synchronized price changes. So there is nothing special about synchronization per se. However the double synchronization requirement may result in selection that affects the result. In particular, it may select disproportionately price changes that occur at very short intervals (especially one month apart). In particular, we have in mind goods like commodities, where prices change at high frequency and are set on world markets. To explore this possibility, we re-estimate (12)

[9] For cases where there is more than one price quote in a particular market, the mean log change is used.

splitting the data by age of prices. The results are reported at the bottom of Table 12. The estimated coefficient on the exchange rate change is significantly different from zero and not significantly different from one in all of the age categories considered. This suggests that high-frequency changers alone are not driving our results. In addition, as we will see in the results on the extensive margin, a different subset of observations and a different estimation approach yield results that are consistent with $\beta_k \simeq 1$.

Given the endogeneity of invoice currency choice, perhaps the finding that conditional on prices changing, $\beta_k \simeq 1$ is not very surprising. We would expect firms to choose the invoice currency where the default movement of relative markups is as close as possible to the desired movement in relative markups. Seen in this light, the fact that firms choose to invoice export sales in destination currency rather than home currency is already evidence that they desire movement in relative markups that is at least closer to one-for-one movement with exchange rate changes than no response to exchange rate changes at all (as it would be if they invoiced in producer currency). The one caveat to this interpretation is that, as we have already noted, there is heterogeneity both within and across similar plants in invoice currency choice. We do not know whether we would come to very different conclusions about desired markup variation for the very same firms, if we were able to identify sales to the UK invoiced in producer currency. When we estimate (10) using a very limited subsample where exports to the UK are explicitly identified as such independent of the invoice currency. We find that β_k is very imprecisely estimated - not significantly different from zero or one. But the sample involved is very small, so this is hardly surprising.

6.2.2 The structure of demand

Beyond concluding that desired markups increase in response to increases in demand and fall in response to reductions in demand, can we draw any further inference about the structure of demand from the estimate of $\beta_k \simeq 1$? In order to give a structural interpretation to this coefficient, we would first have to control for competitors' prices in both home and UK markets, as exchange rate changes may have an indirect effect through competitors' prices as well as a direct effect on revenues.

Our firms face both Irish and non-Irish competitors in the Irish market, and both UK and non-UK competitors in the UK market. We do not have access to disaggregated price indexes that take account of imports as well as domestic production in these two markets.

The best we can do is to try to control for the price of Irish producers in the Irish market and UK producers in the UK market, presuming that this reflects at least to some extent differences in the composition of competitors in the two markets. For the Irish producers, we use our micro-data on prices to construct a sales-weighted sectoral price index based on all plants in the same 2, 3 or 4-digit NACE sector, excluding the plant in question. We also use the official aggregate producer price index (PPI). For the UK, we take the aggregate producer price index and producer price indexes for the relevant 2, 3 or 4-digit NACE sector from EUROSTAT. These indexes are available for only a limited number of sectors. We then estimate:

$$\Delta_{t-s_k^i(t)} \ln p_{kt}^i = \alpha + \theta_{t,s_k^i(t)}^i + \beta_k \Delta_{t-s_k^i(t)} \ln e_{kt} + \gamma \Delta_{t-s_k^i(t)} \ln p_{kt}^{-i*} + \varepsilon_{kt}^i$$

using the price indexes at the four different levels of aggregation to calculate $\Delta_{t-s_k^i(t)} \ln p_{kt}^{-i*}$. The results are reported in Table 13. We find $\beta_k \simeq 1$ irrespective of the measure we use to control for competitors' prices. The coefficient on the sectoral price index is never significantly different from zero.

If we believe that in the above exercise we are controlling adequately for competitors' prices, then β_k has the following interpretation:

$$\beta_k \simeq \frac{\frac{\partial \eta_{kt}^i}{\partial \ln p_{kt}^{i*}}}{\left[\eta_{kt}^i - 1\right]^2 + \frac{\partial \eta_{kt}^i}{\partial \ln p_{kt}^{i*}}}$$

where $\eta_{kt}^i = \partial \ln q_{kt}^i / \partial \ln p_{kt}^{i*}$. To see what $\beta_k \simeq 1$ implies about the structure of demand, consider the following non-constant elasticity demand curve [see Klenow and Willis (2006)]:

$$q_{kt}^i = y_{kt} \left[1 - \theta \left(\ln p_{kt}^{i*} - \ln p_{kt}^{-i*}\right)\right]^{\frac{\sigma}{\theta}}$$

In this demand function, σ is the (negative of the) price elasticity of demand evaluated when price is equal to competitors' price, while θ is the "super-elasticity," the elasticity of the price elasticity of demand with respect to own price, again evaluated when price is equal to competitors' price. This parameter governs the curvature of demand. With this functional form,

$$\beta_k \simeq \frac{-\theta\sigma}{\left[1 - \theta \left(\ln p_{kt}^{i*} - \ln p_{kt}^{-i*}\right) + \sigma\right]^2 - \theta\sigma}$$

so β_k approaches 1 from above if θ is large and positive. This implies that demand falls very sharply to zero when the price is above competitors' prices (the case where β_k approaches 1 from below requires values of θ that yield implausible demand). So if one wanted to push a structural interpretation of $\beta_k \simeq 1$, it would be consistent with a very kinked demand. However given that our controls for competitors' prices are very imperfect, we are reluctant to push this interpretation.

6.3 Extensive margin

Tables 14, 15, 16 and 17 report the results from estimating (13) and (14), respectively. The first row gives our baseline estimates from pooling all the data. As in the case of the intensive margin, these estimates are based on a very narrow subset of the data (though not the same subset as in the intensive margin case). We cannot reject the null hypothesis, which is that either pricing is not state-dependent, or that it is state-dependent but $\beta_k = 1$. Given the results of the previous section this should not come as a surprise, though it is unfortunate that we are unable to separate the latter two possibilities. On the other hand, it is at least somewhat encouraging to find no positive evidence of inconsistencies in pricing behavior across the intensive and extensive margins, even though these two margins are identified by largely different sets of observations.

Subsequent rows of Tables 14, 15, 16 and 17 show the results from estimating (13) and (14) on various subsets of the data. In only three cases is the coefficient on the exchange rate change significantly different from zero at the 5% level. Consistent with the intensive margin results, there is no systematic evidence of heterogeneity across firms of different size, in different industries, etc.

6.4 Time-dependent pricing

Figure 4 plots the (weighted) frequency of price changes in invoice currency month-by-month throughout the sample period. From this figure, there appears to be some degree of time-dependence (and synchronization) in price setting, with spikes in the frequency of price changes in January in many years.

To investigate the possibility that prices are set in advance for a fixed unvarying number of months [as in Taylor (1979) and Taylor (1980)] we perform the following exercise. For each quote-line, we calculate the coefficient of variation (standard deviation divided by the mean) of the length of completed price spells. Censored price spells are excluded from this calculation. If spells are all of the same length, consistent with a fixed frequency of price adjustment, the coefficient of variation will equal zero. Figure 5 is a histogram of the distribution of these coefficients of variation. While there are some quote-lines for which there is no variation in the length of price spells, in general this is not the case. This implies that pure time-dependent pricing of the Taylor type is not prevalent, though firms may engage in a combination of time-dependent and state dependent pricing.

6.5 Robustness

We perform a number of robustness checks of our results. We do not have space to present these fully, but we briefly describe some of them here. Details are available on request.

It has been suggested by the survey literature on pricing behavior that firms tend to respond differently to positive and negative demand shocks [see Pelzman (2000) for the US and Fabiani et al. (2005) for the Euro zone]. We can allow for asymmetry in our intensive margin exercise by allowing the coefficient on appreciations and depreciations to differ:

$$\Delta_{t-s_k^i(t)} \ln p_{kt}^i = \alpha + \theta_{t,s_k^i(t)}^i + \beta_k^+ \Delta_{t-s_k^i(t)} \ln e_{kt}^+ + \beta_k^- \Delta_{t-s_k^i(t)} \ln e_{kt}^- + \varepsilon_{kt}^i \tag{15}$$

Here $\Delta_{t-s_k^i(t)} \ln e_{kt}^+$ is positive when the exchange rate change is positive, and zero otherwise, and conversely for $\Delta_{t-s_k^i(t)} \ln e_{kt}^-$. Under asymmetry, we would expect β_k^+ and β_k^- to be significantly different from each other. We estimate (15) using the full set of identifying observations and the same subsets as in the case of (12). We do not find any evidence that β_k^+ and β_k^- are significantly different from each other. In addition, we check for nonlinearity of a different form by adding a squared term in exchange rates to (12). The coefficient on this term is not significantly different from zero.

We are interested in whether pricing behavior is different before and after the introduction of the Euro. One reason why this might be the case is that the introduction of the Euro increases the comovement between the costs of Irish producers and those of competitors based in the Euro zone. Hence, it may effect the comovement between the Irish-Sterling exchange rate and competitors' prices in both markets. We split the sample into three periods, 1995-98, 1999-2001 and 2002-2004, and estimate (12) on each. In each sub-period, β_k is significantly different from zero and not significantly different from one (see Table 12).

In the PPI data, there are price quotes for exports invoiced in other currencies besides home currency and Sterling. We use home sales invoiced in home currency and export sales invoiced in foreign currency to estimate

$$\Delta_{t-s_k^i(t)} \ln p_{kt}^i = \alpha + \theta_{t,s_k^i(t)}^i + \beta \Delta_{t-s_k^i(t)} \ln e_{kt} + \varepsilon_{kt}^i \tag{16}$$

where $\Delta_{t-s_k^i(t)} \ln e_{kt}$ is the change in the domestic exchange rate with invoice currency, which is not necessarily the same as the currency of the destination market. We find that β is significantly different from zero, and not significantly different from one.

Finally, as we have already noted, exchange rate changes are potentially a source of cost as well as demand shocks. Since the plants in our sample have differential exposure to imported intermediates, and the propensity to use imported intermediates from a particular source appears to be persistent, these shocks affect different plants differentially. Under the assumption that all plants selling a particular product to the Irish market face the same shock to demand over a given horizon, it is possible to use a fixed effects strategy to investigate pricing responses to cost shocks on the intensive and extensive margin in a manner analogous to our approach for demand shocks. Because price changes are much less synchronized across different plants producing a given product than within plant-product pairs, the set of observations that identify the parameters of interest is even smaller than in the demand case. In the case of the intensive margin, we have too few observations to obtain an estimate of price responses to marginal cost shocks with any precision. In the case of the extensive margin, there is weak evidence that the probability of a price change does depend on the size of cost shocks that come through exchange rates.

7 Conclusion

We make use of a unique data set that matches survey data on domestic and export prices to plant census information to explore the pricing behavior of producers in manufacturing and mining sectors. The structure of the data - with matched observations on prices in home and export markets - allows us to identify demand shocks that come through nominal exchange rate movements relatively cleanly. We find that desired markups are variable. In particular, desired markups increase in response to increases in demand and fall in response to reductions in demand. We are unable to distinguish between no state dependence in price setting and state dependence with a unit elasticity of desired relative markups with respect to movements in the nominal exchange rate between home and export markets.

Our findings raise many questions. They appear robust across plants that invoice export sales in foreign currency. But because of the limitations of the data, we can neither say how plants that invoice export sales in home currency behave, nor explain the choice of invoice currency. In addition, the case of Ireland and the UK may be somewhat special, in that the source country is much smaller than the destination country. Our findings have some puzzling implications. Clearly, if markups are allowed to move one-for-one with shocks, some firms will end up with negative markups and negative profits in some markets. It may be that the entry-exit margin is an important one in explaining responses to nominal exchange rate changes. Unfortunately this is not something we can say much about.

However our findings do provide useful evidence that firm behavior is consistent with failures of the law of one price, even conditional on price adjustment. This is not incorporated into standard quantitative models of real exchange rate behavior such as Chari, Kehoe and McGrattan (2002). It suggests that the approach of Bergin and Feenstra (2000) or Atkeson and Burstein (2007) to using "real rigidities" to help explain real exchange rate behavior is likely to be a profitable one.

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Table 1: Coverage of matched sample (%)

Year	Plants	Employees	Sales	Exports
1995	15	36	34	24
1996	14	34	33	24
1997	13	32	30	22
1998	13	30	29	22
1999	11	27	23	20
2000	11	29	24	22
2001	13	32	24	24
2002	15	40	36	30
2003	17	43	38	32
2004	18	46	38	35
Avg	14	35	31	26

Note: Percent of total of relevant category from CIP covered by plants in the matched sample

Table 2: Summary statistics on CIP and merged sample I

	1995		2004	
	PPI sample	CIP	PPI sample	CIP
Sales in current 1,000 EUR				
p25	1,950	343	2,329	491
p50	5,417	1,009	7,648	1,250
p75	20,763	3,796	24,889	4,477
Number of employees				
p25	25	7	23	6
p50	58	15	49	13
p75	129	41	117	34
% of plants foreign-owned				
	34	16	30	13

Table 3: Summary statistics on CIP and merged sample II

	1995		2004	
	PPI sample	CIP	PPI sample	CIP
% of exporting plants				
	75	60	75	47
% of overall sales exported				
	58	65	73	79
% of sales exported in exporting plants				
p25	18	7	14	7
p50	62	30	53	30
p75	96	82	97	85
% of turnover exported to the UK in exporting plants				
p25	4	2	2	1
p50	13	8	10	7
p75	34	22	28	20
% of plants importing materials				
	84	72	94	75
% of overall materials imported				
	41	46	62	65
% of imported materials in materials + wage bill				
p25	20	12	15	10
p50	40	29	36	26
p75	57	49	57	48
% of materials imported from the UK in materials + wage bill				
p25	5	3	3	3
p50	15	11	9	8
p75	31	25	23	18

Note: Information for imports is based on the roughly 80% of the population for which comparable information is available over the entire time period.

Table 4: Sectoral shares

NACE	Description	Share of plants				Share of sales			
		1995		2004		1995		2004	
		PPI	CIP	PPI	CIP	PPI	CIP	PPI	CIP
10-14	Mining	2	2	2	3	2	1	1	1
15-16	Food, Bev., Tobac.	21	18	18	14	43	32	25	21
17-19	Textile, App., Leath.	10	9	7	5	2	3	1	1
20	Wood Products	5	5	5	6	1	1	1	1
21-22	Paper, Printing	5	12	7	13	4	9	7	15
24	Chemicals	7	5	7	4	18	16	19	24
25	Rubber, Plastics	5	5	6	6	3	2	2	1
26	Non-metallic min.	7	6	7	7	3	2	2	2
27-28	Metal, Metal prod.	11	12	11	14	2	3	3	2
29	Machinery	6	7	8	6	5	3	3	2
30-33	Electr. machinery	12	9	12	8	13	25	31	27
34-35	Transport equip.	3	3	2	2	1	2	1	1
36	Other manuf.	6	8	7	10	1	2	1	1
	Total	100	100	100	100	100	100	100	100
		# plants				Total sales (Million Euro)			
		670	4,617	854	4,877	15,064	43,969	37,377	97,979

Table 5: Hierarchical structure of matched data

	3-dig. NACE	Plants	Plant-prd. pairs	Quote-lines	Obs.
1995	85	670	1,100	4,883	53,961
1996	85	647	1,065	4,788	52,079
1997	84	627	1,037	4,651	50,938
1998	85	596	1,010	4,804	49,162
1999	83	556	947	4,174	46,294
2000	86	581	978	4,499	46,932
2001	87	653	1,071	4,925	49,969
2002	91	808	1,234	5,452	53,143
2003	90	878	1,327	5,820	59,752
2004	91	854	1,297	5,370	58,681
total	96	1,169	1,891	11,811	520,911

Note: Number of distinct values of each category observed in the relevant time-frame.

Table 6: Mean adjustment frequency by export status and currency (%)

	Obs	Invoice Currency					Home Currency	
		unw	wgt	wgt, adj. for exit	wgt inc	wgt dec	unw	wgt
total	442,553	11	14	17	8	6	27	40
Destination market								
home	289,197	11	16	17	11	5	11	16
export	153,356	11	14	17	7	7	57	56
Invoice currency for exports								
IEP, EUR	65,691	10	11	14	6	5	10	11
STG	49,535	11	17	19	9	8	99	100
US$	17,084	12	17	21	10	10	100	100
pre-EUR EU	10,941	12	14	16	7	7	100	100
post-EUR EU	6,882	5	8	10	4	4	12	16
other	3,223	15	17	19	9	7	100	100

Note: Obs. weighted by plant sales in home/export market as appropriate. Equal weighting within plant-market-years. Period covered is Jan 1995-Dec 2004, excluding Jul 2001-June 2002.

Table 7: Mean adjustment frequency by type of good and size class (%)

	Obs	Invoice Currency					Home Currency	
		unw	wgt	wgt, adj. for exit	wgt inc	wgt dec	unw	wgt
Type of product (Vermeulen et al., 2007)								
cons food prod	78,097	14	14	16	10	4	24	25
cons non-food non-dur	38,729	5	6	9	4	2	25	57
cons durables	46,873	4	5	7	3	2	28	43
intermediates	205,055	13	16	18	8	8	26	38
energy	2,471	45	69	70	43	26	72	71
capital goods	71,328	7	12	17	6	6	33	63
Type of product (Rauch 1999)								
homogenous	23,995	28	47	48	26	20	40	57
reference priced	66,126	12	13	15	8	5	20	26
differentiated	196,337	10	15	17	8	7	28	46
unclassified	156,095	8	10	14	6	5	26	52
Plant size								
<20	60,112	8	23	25	14	9	14	32
20-49	115,124	10	20	22	11	9	23	30
50-249	205,110	10	17	18	11	6	29	33
250-500	35,529	19	11	13	6	5	45	38
500+	26,678	12	14	18	8	7	40	54

Note: Obs. weighted by plant sales in home/export market as appropriate. Equal weighting within plant-market-years. Period covered is Jan 1995-Dec 2004, excluding Jul 2001-June 2002.

Table 8: Size of price changes in invoice currency

	Increases				Decreases			
	Mean	p25	p50	p75	Mean	p25	p50	p75
total	5.80	1.43	3.11	6.70	-5.39	-7.18	-3.30	-1.43
Destination market								
home	5.03	1.53	3.03	5.87	-5.00	-6.44	-3.00	-1.25
export	6.59	1.35	3.30	7.55	-5.58	-7.41	-3.41	-1.54
Invoice currency for exports								
IEP,EUR	6.06	1.77	3.51	6.90	-5.64	-7.27	-3.18	-2.00
STG	4.57	1.12	2.73	5.45	-4.21	-5.41	-2.44	-0.62
US $	9.34	1.41	4.99	11.48	-6.81	-8.83	-5.22	-2.04
pre-EUR EU	4.94	0.01	1.22	4.55	-3.97	-5.62	-1.69	-0.02
post-EUR EU	5.56	0.58	3.92	7.14	-4.83	-5.46	-2.74	-0.64
other	3.62	0.01	1.70	5.97	-4.31	-5.04	-0.69	-0.01
Type of product (Vermeulen et al., 2007)								
cons food prod	4.95	1.48	2.86	5.27	-5.86	-7.53	-3.80	-1.56
cons non-food non-durab	8.17	0.01	0.67	7.91	-4.71	-6.45	-0.02	-0.01
cons durables	9.69	2.66	5.00	10.00	-6.62	-9.96	-4.23	-1.50
intermediates	4.94	1.22	2.94	5.71	-4.06	-5.39	-2.64	-1.12
energy	8.58	3.72	7.23	11.48	-7.77	-10.60	-5.77	-2.83
capital goods	8.68	1.82	4.32	9.96	-7.97	-9.52	-6.06	-2.86
Type of product (Rauch, 1999)								
organized exchange	8.26	2.96	6.03	10.81	-7.59	-10.35	-5.28	-2.62
reference priced	5.04	1.54	2.72	5.04	-4.38	-5.46	-3.00	-1.84
differentiated	5.66	1.07	3.09	7.69	-5.29	-7.65	-3.11	-0.85
unclassified	5.61	1.01	2.79	5.74	-5.34	-6.62	-2.93	-0.94
Plant size								
<20	3.49	1.00	2.13	4.17	-3.46	-4.94	-1.93	-0.70
20-49	4.62	1.34	2.82	5.21	-3.71	-4.54	-2.38	-1.07
50-249	5.93	1.47	3.44	7.19	-5.77	-7.69	-3.71	-1.51
250-500	5.63	1.46	2.96	6.30	-4.37	-5.46	-2.73	-1.06
500+	6.23	1.42	3.15	6.95	-6.44	-8.23	-4.27	-1.97

Note: Obs. weighted by plant sales in home/export market as appropriate. Equal weighting within plant-market-years. Period covered is Jan 1995-Dec 2004, excluding Jul 2001-June 2002.

Table 9: Price synchronization within plant-product pairs

	% of plant-prod-mths with >1 quote and >=1 price change	Of which		
		One price changes	>1 but < all change	All prices change
Full sample	16.97	21.72	27.60	50.68
Irl & UK sample	16.53	21.16	28.74	50.10

Note: Calculated based on the full sample.

Table 10: Summary statistics for distribution of estimated markup errors

Conditional on	mean	s.d.	p10	p25	p50	p75	p90	N
All observations	.000	.056	-.048	-.014	0	.014	.048	327,510
No price change	-.000	.054	-.046	-.014	0	.013	.046	290,984
Price change	.002	.071	-.058	-.019	.000	.022	.066	36,526

Note: Distribution of log deviation of actual from desired markup based on null hypothesis of constant desired markup.

Table 11: Intensive margin of price adjustment I

	$\Delta_{t-s_k^i(t)} \ln e_t\,(uk)$		constant		R^2 adj	N	# f.e.	# clust
all	1.002	(0.080)**	0.005	(0.000)**	0.74	3,851	956	77
Type of product (Vermeulen et al., 2007)								
cons food prod	0.889	(0.144)**	0.009	(0.001)**	0.68	1,193	361	17
cons n-food n-dur	1.853	(0.445)**	0.009	(0.023)	0.68	29	13	6
cons durab	1.064	(0.168)**	0.056	(0.006)**	0.74	124	25	8
intermediates	1.118	(0.232)**	0.002	(0.001)**	0.86	1,339	364	30
capital goods	1.042	(0.090)**	0.006	(0.000)**	0.66	1,162	191	17
Type of product (Rauch, 1999)								
org exchange	0.999	(0.365)**	-0.001	(0.001)	0.65	905	265	8
reference priced	0.863	(0.140)**	0.003	(0.001)**	0.91	374	144	7
differentiated	1.142	(0.147)**	0.005	(0.001)**	0.64	1,511	306	42
Plant size								
<20	1.219	(0.100)**	0.021	(0.000)**	0.94	249	86	8
20-29	0.983	(0.166)**	0.016	(0.000)**	0.76	817	168	21
50-249	1.049	(0.114)**	0.009	(0.000)**	0.63	1,900	425	40
250-499	1.072	(0.068)**	0.006	(0.000)**	0.84	391	127	6
500+	0.162	(0.106)	0.002	(0.000)	0.84	494	150	2
Ownership								
domestic	1.029	(0.113)**	0.005	(0.000)**	0.68	2,555	711	54
foreign	0.949	(0.082)**	0.005	(0.000)**	0.85	1,296	245	24

Note: Estimation method is OLS. Dependent variable is log change in home currency price since last price change. Full set of plant-product-month-age of price fixed effects is included. Observations are weighted by sales. Standard errors are clustered at the firm level. Standard errors in brackets. Two stars indicates significantly different from zero at the 5% level, one star indicates significantly different from zero at the 10% level.

Table 12: Intensive margin of price adjustment II

	$\Delta_{t-s_k^i(t)} \ln e_t\,(uk)$		constant		R^2 adj	N	# f.e.	# clust
all	1.002	(0.080)**	0.005	(0.000)**	0.74	3,851	956	77
Quartiles of the share of imported materials in materials and wage bill								
Q1	0.714	(0.418)	-0.002	(0.001)*	0.67	693	213	12
Q2	0.902	(0.106)**	0.021	(0.001)**	0.73	669	168	33
Q3	1.082	(0.162)**	0.010	(0.001)**	0.70	434	125	27
Q4	1.107	(0.153)**	0.002	(0.001)**	0.82	1,753	346	23
Quartiles of the export intensity								
Q2	0.812	(0.165)**	0.017	(0.000)**	0.56	1,431	254	24
Q3	1.078	(0.104)**	0.003	(0.000)**	0.71	1,936	537	49
Q4	1.063	(0.357)**	0.001	(0.002)	0.89	446	147	15
Quartiles of the share of exports to the UK								
Q1	1.591	(0.498)*	0.004	(0.005)	0.60	201	56	7
Q2	1.088	(0.162)**	0.001	(0.001)	0.82	759	237	22
Q3	0.953	(0.100)**	0.003	(0.000)**	0.70	1,501	389	33
Q4	0.960	(0.169)**	0.020	(0.000)**	0.61	1,352	256	39
Euro changeover								
before 95-98	0.923	(0.099)**	-0.002	(0.000)**	0.78	1,527	433	47
during 99-01	1.059	(0.064)**	0.010	(0.000)**	0.79	1,291	289	41
after 02-04	1.100	(0.453)**	0.021	(0.001)**	0.59	1,033	234	41
Age of price								
1 month	0.990	(0.191)**	0.005	(0.000)**	0.72	2,429	605	34
2-5 months	0.956	(0.114)**	-0.007	(0.000)**	0.79	866	225	40
6-11 months	0.734	(0.243)**	0.039	(0.002)**	0.70	253	61	35
12+ months	1.149	(0.141)**	0.018	(0.005)**	0.80	303	65	41

Note: Estimation method is OLS. Dependent variable is log change in home currency price since last price change. Full set of plant-product-month-age of price fixed effects is included. Observations are weighted by sales. Standard errors are clustered at the firm level. Standard errors in brackets. Two stars indicates significantly different from zero at the 5% level, one star indicates significantly different from zero at the 10% level.

Table 13: Intensive margin of price adjustment: Controlling for competitors' prices

	$\Delta_{t-s_k^i(t)} \ln e_t\,(uk)$		$\Delta_{t-s_k^i(t)} \ln p_t\,(k)$		constant		R^2-adj	N	# f.e.	# clust
Controlling for competitors' prices										
PPI	1.119	(0.140)**	0.363	(0.309)	0.004	(0.001)**	0.74	3,851	957	77
NACE2	1.067	(0.115)**	0.532	(0.502)	0.003	(0.001)**	0.78	3,056	957	77
NACE3	0.951	(0.082)**	-0.006	(0.246)	0.004	(0.001)**	0.79	2,907	956	76
NACE4	0.942	(0.100)**	-0.220	(0.439)	0.005	(0.001)**	0.71	2,580	901	76

Note: Estimation method is OLS. Dependent variable is log change in home currency price since last price change. Full set of plant-product-month-age of price fixed effects is included. Observations are weighted by sales. Standard errors are clustered at the firm level. Standard errors in brackets. Two stars indicates significantly different from zero at the 5% level, one star indicates significantly different from zero at the 10% level.

Table 14: Extensive margin of price adjustment: Probability of a Price Increase I

	$\Delta_{t-s_k^i(t)} \ln e_t\,(uk)$		Pseudo-R^2	χ^2 [p]	N	# f.e.	# clust
all	1.08	(3.63)	0.00	0.09 [0.77]	4,555	856	120
Type of product (Vermeulen et al., 2007)							
cons food prod	-0.15	(6.59)	0.00	0.00 [0.98]	1,307	308	26
cons non food non dur	24.25	(25.57)	0.08	0.90 [0.34]	101	26	11
cons durab	-1.31	(9.15)	0.00	0.02 [0.89]	323	42	13
intermediates	1.32	(6.87)	0.00	0.04 [0.85]	1,768	345	51
capital goods	1.28	(6.65)	0.00	0.04 [0.85]	1,054	134	19
Type of product (Rauch, 1999)							
organized exchange	2.72	(11.92)	0.00	0.05 [0.82]	1,094	256	10
reference priced	-16.88	(5.42)**	0.01	9.71 [0.00]	360	108	13
differentiated	4.62	(5.61)	0.00	0.68 [0.41]	1,797	288	62
Plant size							
<20	-12.78	(17.95)	0.01	0.51 [0.48]	120	34	12
20-29	3.44	(2.54)	0.00	1.83 [0.18]	944	145	30
50-249	4.77	(5.61)	0.00	0.72 [0.40]	2,622	459	64
250-499	-7.80	(8.80)	0.01	0.79 [0.37]	205	70	9
500+	-1.20	(11.90)	0.00	0.01 [0.92]	664	148	5
Ownership							
domestic	0.96	(4.38)	0.00	0.05 [0.83]	3,093	607	86
foreign	1.22	(6.20)	0.00	0.04 [0.84]	1,462	249	35

Note: Dependent variable is indicator for increase in invoice currency price. Estimator is conditional logit, conditioning on plant-product-month-age of price fixed effects. Observations are weighted by turnover. Standard errors in brackets. Standard errors are clustered at the firm level. Two stars indicates significantly different from zero at the 5% level, one star indicates significantly different from zero at the 10% level.

Table 15: Extensive margin of price adjustment: Probability of a Price Increase II

	$\Delta_{t-s_k^i(t)} \ln e_t \, (uk)$		Pseudo-R^2	χ^2 [p]	N	# f.e.	# clust
all	1.08	(3.63)	0.00	0.09 [0.77]	4,555	856	120
Quartiles of the share of imported materials in materials and wage bill							
Q1	-0.44	(3.99)	0.00	0.01 [0.91]	906	205	15
Q2	7.38	(8.04)	0.01	0.84 [0.36]	909	154	40
Q3	-6.47	(9.65)	0.00	0.45 [0.50]	827	153	47
Q4	2.40	(6.75)	0.00	0.13 [0.72]	1,772	299	36
Quartiles of the export intensity							
Q2	-3.05	(3.87)	0.00	0.62 [0.43]	1,532	228	32
Q3	1.19	(5.90)	0.00	0.04 [0.84]	2,473	503	78
Q4	5.99	(8.39)	0.00	0.51 [0.48]	506	116	24
Quartiles of the share of exports to the UK							
Q1	5.95	(11.79)	0.00	0.25 [0.61]	257	54	9
Q2	1.19	(8.32)	0.00	0.02 [0.89]	756	194	28
Q3	0.57	(5.73)	0.00	0.01 [0.92]	1,994	378	61
Q4	-0.30	(4.78)	0.00	0.00 [0.95]	1,504	221	50
Euro changeover							
95-98	-0.15	(4.04)	0.00	0.00 [0.97]	1,789	374	64
99-01	-4.56	(5.79)	0.00	0.62 [0.43]	1,446	268	63
02-04	24.40	(13.70)*	0.02	3.17 [0.07]	1,320	214	63
Age of price							
1 month	-3.97	(7.18)	0.00	0.31 [0.58]	2,422	469	46
2-5 months	11.91	(8.39)	0.01	2.02 [0.16]	1,104	210	62
6-11 months	2.29	(8.48)	0.00	0.07 [0.79]	538	91	56
12+ months	0.39	(5.35)	0.00	0.01 [0.94]	491	86	57

Note: Dependent variable is indicator for increase in invoice currency price. Estimator is conditional logit, conditioning on plant-product-month-age of price fixed effects. Observations are weighted by turnover. Standard errors in brackets. Standard errors are clustered at the firm level. Two stars indicates significantly different from zero at the 5% level, one star indicates significantly different from zero at the 10% level.

Table 16: Extensive margin of price adjustment: Probability of a Price Decrease I

	$\Delta_{t-s_k^i(t)} \ln e_t\,(uk)$		Pseudo-R^2	χ^2 [p]	N	# f.e.	# clust
all	1.96	(4.72)	0.00	0.17 [0.68]	4,287	819	98
Type of product (Vermeulen et al., 2007)							
cons food prod	-5.27	(6.40)	0.00	0.68 [0.41]	1,289	300	19
cons non food non dur	39.79	(45.24)	0.07	0.77 [0.38]	70	14	9
cons durab	25.43	(14.80)*	0.08	2.96 [0.09]	162	26	10
intermediates	4.47	(8.75)	0.00	0.26 [0.61]	1,713	344	44
capital goods	-0.23	(8.10)	0.00	0.00 [0.98]	1,051	134	18
Type of product (Rauch, 1999)							
organized exchange	2.08	(7.43)	0.00	0.08 [0.78]	1,138	262	8
reference priced	13.71	(13.60)	0.01	1.02 [0.31]	344	103	11
differentiated	2.83	(5.65)	0.00	0.25 [0.62]	1,685	263	51
Plant size							
<20	3.69	(2.15)*	0.00	2.95 [0.09]	66	20	7
20-29	19.82	(10.31)*	0.02	3.70 [0.05]	872	136	29
50-249	-1.83	(5.39)	0.00	0.12 [0.73]	2,414	433	49
250-499	-8.71	(10.98)	0.01	0.63 [0.43]	220	73	10
500+	20.40	(14.24)	0.02	2.05 [0.15]	715	157	3
Ownership							
domestic	5.23	(4.26)	0.00	1.51 [0.22]	2,777	570	69
foreign	-1.26	(8.34)	0.00	0.02 [0.88]	1,510	249	31

Note: Dependent variable is indicator for decrease in invoice currency price. Estimator is conditional logit, conditioning on plant-product-month-age of price fixed effects. Observations are weighted by turnover. Standard errors in brackets. Standard errors are clustered at the firm level. Two stars indicates significantly different from zero at the 5% level, one star indicates significantly different from zero at the 10% level.

Table 17: Extensive margin of price adjustment: Probability of a Price Decrease II

	$\Delta_{t-s_k^i(t)} \ln e_t \, (uk)$		Pseudo-R^2	χ^2 [p]	N	# f.e.	# clust
all	1.96	(4.72)	0.00	0.17 [0.68]	4,287	819	98
Quartiles of the share of imported materials in materials and wage bill							
Q1	-4.02	(6.73)	0.00	0.36 [0.55]	866	198	14
Q2	-5.65	(4.95)	0.00	1.30 [0.25]	943	163	34
Q3	1.20	(7.60)	0.00	0.03 [0.87]	599	126	30
Q4	4.08	(9.37)	0.00	0.19 [0.66]	1,729	280	34
Quartiles of the export intensity							
Q2	7.22	(3.80)*	0.00	3.61 [0.06]	1,382	210	21
Q3	-4.33	(5.97)	0.00	0.53 [0.47]	2,301	474	67
Q4	9.49	(13.17)	0.01	0.52 [0.47]	542	123	25
Quartiles of the share of exports to the UK							
Q1	-16.76	(6.66)**	0.03	6.33 [0.01]	230	50	9
Q2	9.38	(11.12)	0.00	0.71 [0.40]	742	186	25
Q3	-1.06	(6.28)	0.00	0.03 [0.87]	1,949	369	45
Q4	8.45	(3.05)**	0.00	7.69 [0.01]	1,304	202	41
Euro changeover							
95-98	-2.83	(5.84)	0.00	0.23 [0.63]	1,608	350	45
99-01	9.74	(7.19)	0.01	1.83 [0.18]	1,405	254	55
02-04	-5.23	(6.06)	0.00	0.74 [0.39]	1,274	215	62
Age of price							
1 month	8.59	(6.92)	0.00	1.54 [0.21]	2,314	452	42
2-5 months	3.14	(7.56)	0.00	0.17 [0.68]	1,251	236	53
6-11 months	2.07	(9.01)	0.00	0.05 [0.82]	428	79	48
12+ months	-4.88	(7.02)	0.01	0.48 [0.49]	294	52	37

Note: Dependent variable is indicator for decrease in invoice currency price. Estimator is conditional logit, conditioning on plant-product-month-age of price fixed effects. Observations are weighted by turnover. Standard errors in brackets. Standard errors are clustered at the firm level. Two stars indicates significantly different from zero at the 5% level, one star indicates significantly different from zero at the 10% level.

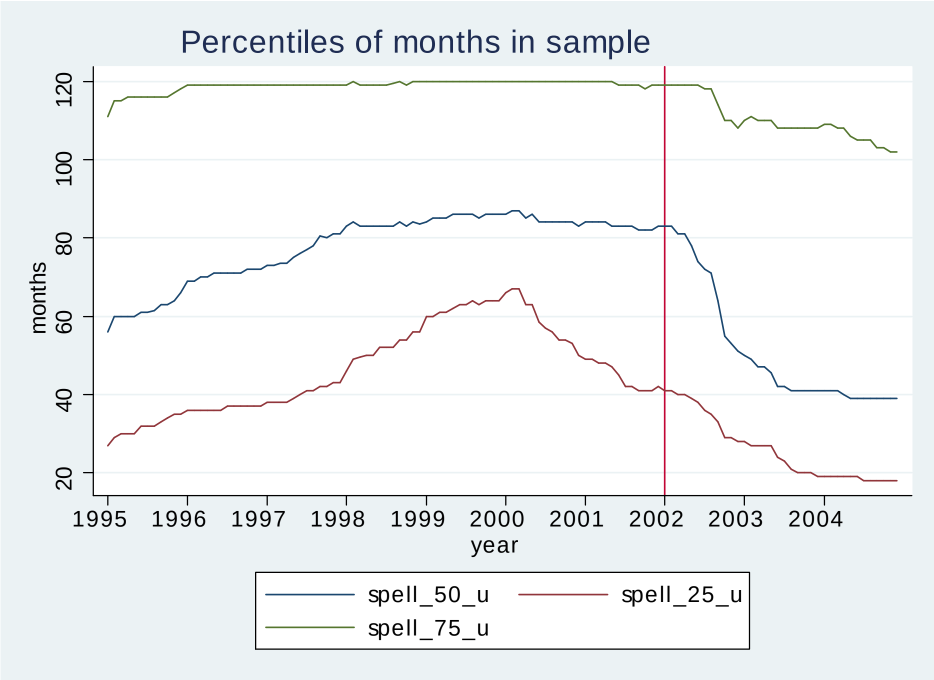

Figure 1: Percentiles of distribution of duration of active quote-lines

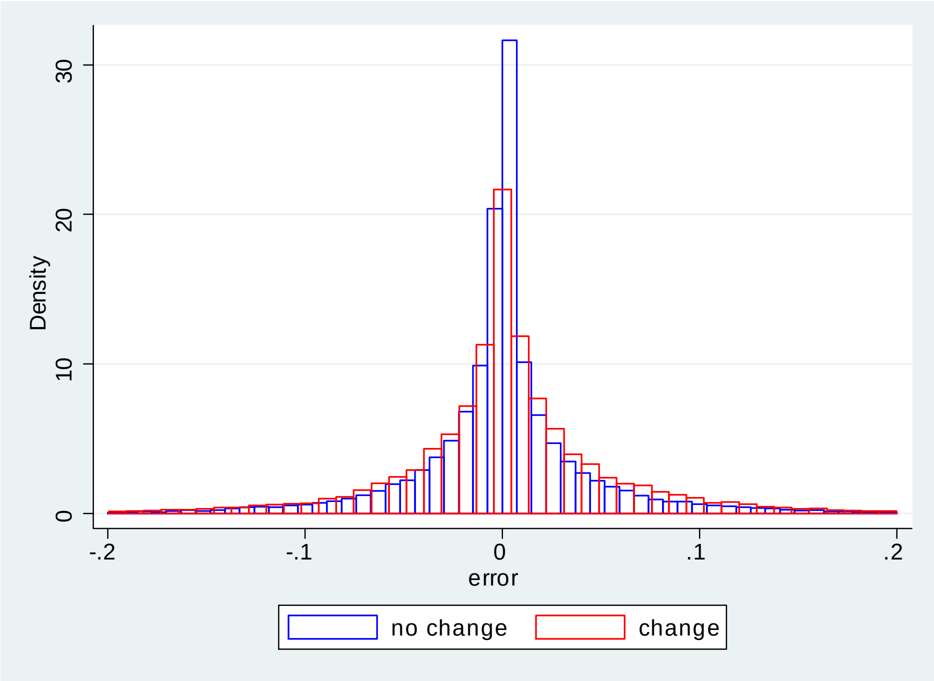

Figure 2: Distribution of markup deviations under constant markup null

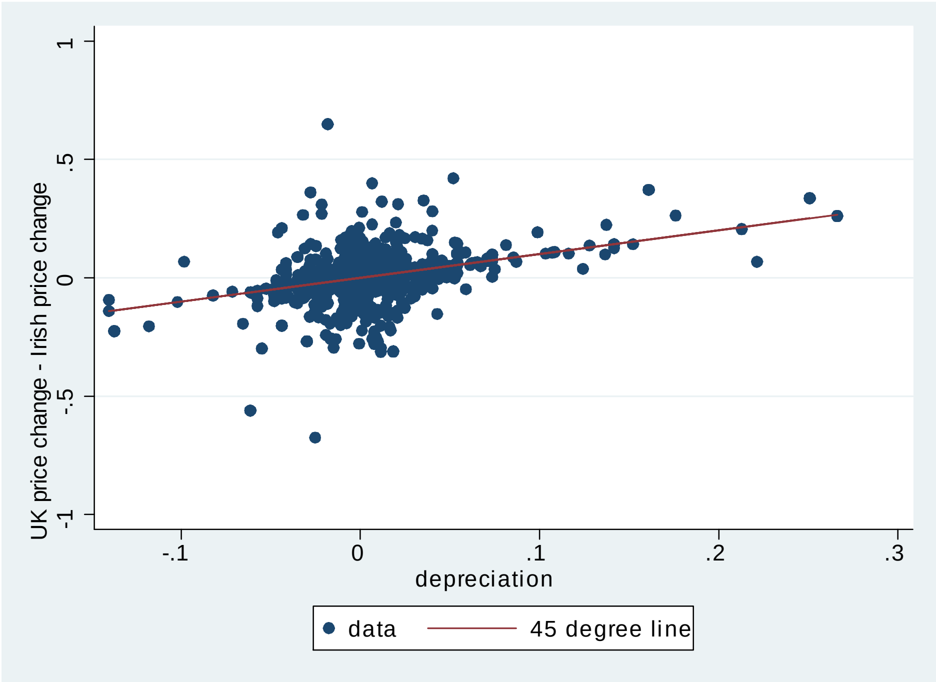

Figure 3: Variation identifying β_k: Difference between % change in Sterling and home price against exchange rate change

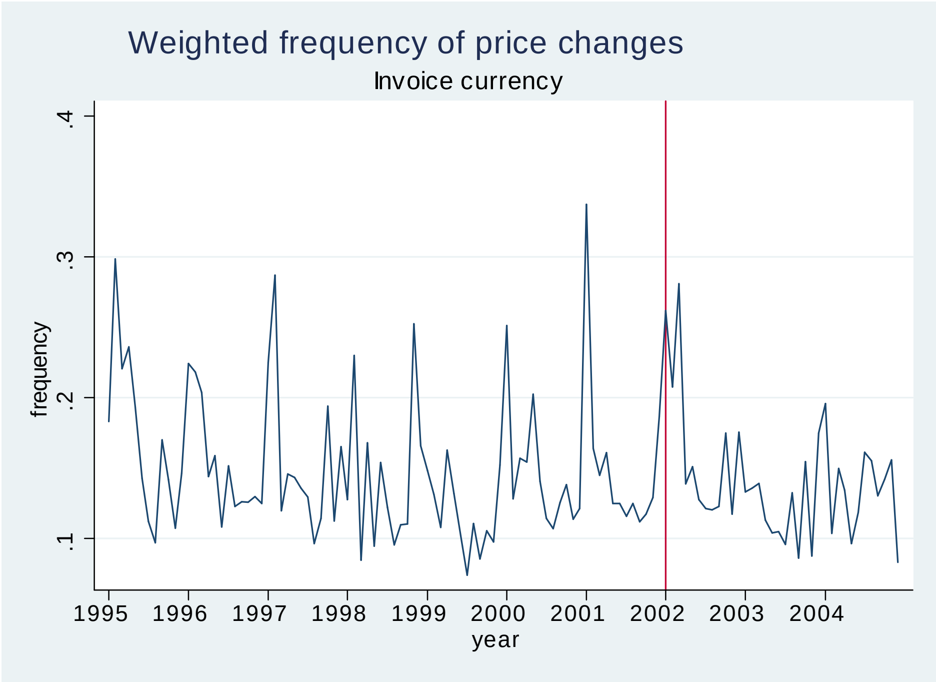

Figure 4: Weighted frequency of price changes measured in invoice currency

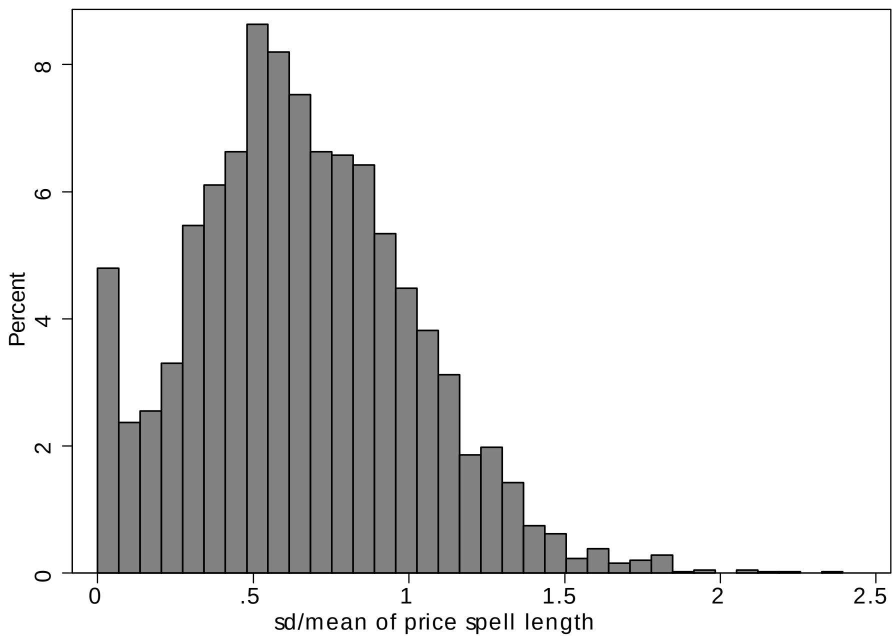

Figure 5: Distribution of coefficient of variation of spell length