# PRICE ADJUSTMENT LAGS: EVIDENCE FROM FIRM-LEVEL DATA*

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## 1. INTRODUCTION

Price stickiness has a central role in macroeconomics and, besides a vast theoretical literature, it has generated numerous empirical studies trying to explain its origins and gauge its importance. A consensual finding of this work is that prices at the micro level may remain unchanged for periods that can last up to several months. Studies documenting this stylised fact include, among many others, Bils and Klenow (2004), Klenow and Kryvtsov (2008), and Nakamura and Steinson (2008), who study consumer prices in the United States (US), and Dhyne *et al.* (2006) and Vermeulen *et al.* (2007), who give a synthesis of studies carried out for the Euro Area (EA). For example, using comparable micro data on consumer prices, Dhyne *et al.* (2006) find that the estimated monthly frequency of price changes is around 15 percent in the EA and 25 percent in the US, and that the implied average duration of a price spell is 13 months in the EA and 6.7 months in the US. These results are consistent with evidence from survey data: according to Fabiani *et al.* (2006), the median frequency of price changes is one per year in the EA, lower than the estimated 1.4 price changes per year in the US reported in Blinder *et al.* (1998).

The empirical literature investigating the reasons for such infrequent price changes at the firm-level is, however, scanter. Dhyne *et al.* (2008) have recently made an important contribution to the understanding of this phenomenon by distinguishing between intrinsic price rigidity (price rigidity that is inherent to the price-setting mechanism), and extrinsic rigidity (price rigidity that is induced by a low degree of volatility of shocks to the marginal cost and/or the desired mark-up). They find that the differences across products in the frequency of price changes do not strictly correspond to differences in intrinsic price rigidity, i.e., the frequency of price changes also depends, in a significant way, on the magnitude of the shocks to the unobserved optimal price. Thus, as Blinder (1991, p. 94) puts it: "From the point of view

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of macroeconomic theory, frequency of price change may not be the right question to ask, for it depends as much on the frequency of shocks as on the firms' pricing strategies. We are more interested to know how long price adjustments lag behind shocks to demand and cost".

Therefore, rather than looking into the reasons for infrequent price changes, as done in most of the previous literature on price stickiness (Munnick and Xu, 2007, Vermeulen *et al.*, 2007, Dhyne *et al.*, 2006, and the references therein), in this paper we directly investigate the deeper and more meaningful question of the determinants of the speed of price adjustments to demand and cost shocks. In particular, we use survey data on price adjustment lags reported by Portuguese firms to investigate how they adjust their prices in response to changes in market conditions. The advantage of using such data is that, in order to study the intrinsic price rigidity, we do not need to match market conditions with price changes decisions, which is usually a difficult task.

A potential disadvantage of our dataset is that it does not distinguish between aggregate and idiosyncratic shocks. Indeed, the economic literature has stressed that the reaction of firms to shocks may depend on whether these are aggregate or idiosyncratic (Lucas 1973), and recently Mackowiak and Wiederholt (2009) developed a model in which firms' prices react quickly to idiosyncratic shocks, but only slowly to aggregate shocks. The fact that our data has no information on whether the shock is aggregate or idiosyncratic is an important limitation that should be borne in mind when evaluating the findings in this paper.[1]

In this paper we tackle several interesting questions. Do prices respond with different lags to demand and cost shocks? Do prices respond differently to shocks that would imply a rise in prices than to shocks that would imply a fall in prices? Are prices stickier when a firm operates in a less competitive industry? Does price stickiness depend on how long firms have been dealing with their customers? Are prices stickier when goods are sold in foreign markets? Do the competitiveness factors affect the degree of price stickiness and, if so, in which direction?

The analysis is conducted in the context of a panel-ordered probit model that allows for the presence of unobserved firm-specific random-effects. This a major distinguishing feature of our approach, which in our view allows a richer analysis of the data than the simple probit models used so far in the literature.

We find that adjustment lags to cost and demand shocks (either positive or negative), vary significantly with firm characteristics such as the type of pricing policy, cost structure, and sources of competitiveness, among others. Interestingly, and in contrast to what one could expect, measures of the importance of explicit and implicit contracts — two of the most cited sticky-price theories in firms' surveys — do not emerge as having significant implications for the speed of price reaction to demand or cost shocks. The evidence also suggests that firms with similar characteristics react asymmetrically to positive and negative shocks.

(1) Another potential disadvantage of this type of data is that these are reported, not actual, lags and it is impossible to know whether the answers provided are close to reality. However, the fact that in our model we only use the ordinal information in the answers given by the firms will significantly mitigate potential measurement errors.

As a by-product of our analysis, we also explore the information provided by the firms on the relative importance of different sticky-price theories as determinants of price adjustment lags. Since the pioneering work of Blinder et al. (1998), several surveys have asked firms to rank the main reasons underlying infrequent price changes or infrequent price reviews (see, for instance, Almirault et al., 2006, Fabiani et al., 2006, and the references therein), and this information has been used to empirically assess the relevance of alternative sticky-price theories. Although this information may allow the evaluation of the relative importance of intrinsic and extrinsic price rigidity,[2] we find that the rankings of sticky-price theories as reported directly by firms do not help explaining the differences in price adjustment lags.

The rest of the article is organised as follows. Section 2 presents the theoretical background which underlies the estimated model. Section 3 describes the dataset used and presents the results of a preliminary data analysis. Section 4 presents the estimated model and discusses the main results. Finally, Section 5 summarizes the main conclusions.

## 2. THEORETICAL BACKGROUND

Individual firms do not continuously adjust their prices in response to shocks that hit the economy. To model this fact, the economic literature considers mainly two types of pricing behaviour: time dependent and state dependent pricing rules. According to the former, firms are assumed to change their prices periodically using either a deterministic (Taylor, 1980) or a stochastic (Calvo, 1983) process of price adjustment, i.e., the timing of the price changes is exogenous and does not depend either on the state of the economy or on the timing of the shocks.

Firms following state-dependent pricing rules are usually assumed to review their prices whenever relevant shocks hit the economy, but, due to the existence of fixed costs of changing prices (e.g., the cost of printing and distributing new price lists), they change their prices only when the difference between the actual and target prices is large enough (see, for example, Sheshinski and Weiss, 1977, Caplin and Spulber, 1987, Caballero and Engel, 1993, Dotsey *et al.*, 1999). Thus, a company facing these menu costs will change its price less frequently than an otherwise identical firm without such costs.

Some authors have, however, argued that the main benefit of infrequent price changes is not lower menu costs, but reduction of the costs associated with information collection and decision-making. Obtaining this benefit necessarily means that the timing of the occasions upon which prices are reconsidered may be largely independent of current market conditions (see Woodford, 2003, Zbaracki *et al.*, 2004). In the same vein, Ball and Mankiw (1994a) argue that "the most important costs of price adjustment are the time and attention required of managers to gather the relevant information and to make and implement decisions".

(2) Among the many reasons for price stickiness suggested to firms in the surveys, some may be seen as relating to extrinsic rigidities (for example, the importance of changes in variable costs induced by shocks) and some to intrinsic rigidities (for example, the importance of information and menu costs).

In addition to menu costs and/or information costs, economic theory has suggested a large number of other potential explanations for the existence of price rigidities, of which the theories of explicit and/or implicit contracts, cost-based pricing, coordination failure, and pricing thresholds, are notable examples.

With explicit contracts, firms aim at building long-term relationships with their customer in order to stabilise their future sales. Customers, on the other hand, are attracted by a constant price because it makes their future costs more predictable and helps to minimize transaction costs (e.g., shopping time). In turn, the theory of implicit contracts is based on the idea that firms try to win customer loyalty by changing prices as little as possible. The idea that explicit contracts may be central for price stickiness was first introduced in the economic literature through wage contracts (see, for instance, Fisher, 1977), while the idea of implicit contracts goes back to Okun (1981), who distinguishes between price increases due to cost shocks and those that are due to demand shocks. He argues that higher costs are an accepted rationale for rising prices, while increases in demand are viewed as unfair. Consequently, firms hold prices constant in the face of demand shocks, as they do not want to jeopardise customer relations. The idea that consumers wish to buy from firms whose prices are fair is also stressed by Rotemberg (2005).

Rather than emphasizing the firm-customer relation, the theory of coordination failure focuses on the interaction between firms as the explanation for sticky prices. Like in the case of explicit contracts, the idea was first introduced for the analysis of the labour market (see, for instance, Clower, 1965). After a shock, a firm might want to change its price, but only if the other firms change their prices too. Without a coordinating mechanism which allows the firms to move together, the prices might remain unchanged.

As regards the cost-based pricing theory, the idea is that input costs are an important determinant in firms' pricing decision, and that if costs do not change, prices will not change either. Basically, this means that prices do not change because other prices (input costs) do not change (see Hall, 1986). Finally, some firms set their prices at psychologically attractive thresholds. This pricing strategy can cause price stickiness because, in face of small shocks calling for small price changes, firms might not react and postpone price adjustments until new events justify a price change to the next pricing threshold.

The different sticky-price theories discussed above have informed most of the empirical research on the existence and significance of infrequent price changes, and the present work is no exception to this trend. A useful way of looking at these sticky-price theories is to think of them as reflecting the existence of both real and nominal rigidities. As Ball and Romer (1990) noticed, nominal price stickiness depends not only on the costs of changing nominal prices (nominal frictions) but also on the benefits of changing prices (real rigidities). Thus, as a general principle, we may expect that the less (the more) profits change when firms set their prices away from the optimum, the smaller (the bigger) will be the benefits from adjusting more rapidly, and so the more slowly (rapidly) firms will adjust their prices towards the optimum. In this paper we look into the factors that may explain why some firms adjust their prices more rapidly than others. For that purpose, we will look into the factors that might reflect differ-

ences in the relative importance of the alternative sticky-price theories at the firm-level i.e., the factors that might reflect differences in the firms' adjustment costs or that might be expected to make profits more or less sensitive to sub-optimal prices.

## 3. THE DATA

### 3.1. Data sources

Most of the data used in this study come from a survey about price setting practices carried out by Banco de Portugal.[3] In this survey, firms were asked how long they would take to react to significant cost and demand shocks. More specifically, they were asked the following four questions: 1) After a significant increase in demand how much time on average elapses before you raise your prices?; 2) After a significant increase in production costs how much time on average elapses before you raise your prices?; 3) After a significant fall in demand, how much time on average elapses before you reduce your prices?; and 4) After a significant decline in production costs how much time on average elapses before you reduce your prices?. The responses to these questions, which will be the dependent variable in our model, are recorded as continuous interval data with six categories: 1 - less than one week; 2 - from one week to one month; 3 - from one month to three months; 4 - from three to six months; 5 - from six months to one year; 6 - the price remained unchanged. With the expression significant increase or significant decline the authors of the survey seem to have had in mind inducing respondents to interpret the shock as significant enough to lead firms to react to it by changing their price. Therefore, we interpret option 6 as indicating that the price will eventually change, but the adjustment lag is longer than one year.

Besides the questions on price adjustments lags, the survey also contains information on a large set of firms' characteristics. These include information on the main market of the firm (internal versus external market), main destinations of sales (wholesalers vs. retailers, private vs. public sector), number of competitors, relations with customers (long-term vs. short-term), type of product competition (price vs. quality, differentiation vs. after sales service), price discrimination (same price for all customers vs. decided on a case-by-case basis), price setting decisions (own company vs. external entity, main customers vs. main competitors), and reasons for postponing price changes (the risk that competitors do not follow, existence of implicit or written contracts, cost of changing prices, costs of collecting information, absence of significant changes in variable costs, preference for maintaining prices at psychological thresholds, etc.).

The information from the survey is supplemented with data from two other sources. From *Central de Balanços*, a comprehensive dataset maintained by Banco de Portugal in which the balance sheets and income statements of most Portuguese firms are registered, we obtain data on the number of employees, the share of sales that are made abroad, and the shares of labour, inputs and financial costs. Fi-

(3) For further details on this survey, see Martins (2010).

nally, we obtain information about the proportion of domestic and foreign capital of the firm from *Quadros de Pessoal*, a large administrative database collected by the Ministry of Employment which, among other, includes information about all the Portuguese firms with wage earners (size, ownership, location, etc.).

By combining the three datasets through the individual tax identification number of each firm, we are able to obtain detailed information on 903 firms from different branches of activity. More specifically, our sample includes firms with 20 or more employees, from which almost 90 percent belong to Manufacturing (NACE - classification of economic activities - 15 to 37) and the remaining to Services (NACE 60 to 64, 80 and 85 - Transport, Storage and Communication, Education and Healthcare). Sectors such as agriculture, construction, or wholesale and retail trade are not included.

### 3.2. Preliminary data analysis

As mentioned above, the four survey questions about price adjustment lags are our variates of interest. Table 1 summarises the information on these variables by displaying the distribution of the observed price adjustment lags for each type of shock. These results suggest that firms are quicker to react to cost shocks, in particular when they are positive, than to demand shocks. For example, only around 10 percent of the firms keep their prices unchanged in the first year after a positive cost shock, while the fraction of firms that hold their prices unchanged in response to a positive demand shock is around 35 percent. Interestingly, firms seem to react more quickly to positive cost shocks than to negative cost shocks, but to be slower to react to positive demand shocks than to negative demand shocks. A formal test for the hypothesis that the reaction time is the same for positive and negative shocks will be performed in the next section.

The results of this preliminary analysis, however, are not informative about the possible effect of the characteristics of the firms on the speed of adjustment. As an illustration of the importance of these characteristics, Table 2 gives the breakdown by sector and firm size of the firms that do not adjust the price in the first year after the shock. Clearly, the speed of price adjustment varies with firm sizes and across sectors. Naturally, all these findings will be taken into account in the econometric analysis we present in the next Section.

**Table 1**

SPEED OF PRICE RESPONSE TO DEMAND AND COST SHOCKS

| | Cost shocks | | Demand shocks | |
|---|---|---|---|---|
| **Price adjustment lag** | **Positive** | **Negative** | **Positive** | **Negative** |
| 1 - less than one week | 4.7 | 3.5 | 2.8 | 4.8 |
| 2 - from one week to one month | 16.8 | 15.2 | 12.2 | 16.8 |
| 3 - from 1 month to 3 months | 25.0 | 25.7 | 19.3 | 23.4 |
| 4 - from 3 to 6 months | 17.6 | 15.0 | 13.4 | 13.7 |
| 5 - from 6 months to one year | 26.3 | 21.2 | 17.7 | 14.0 |
| 6 - the price remained unchanged | 9.6 | 19.5 | 34.7 | 27.4 |
| Total | 100 | 100 | 100 | 100 |

**Table 2**

PERCENTAGE OF FIRMS THAT DO NOT CHANGE THEIR PRICES IN THE FIRST YEAR AFTER THE SHOCK

| | Cost shocks | | Demand shocks | |
|---|---|---|---|---|
| | Positive | Negative | Positive | Negative |
| Manufacturing | 8.5 | 17.5 | 33.0 | 25.1 |
| Services | 20.0 | 37.8 | 50.0 | 47.8 |
| Small firms | 9.0 | 18.7 | 35.2 | 27.1 |
| Large firms | 13.5 | 24.1 | 31.6 | 28.6 |
| Total | 9.6 | 19.5 | 34.7 | 27.4 |

**Note:** Small and large firms are firms with up to 250 employees and more that 250 employees, respectively. The percentages in the table are computed as a proportion of the total number of firms in the corresponding sector or firm type.

As in similar studies, the survey data also contains information on the reasons why firms may delay price changes. Specifically, firms were asked to rank the main sticky-price theories according to their importance in explaining why firms sometimes avoid or postpone price changes in the face of changes in the relevant economic environment. Respondents were asked to indicate the degree of importance attached to each theory in a scale ranging from 1 (unimportant) to 4 (very important). Table 3 summarises these results by ranking theories by mean scores.

The results in Table 3 are in line with the findings of similar surveys. For example, implicit contracts, explicit contracts, cost-based pricing and coordination failure, also emerge as the top four theories for the EA (Fabiani *et al.*, 2006), while coordination failure, cost-based pricing, implicit contracts and explicit contracts rank first, second, fourth and fifth, respectively, for the US (Blinder *et al.*, 1998). Similar results were obtained for Sweden (Apel *et al.*, 2005) and the UK (Hall *et al.*, 1997). The results for the lower part of the ranking are also similar across countries. In these surveys, menu costs and information costs systematically rank very poorly as explanations for price rigidities. For example, menu costs rank eighth and information costs ninth out of ten alternative explanations in the EA (Fabiani *et al.*, 2006), and similar results were obtained for other countries such as the UK, Canada and Sweden (Hall *et al.*, 1997, Almirault *et al.*, 2006, Apel *et al.*, 2005).

**Table 3**

THEORIES OF PRICE STICKINESS (MEAN SCORES)

| | | Sectors | | Size | |
|---|---|---|---|---|---|
| Theory | Total | Manufacturing | Services | Small | Large |
| Implicit contracts | 3.2 | 3.2 | 3.1 | 3.2 | 3.0 |
| Coordination failure | 2.8 | 2.8 | 2.7 | 2.8 | 2.8 |
| Cost-based pricing | 2.7 | 2.7 | 2.9 | 2.7 | 2.6 |
| Explicit contracts | 2.6 | 2.6 | 2.9 | 2.5 | 2.8 |
| Temporary shock | 2.5 | 2.5 | 2.1 | 2.5 | 2.5 |
| Quality signal | 2.3 | 2.3 | 2.3 | 2.3 | 2.2 |
| Menu costs | 2.0 | 2.0 | 2.1 | 2.0 | 1.8 |
| Costly information | 1.7 | 1.7 | 1.7 | 1.7 | 1.6 |
| Pricing thresholds | 1.6 | 1.6 | 1.8 | 1.7 | 1.6 |

In the literature, the rankings of sticky-price theories have been used either directly, as a way of ranking the importance of the different sticky-price theories (see, among others, Fabiani *et al.*, 2006, and the references therein), or indirectly through regression analyses, to explain the frequency of price changes (see, for instance, Munnick and Xu, 2007). However, although these rankings provide evidence on the causes of the existence of price adjustment lags, they tell us little about the length of the lags and on how these vary across firms, which is the main purpose of this paper. For this reason, in the model to be presented in the next Section, the rankings of the sticky-price theories as reported by the firms are not used as covariates. Rather, and for the reasons explained above, we will look into the factors that might reflect differences in the relative importance of the alternative sticky-price theories at the firm-level by identifying the factors that might affect the firms' adjustment costs, or that are expected to affect the sensitivity of profits to deviations from the optimal price.

## 4. AN ECONOMETRIC MODEL FOR PRICE ADJUSTMENT LAGS

The model we use to gauge the impacts of the different covariates on the lags of price adjustments takes into account both the interval nature of the data and the fact that each firm contributes to the sample with four observations. We therefore use a panel-ordered probit model that allows for the presence of unobserved firm-specific effects.[4] More specifically, we model the latent variable $y_{ij}$, which represents the time firm $i$ takes to react to a shock of type $j$, as a function of a set of firm characteristics. Because $y_{ij}$ is not fully observable, and due to the potential existence of reporting errors, our model uses only the ordinal information provided by the firms. That is, the dependent variable in our model is $\tilde{y}_{ij} = m$, where $m = 1,2,..,6$ indicates one of the six possible response categories.

Because the preliminary data analysis suggests that the speed of price adjustment is shock specific, we estimate a model which allows for the possibility of different coefficients for each type of shock, including different cut-off parameters and different variances for the non-observed stochastic components.[5]

To complete the model specification it is necessary to define the set of regressors to use. As mentioned above, this choice was guided by the literature on the sticky-price theories briefly reviewed in Section 2. Ultimately, the importance of the different sticky-price theories at the firm-level may be captured by the characteristics of the firm itself, the good that is produced, or the sector in which the firm operates. For this reason, we have chosen as regressors sectoral, product, and firm-level characteristics that may be related directly to the above discussed sticky-price theories, or may be expected to make profits more or less sensitive to shocks.

(4) This a major distinguishing feature of our approach, which in our view allows a richer analysis of the data than the simple probit models used so far in the literature. To our knowledge, all the papers in the empirical literature that have looked at the speed of price reactions by firms in face of demand and costs shocks, have estimated binary probit models. In these models the dependent variable is defined such that it equals 1 if the price reaction occurs in the first three months (say) after the shock and is zero otherwise, or such that it equals one, if the firm reports that it reacts to shocks (and is zero otherwise). As a robustness check we also estimated a binary probit model (allowing for unobserved heterogeneity) with the dependent variable defined such that it equals 1 if the adjustment takes more than one month and equals zero otherwise. Although the point-estimates obtained with this model are not very different from those of the ordered model, the binary model is considerably less efficient and therefore most of its parameters are not statistically significant.

(5) Therefore, this is almost equivalent to estimating four different models, one for each type of shock, with the difference being that in our case the models are linked by the unobserved heterogeneity component, which is assumed to be common to the four shocks. Further details on the model may be seen in Dias *et al.* (2009).

The Appendix describes the different regressors and provides the corresponding summary statistics, and Table 4 presents the results of the estimated model.[6] For ease of presentation we grouped these variables into the following six categories: 1) Price setting practices, 2) Cost structure, 3) Market environment, 4) Source of competitiveness, 5) Type of good, and 6) Other characteristics.

**Table 4**

PANEL-ORDERED PROBIT ESTIMATES FOR THE PRICE ADJUSTMENT LAGS

| | Cost shocks | | Demand shocks | |
|---|---|---|---|---|
| **Covariates** | **Positive** | **Negative** | **Positive** | **Negative** |
| Constant | 3.477** | 4.665** | 3.345** | 3.611** |
| | (0.327) | (0.448) | (0.321) | (0.382) |
| Explicit contracts | 0.041 | -0.037 | 0.073 | 0.116 |
| | (0.127) | (0.154) | (0.123) | (0.146) |
| Implicit contracts | -0.142 | -0.114 | 0.101 | -0.196 |
| | (0.148) | (0.180) | (0.143) | (0.171) |
| Price discrimination | -0.392** | -0.383* | -0.565** | -0.621** |
| | (0.163) | (0.198) | (0.160) | (0.189) |
| Quantity discount | -0.425** | -0.301* | -0.402** | -0.430** |
| | (0.152) | (0.184) | (0.149) | (0.176) |
| Price set by customers | 0.418** | -0.213 | 0.113 | -0.139 |
| | (0.181) | (0.219) | (0.174) | (0.206) |
| Price set by competitors | 0.314* | -0.079 | -0.408** | -0.671** |
| | (0.163) | (0.196) | (0.156) | (0.186) |
| Labour costs | 0.417** | 0.394** | 0.413** | 0.514** |
| | (0.122) | (0.149) | (0.119) | (0.141) |
| Intermediate input costs | -0.252** | -0.291* | -0.052 | 0.036 |
| | (0.126) | (0.153) | (0.122) | (0.144) |
| Competition | -0.358** | -0.366** | -0.302** | -0.399** |
| | (0.136) | (0.165) | (0.132) | (0.157) |
| Domestic market | -0.029 | -0.067 | 0.047 | 0.233 |
| | (0.128) | (0.154) | (0.123) | (0.146) |
| Price competitiv. | -0.027 | -0.241* | -0.213* | -0.407** |
| | (0.113) | (0.137) | (0.109) | (0.130) |
| Quality competitiv. | 0.271** | 0.204 | 0.314** | 0.489** |
| | (0.130) | (0.157) | (0.125) | (0.150) |
| Delivery competitiv. | -0.091 | -0.107 | 0.268** | 0.301** |
| | (0.111) | (0.134) | (0.108) | (0.128) |
| Services | 1.035** | 1.112** | 0.561** | 0.951** |
| | (0.205) | (0.253) | (0.199) | (0.238) |
| Intermediate goods | -0.263** | -0.424** | -0.419** | -0.418** |
| | (0.158) | (0.151) | (0.120) | (0.143) |
| Size | 0.352** | 0.520** | -0.134 | 0.164 |
| | (0.157) | (0.193) | (0.152) | (0.181) |
| Capital structure | -0.418** | -0.477** | -0.146 | -0.270 |
| | (0.177) | (0.216) | (0.171) | (0.202) |

**Note:** Standard errors computed from analytical second derivatives are in parenthesis. **Marks significance at 5%; *marks significance at 10% level.

### Price setting practices

This category includes six regressors that we view as affecting directly the ability of the firm to change its price in the event of a shock: the proportion of sales under written contracts, information on whether the relation with the customers is essentially of a long- or short-term nature, information on whether the firm

(6) Given the definition of the categorical variables (given in the Appendix), the reference or baseline group is composed of firms for which: a) the proportion of sales under written contracts is less than 50 percent; b) the relationship with their customers is essentially of a short-term nature; c) the price is the same for all customers (absence of price discrimination) and there are no quantity discount prices; d) the price of the product is set by the firm itself and not by an external entity, including the main competitors or main customers; e) the share of labour and input costs are below the corresponding median share; f) the number of competitors is less than 5; g) exports represent more than 50 percent of their main product; h) price, quality and delivery time are not considered very important factors for the competitiveness of the main product; i) belong to the manufacturing sector; j) the production is essentially for final consumption (the main destination market is composed of wholesalers, retailers or final consumers), as opposed to intermediate consumption; and k) the number of employees is equal or less than 250.

practices price discrimination and/or quantity discounts, and, finally, information on whether the price is set by the firm's main customers or main competitors.

The first variable measures how important explicit contracts are for firms' regular operations, while the second may be seen as a proxy for the existence of implicit contracts. As we have seen in Section 2, economic theory suggests that the existence of explicit and/or implicit contracts may be an important source of price stickiness, and thus may help explaining the lags of price adjustment across firms in the event of a shock. The results in Table 4, however, show that the coefficients of these two covariates are not statistically different from zero for either of the four shocks. Thus, in contrast to what the analysis in Section 3 could suggest, the fact that the firm has a large proportion of sales under written contracts, or whether the relation with the customers is essentially of a long-term nature, does not have a bearing on the speed with which firms adjust prices following significant demand or cost shocks.

In contrast, the type of pricing policy (single price versus price discrimination and existence of quantity price discounts) emerges as playing an important role in determining the speed of price adjustments. Firms that decide the price on a case-by-case basis, or that do quantity price discounts, tend to be faster to adjust to both cost and demand shocks. These results can be interpreted as reflecting the fact that firms with such flexible pricing practices are likely to face relatively low information, managerial, or menu costs, which also allow them to react more quickly to shocks.

Finally, we consider two variables related to the firms' lack of autonomy in setting their own prices (as opposed to cases in which the price is set by the firm itself). We find that the price set by customers variable has a positive and significant impact only in the case of positive cost shocks, suggesting that customers have enough power to delay the firms' reaction when costs push prices up. Regarding the price set by competitors variable, our results show that firms that have their prices set by the main competitors are faster to respond to demand shocks than firms that set their own prices. This suggests that firms whose prices are set by the main competitors may be acting as market followers in a market where the presence of market leaders helps reducing, or even eliminating, potential coordination problems.

We notice that in our sample only about 12 percent of the firms recognised the lack of autonomy in setting their own prices (both when they are set by the main customers or by the main competitors), which suggests that these characteristics do not contribute much to explain differences in the speed of price adjustment across firms for the whole economy. In contrast, the type of pricing policy (single price versus price discrimination and existence of quantity price discounts) may be seen as an important characteristic with important implications for the speed of price adjustment as 37 percent of the firms set their prices on a case-by-case basis, and 41 percent do quantity discounts (see Table A1 in the Appendix).

### Cost structure

In order to test whether the cost structure matters for explaining the differences in the lags of price adjustments, we included two variables that measure the importance of labour costs and other input costs (intermediate inputs). From Table 4 we see that the shares of labour and intermediate input costs emerge as important factors in explaining the lags of price adjustment. Irrespective of the type of shock, firms with a labour share above the median tend to be slower to react to shocks. On the other hand, firms with a share of intermediate input costs above the median tend to react more quickly to cost shocks than otherwise similar firms.[7]

Cost structure is an important determinant of how firms react to cost shocks. In monopolistic competition models, under quite general conditions, firms choose to charge a price that represents a mark-up over marginal cost. Thus, for firms following mark-up rules, the higher the volatility of input prices, the higher will be the frequency with which they change their prices. If input costs are relatively stable, such as wages which are changed, on average, once a year, prices can also be expected to be relatively stable. On the contrary, if input costs are highly volatile, in particular some raw materials, the frequency of price changes could be much higher. Thus, *ceteris paribus*, one may expect firms with higher labour cost shares to change their prices less frequently than firms with higher shares of more volatile intermediate inputs. Our findings suggest that this result translates into the speed of price adjustment to cost shocks: firms with a higher labour share tend to be slower to react, while firms with a higher share of intermediate input costs tend to be faster (see also Altissimo *et al.*, 2006). As for demand shocks we may expect a similar result. Infrequent wage changes give rise to flatter product supply curves, making the optimal price more inelastic to demand shocks. Thus, we may expect demand shocks to have larger implications in terms of the lags of price adjustments for firms with higher labour cost shares. This is confirmed by our findings.

### Market environment

To capture the market environment in which firms operate, we use a direct measure of market competition (number of competitors), and information on the main destination market (domestic vs. foreign market). According to the estimated model, the degree of competition is a very relevant factor in determining the speed of price adjustment. Firms in more competitive environments tend to be faster to react to shocks. Indeed, it is known that the more competitive a sector is, the more sensitive profits are to sub-optimal prices. Thus, for given nominal adjustment costs (due for instance to the presence of information or menu costs) stronger competition may be expected to translate into quicker responses to shocks (see, for instance, Martin, 1993).

Regarding the market destination variable, we find that the coefficients of the covariate that measures the importance of the domestic market are not statistically significant for any of the four shocks. Thus,

(7) This is a very robust result that has been extensively documented in the literature for the frequency of price adjustments (see, among other, Altissimo, Ehrmann and Smets, 2006, and the references therein). Our results show that the same result is valid for the speed with which firms react toshocks.

whether the firm sells their products in the domestic market or abroad does not seem to make a difference for the speed with which firms react to shocks.

### Source of competitiveness

In order to investigate if the different competitiveness factors affect the speed with which firms respond to shocks, we distinguish between price, quality, and delivery period, as alternative sources of competitiveness. It turns out that firms that consider price as an important variable for competitiveness tend to adjust prices more quickly, while firms that value more the quality of the product or the delivery period as competitiveness factors tend to adjust their prices at a slower pace in response to shocks (specially so, in face of demand shocks).

We may think of these factors as reflecting different product characteristics which translate into different demand elasticities (higher demand elasticity for firms for which price is an important factor, and lower elasticity for firms that value more the quality of the product or the delivery period).[8] In our sample 60 percent of the firms consider price as a very important source of competitiveness, while 77 percent and 51 percent select quality and the delivery period, respectively. These figures suggest that the competitiveness factors, especially the price and the delivery period, are important factors in shaping the time responses to demand shocks across firms.

### Type of good

In the data we have information regarding the sector where firms operate (manufacturing or services), and the destination of the product (final vs. intermediate consumption). As earlier results suggested (see Table 2), from Table 4 we find that firms that operate in the services sector are substantially slower to react to shocks than firms that operate in the manufacturing sector. The speed of price adjustment also varies according to the type of market for the product. Firms that sell their products to other firms (intermediate goods) tend to be quicker to adjust their prices than firms whose products are mainly for final demand (whose main destinations are wholesalers, retailers or consumers). These results my reflect the fact that services and final goods are typically more differentiated than manufacturing and intermediate goods, respectively, and thus face a less elastic demand.

In our sample 31 percent of the firms declared that its main destination market is composed of other companies, which means that the "intermediate goods" covariate may have a significant contribution in explaining the differences in the lags of price adjustment across firms.

**(8)** Martin (1993) showed that the speed of price adjustment increases with the elasticity of demand, that is, firms react faster to shocks when the demand schedule facing them is flatter. This same idea was used by Gopinath and Itskhoki (2009) to show the link between the frequency of price adjustment and exchange rate pass-through.

### Other characteristics

The last group of variables we considered as potentially relevant to explain the differences in the lags of price adjustment includes the firm size and the capital structure. In line with the findings fom the previous section, size matters for the speed of price adjustment. In the face of cost shocks, large firms tend to be slower at adjusting their prices than small firms. The fact that size matters is probably because the products of large firms are typically more differentiated and therefore face a less elastic demand, or because firm size is capturing some remaining firm characteristics, like the flexibility of the decision making process.

As regards the capital structure, we find that firms with a higher share of domestic capital tend to adjust faster in the face of shocks (especially so in the face of cost shocks), probably because, in contrast to what can be expected for foreign firms, the decision making process of domestic firms resides inside the country allowing a prompter reaction to shocks.

Overall we do not expect the covariates "size" and "capital structure" to contribute much to explain the differences in the lags of price adjustment, as large firms only represent 15 percent of total firms in the sample and only 11.6 percent of the firms have a share of foreign capital larger than 50 percent.

### Symmetric or asymmetric response lags?

An interesting issue is whether the lags of price adjustments to cost and demand shocks are symmetric or asymmetric, as the consequences of monetary policy shocks might differ depending on the direction of the shock. There is now a vast theoretical literature that focus on the question of whether prices are more sticky in response to a shock that warrants a price decrease than to a price increase. Such asymmetries may arise because of strategic behaviour (Hansen *et al.*, 1996, Kavenock and Widdows, 1998, Bhaskar, 2002, Devereux and Siu, 2007), adjustment costs under trend inflation (Tsiddon, 1993, Ball and Mankiw, 1994b, Ellingsen *et al.*, 2006), search models (Lewis, 2004, Yang and Ye, 2008, Bayer and Ke, 2009), capacity constraints (Finn, 1996, Laxton *et al.* 1996, Loertscher, 2005), inattentive consumers (Chen *et al.*, 2008), or customer anger (Okun, 1981, Rotemberg, 2005). Importantly, there seems to be no theoretical unanimity as to whether prices will be more sticky when warranted prices move up or down.

According to the preliminary analysis in Section 2, and in accordance with results found in other countries, some asymmetry is expected as firms seem to react more quickly to positive than to negative cost shocks, and more slowly to positive than negative demand shocks. However, formal tests of possible asymmetric reaction times were not performed, and therefore it is important to investigate whether the observed differences are statistically significant.

In the context of our model, comparing just the individual coefficients of the covariates for positive and negative shocks provides little information on the symmetry of the responses, because of the different parameters defining the functional form of the model. Therefore, symmetry tests have to conducted by testing not only the coefficients of the covariates, but also all other parameters that are shock specific. The

results of the two global tests — one for cost shocks and one for demand shocks — clearly reject the null of equal coefficients for positive and negative shocks in both cases, so that we conclude that firms react differently to negative and positive shocks.

## 5. CONCLUSIONS

This paper investigates firm-level price rigidities by looking at the lags of price adjustments to demand and cost shocks, which is a better measure of price rigidities than the commonly used frequency of price changes.

By estimating a panel-ordered probit model, we find that the lags of price adjustments vary with the sector, product, and firm characteristics, namely the competitive environment, the cost structure of the firm, the different factors of competitiveness, pricing policy, or the type of market for the firm's product. These factors, using the terminology in Ball and Romer (1990), affect directly the degree of real rigidities, which in turn, determines the speed at which firms adjust their prices, for a given level of nominal adjustment costs (or nominal frictions).

In particular, we document that, *ceteris paribus*, firms with a high share of labour costs, that value the quality of the product or the delivery period as important competitiveness factors, that have their price set by their main customers, are large, or belong to the services sector, tend to be slower to react to shocks. In turn, firms that operate in a competitive environment, have a large share of other input costs, consider price as an important competitiveness factor, decide the price on a case-by-case basis, have their price set by the main competitors, do quantity discount prices, sell their products to other firms (intermediate goods), or have a large share of national capital, tend to react more quickly to demand or costs shocks. Among these factors, the cost structure (labour share and intermediate input share), the type of pricing policy (single price versus price discrimination and existence of quantity price discounts), the competitiveness factors (especially the price and the delivery period), and the destination of the product (final vs. intermediate consumption), emerge as especially important characteristics in explaining the differences in the lags of price adjustment across firms.

In contrast to what one could expect, the fact that the firm has a large proportion of sales under written contracts, or whether the relation with the customers is essentially of a long-term nature, does not have implications on the speed with which firms adjust prices following significant demand or cost shocks. Likewise, whether the firm sells its products in the domestic market or abroad does not seem to make a difference.

Finally, both for demand and cost shocks, statistical tests clearly reject the null hypothesis that firms respond symmetrically to positive and negative shocks.

Overall, the findings in this paper are consistent with the idea that differences in the speed of price adjustment depend on the costs of changing nominal prices, as well as on the sensitivity of firms' profits to deviations from the optimal price, and that firms behave asymmetrically in the face of positive and negative shocks.

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## APPENDIX

In this Appendix we describe the covariates used in the ordered probit model whose results are presented in section 4, and provides the corresponding summary statistics. With the exception of "capital structure" which measures the share of domestic capital in the total capital of the firm, all the other covariates are dummy variables. The details are as follows:

- *Explicit contracts* — Equal to one if the percentage of sales under written contracts is larger than 50 percent of total sales;
- *Implicit contracts* — Equal to one if the relationship with customers is essentially a long-term one (more than one year);
- *Price discrimination* — Equal to one if the price of the firm's product is decided in a case-by-case basis;
- *Quantity discount* — Equal to one if the price depends on the quantity sold but according to a uniform price list;
- *Price set by customers* — Equal to one if the price of the product is set by the firm's main customer(s);
- *Price set by competitors* — Equal to one if the price of the product is set by the firm's main competitor(s);
- *Labour costs* — Equal to one if the labour cost share is above the median of the sample;
- *Intermediate input costs* — Equal to one if the other input costs share is above the median of the sample;
- *Competition* — Equal to one if the number of firm's competitors is equal to 5 or bigger;
- *Domestic market* — Equal to one if Portugal is the main destination market for the firm's product;
- *Price competitiveness* — Equal to one if the firm considers price as a very important factor for competitiveness;
- *Quality competitiveness* — Equal to one if the firm considers quality as a very important factor for competitiveness;
- *Delivery competitiveness* — Equal to one if the firm considers delivery period as a very important factor for competitiveness;
- *Services* — Equal to one if the firm operates in the Services sector;
- *Intermediate goods* — Equal to one if "other companies" is the main destination of sales (as opposed to wholesalers, retailers, Government, consumers);

- *Size* — Equal to one if the number of employees is larger than 250;
- *Capital structure* — Share of domestic capital (owned by Portuguese entrepreneurs) on the total capital of the firm.

Table A1 summarizes the relative importance in the sample of the above defined covariates. The entries in the Table record the share of firms in each category, with the exception of the labour and intermediate input costs, which represent the corresponding average shares, and the capital structure, which represents the share of firms whose national capital accounts for 50 percent or more of total capital. For instance, from the Table we see that around 83 percent of firms have implicit contracts, i.e., they have an essentially long-term relationship with customers, and that the distribution of implicit contracts is relatively homogeneous across sectors and do not vary much with the size of firms. In contrast, only in about 25 percent of the firms do formal contracts account for 50 percent or more of total sales (explicit contracts), and its distribution varies significantly across sectors and firms' size.

**Table A1**

MAIN CHARACTERISTICS OF THE SAMPLE

Share of firms in each category in percentage

| | Total | Sectors | | Firms' size | |
|---|---|---|---|---|---|
| | | Manufacturing | Services | Small | Large |
| Explicit contracts | 25.5 | 23.9 | 40.0 | 23.6 | 36.1 |
| Implicit contracts | 82.6 | 83.3 | 76.7 | 82.0 | 86.5 |
| Price discrimination | 37.4 | 38.3 | 30.0 | 37.8 | 35.3 |
| Quantity discount | 41.0 | 42.2 | 30.0 | 40.8 | 42.1 |
| Price set by customers | 11.7 | 11.8 | 11.1 | 10.9 | 16.5 |
| Price set by competitors | 12.3 | 12.9 | 6.7 | 13.6 | 4.5 |
| Labour costs [(a)] | 27.3 | 26.2 | 36.8 | 27.6 | 25.2 |
| Intermediate input costs [(a)] | 39.3 | 43.1 | 5.1 | 39.2 | 40.3 |
| Competition | 76.0 | 74.8 | 86.7 | 79.0 | 58.6 |
| Domestic market | 68.4 | 66.3 | 87.8 | 70.5 | 56.4 |
| Price competitiveness | 59.5 | 61.4 | 42.2 | 59.2 | 60.9 |
| Quality competitiveness | 77.0 | 76.4 | 82.2 | 76.1 | 82.0 |
| Delivery competitiveness | 51.1 | 51.7 | 45.6 | 50.0 | 57.1 |
| Intermediate goods | 30.9 | 30.6 | 33.3 | 31.8 | 25.6 |
| Size (large firms) | 15.0 | 14.5 | 18.9 | – | – |
| Capital Structure [(b)] | 88.2 | 87.6 | 93.2 | 90.4 | 75.4 |

**Notes:** **(a)** Average of labour or intermediate input cost share (percent). **(b)** Share of firms whose national capital accounts for 50 percent or more of total capital.