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Choosing between time and state dependence: Micro evidence on firms' price-reviewing strategies

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Abstract

Thanks to recent findings based on survey data, it is now well known that firms differ from each other with respect to their price-reviewing strategies. While some firms review their prices at fixed intervals of time, others prefer to perform price revisions in response to changes in economic conditions. In order to explain this fact, some theories have been suggested in the literature. However, empirical evidence on the relative importance of the factors determining the firms' different strategies is virtually nonexistent. This paper contributes to filling this gap in the literature by investigating the factors that explain why firms follow time-, state- or time- and state-dependent price-reviewing rules. We find that firms' strategies vary with firm characteristics that have a bear on the importance of information costs, the variability of the optimal price and the sensitivity of profits to non-optimal prices. Menu costs, however, do not seem to play a significant role.

JEL classification: C41, D40, E31.

Key words: Price stickiness, menu costs, information costs, multinomial probit.

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1 Introduction

Price stickiness has a central role in modern macroeconomics, which explains the extensive amount of theoretical and empirical research aimed at understanding its origins and gauging its importance at both the micro and macro levels.

An important conclusion that emerges from this literature is that firms differ from each other with respect to their price-reviewing or price-setting strategies, and that the different strategies are all widespread in the economy.[1]

In this paper, we further add to this literature by studying the determinants of the choice of the price-reviewing strategies followed by firms. On the theoretical front, there is now a significant literature that directly addresses this issue[2], but a corresponding empirical contribution is virtually nonexistent. By using the information from a firm-level survey we investigate the main reasons that lead firms to select time-dependent, state-dependent or a combination of both price-reviewing practices, which we shall denote by time- and state-dependent strategy. Specifically, we explore the information available on firms' pricing decisions using a three-category multinomial probit model to study the link between their price-reviewing strategies and a number of their characteristics.

Investigation of the relevant factors behind the firms' choices of different price-reviewing strategies is a very important matter. On the one hand, the identification of such factors allow us to anticipate changes in firms's behaviour, i.e., changes from time- to state-dependent and vice-versa, as a reaction to changes in economic conditions. And such changes are known to be relevant for monetary policy. In fact, another important

[1]For instance, Fabiani et al. (2006) find that in the Euro Area about 34 percent of the firms follow time-dependent rules, 20 percent follow sate-dependent rules and the remaining 46 percent follow a combination of both, i.e., follow time-dependent rules under normal circumstances, but change to state-dependent rules upon the occurrence of specific events.

[2]See, for instance, Barro (1972), Caballero (1989), Reis (2006), Woodford (2009), Alvarez et al. (2010) and Bonomo et al. (2010).

conclusion that emerges from the literature on price stickiness is that the effects of monetary policy may depend crucially on the underlying mechanism of firms' price adjustment, namely on whether firms follow state-dependent or time-dependent price-setting rules[3]. On the other hand, the results of our exercise also allow us to answer several interesting questions, from which the following are just some examples. How does the frequency of price changes vary between time- and state-dependent firms? How important are menu and/or information costs for the choice between time- and state-dependent price-reviewing rules? Does the type of price-reviewing strategy vary with the size of the firms? Does the cost structure matter for the strategy of the firm? Are firms more likely to be state-dependent when they operate in more competitive environments? How does uncertainty affect firms' choice? Do the competitiveness factors affect the type of price-reviewing strategies and, if so, in which direction?

A potential disadvantage of using survey data for this type of investigation is that, in our case, these are reported, not actual data, and thus, it is impossible to know how accurate the answers provided in the survey are. However, in this particular case, this might be the best suited approach for the purpose at hand as there does not seem to be a valid alternative to identify the price-reviewing strategies at the firm level. In particular, quantitative data on the frequency of price changes or the duration of price spells does not allow addressing the issue. On the one hand, these data do not distinguish between price changes and price reviews, the latter being the variable of interest in this paper. On the other hand, time-dependent rules as implied by the models with information costs, are not distinguishable, in practice, from state-dependent rules, as the frequency of price changes or of price reviews depends on

[3]See, among many others, Sheshinski and Weiss (1977), Caplin and Spulber (1987), Ball and Mankiw (1994), Danziger (1999), Caballero and Engel (1993, 2007), Dotsey et al. (1999), Bonomo and Carvalho (2004), Dotsey and King (2005), Burstein and Hellwig (2007), Midrigan (2007), Golosov and Lucas (2007), Bils et al. (2009), Woodford (2009).

the underlying relevant parameters that may change over time. Therefore, by simply looking at the relationship between the frequency of price changes or the duration of price spells and the state of the economy, it is not possible to tell whether a firm follows time-dependent, state-dependent or a combination of both price-reviewing strategies (see Blanchard and Fischer (1989) ch. 8)[4].

In this paper we document that whether firms follow time-, time- and state-, or state-dependent price-reviewing strategies has important consequences for the frequency of price changes and the speed of price reaction to shocks. In particular, firms that follow state-dependent price-reviewing rules change their prices more frequently and react more quickly to demand and cost shocks than firms following time-dependent strategies.

We also find that the type of price-reviewing strategy varies significantly with those firm characteristics used to measure the importance of information costs, the variability of the optimal price and the sensitivity of profits to sub-optimal prices. In particular, we document that smaller firms, firms for which changes in prices of raw materials are important factors for pricing decisions, face wage-setting uncertainty, or operate in competitive environments are more likely to follow state-dependent price-reviewing rules. In turn, larger firms, firms for which changes in wages are important factors for pricing decisions, or operate in the services sector are more likely to follow time-dependent price-reviewing strategies. Menu costs do not seem to play a significant role in explaining the different price-reviewing strategies. Interestingly, we also find that

[4]An important strand of the literature on time-dependent pricing models assumes that the timing of price reviews and/or price changes is periodic and exogenous, i.e., taken as given and hence neither explained nor assumed to be affected by the state of the economy, the timing of the shocks or monetary policy rules. Notable examples of these, sometimes called exogenous time-dependent models, include Taylor (1980) and Calvo (1983). In this paper, we are interested in explaining the choices between time- and state-dependent price-reviewing practices, so that we focus on the sometimes also called endogenous time-dependent models in which the optimal timing of price-reviewing depends on underlying relevant parameters, which would be discussed further below.

firms that follow both time- and state-dependent price-reviewing strategies are closer to time-dependent, than to state-dependent firms as regards its determinants, but the impact on the two categories for many regressors is significantly different.

The rest of the paper is organised as follows. Section 2 presents the theoretical background which underlies the estimated model. Section 3 describes the dataset used in the paper and presents some preliminary results. Section 4 presents the estimated model and discusses the main results. Section 5 contains some concluding remarks, and finally an appendix provides an explanation of how the different variables were constructed.

2 Theoretical background

This section briefly reviews the literature on firms' pricing strategies with a special focus on the contributions that have implications for the price-reviewing strategies followed by firms. The process of charging an optimal price by firms may be thought of as usually involving price-reviewing and price-setting as two distinct steps. A price review may be defined as the activity of assessing whether the firm's current price is appropriate or not, and in general precedes the price-setting decision which involves adjusting the price to the optimal level. In practice, a price review may or may not be followed by a price adjustment, so that if the two activities required different types of costs it may be the case that the firm follows distinct price-reviewing and price-setting strategies.

Formal models that look into this problem date back at least to Barro (1972). By assuming that firms face menu-costs for changing their prices, Barro is able to show that it may be optimal for the firm to reset prices only infrequently by following a state-dependent price-setting strategy. Dixit (1991) generalized Barros's results for

the context of a generic quadratic loss function. In order to make the presentation easier, let us assume that the efficiency loss of the firm (out-of-equilibrium cost) may be captured by a quadratic function, L=θ[p(t)-p*(t)]^2, where θ measures the degree of convexity of the loss function, i.e., the sensitivity of profits to deviations of the actual price, $p(t)$, from the optimal price, $p^*(t)$. Let us assume also that the optimal price follows a random walk with Gaussian innovations with variance σ^2 per unit of time[5]. This variance may be seen as measuring the volatility of demand and cost functions. If we further assume that the firm has to pay a fixed menu-cost, γ, in order to reset its price, it may be shown that it is optimal for the firm to follow a state-dependent price setting strategy in which the optimal expected length between two price changes is given by

$$\tau_1 = \sqrt{\frac{6\gamma}{\theta\sigma^2}} \tag{1}$$

In this type of model, as there are no information costs, firms are assumed to review their prices in every period 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 the optimal price i.e., the price gap, is outside the inaction band. [6]

A major limitation of the standard state-dependent model is that it implicitly assumes that at each point in time the firm has complete information about current

[5]Note that θ depends on the parameters of the demand and costs functions, and that, in particular, θ is increasing with the elasticity of demand faced by the firm.

[6]Notice that equation (1) above is derived under the assumptions that the time discount rate is zero or very small and that there is no drift (inflation) in the process generating the optimal price. These assumptions underly also equations (2) and (3) below.

The standard state-dependent model has been generalized in very different ways. See, among others, Sheshinski and Weiss (1977, 1983), Caplin and Spulber (1987), Caballero and Engel (1993, 2007), Danziger (1999), Dotsey et al. (1999), Dotsey and King (2005), Burstein and Hellwig (2007), Golosov and Lucas (2007), Midrigan (2007) and Woodford (2009).

demand and cost conditions and constantly evaluates the convenience of price adjustment, so that the prices are reviewed in each and every period. In this respect, some literature has argued that the main benefit of infrequent price changes is not the lower menu costs, but the reduction of the costs associated with information collection and decision-making (see Ball and Mankiw (1994), Woodford (2003, 2009) and Zbaracki et al. (2004). Gray (1978) in a context of continuous time and Caballero (1989) in a discrete-time setting, by assuming the existence of information gathering costs, were able to show that it would be optimal for the firm to follow time-dependent price-reviewing practices, where the optimal price-reviewing interval is given by

$$\tau_2 = \sqrt{\frac{2\rho}{\theta\sigma^2}} \tag{2}$$

where ρ measures the fixed information costs and the remaining parameters are the same as in equation (1). According to equation (2), the optimal length for price-reviewing is increasing on the information costs and decreasing on the parameters measuring efficiency loss from sub-optimal prices and the variability of the underlying optimal price.[7]

Recently, Woodford (2009) developed a model with information costs which nests both the standard full-information menu-cost model and the exogenous time-dependent model a la Calvo as limiting cases (corresponding to a zero information cost and to

[7]The model by Caballero (1989) was further developed by Bonomo and Carvalho (2004) and Reis (2006). Bonomo and Carvalho (2004), by assuming the existence of menu and information costs that are borne together, provide a model with time-dependent price reviewing (and price adjustment) in which prices are fixed in between price reviews. Reis (2006) models imperfect information as arising from a fixed cost of observing the state. In the general case, the optimal planning intervals are not always the same, since they depend recursively on the state of the economy at the last revision date. However, in standard frameworks the optimal price-reviewing rule is also purely time dependent. Given the absence of menu costs, the optimal rule in Caballero (1989)'s and Reis (2006)'s models implies potentially continuous price adjustments between price reviews (firms set price plans), while in Bonomo and Carvalho (2004) the existence of menu and information costs that are borne together ensures that firms set a fixed price between price reviews.

an unboundedly large information cost, respectively). In this model, the assumptions about information availability have important implications for the timing and nature of price reviews. In particular, if we assume that:

i) the firm obtains full information about the economy's state at the moment when it decides to pay the information costs and review the price,

ii) partial information about current conditions is available between the occasions when the fixed information cost is paid (in contrast to Caballero (1989) , Bonomo and Carvalho (2004) and Reis (2006)), which allow firms to decide whether or not to review prices, and

iii) the memory of the firm (information on the time at which one last reviewed one's pricing policy) is as costly as information about current conditions external to the firm,

then, the optimal timing of price reviews is state-dependent, and not time-dependent as in full-information menu-cost models. However, when the information cost is sufficiently large, the dependence of the optimal hazard on the current state is attenuated, so that in the limit when the information cost becomes unboundedly large, the resulting model approaches one with a constant hazard rate as assumed in Calvo (1983). If, instead, memory is costless, the optimal hazard also depends on the number of periods since the last price review. If, memory is costless and the information costs are unboundedly large, the model becomes one in which prices are reviewed at deterministic intervals, as in Caballero (1989), and Bonomo and Carvalho (2004).

In the model suggested in Caballero (1989), Bonomo and Carvalho (2004), Reis (2006) and Woodford (2009) there are no menu costs dissociated from information costs, so that every price review implies a price change (except for zero measure events, i.e., when no price change is needed because given the observed state the current price coincides exactly with the optimal price). However, in the face of both types of costs,

firms' behaviour is likely to be more complex than simple menu or information cost models might suggest. In fact, survey data indicate that firms review their prices infrequently, and that not all price reviews yield a price adjustment[8]. But, such a pattern cannot be accounted for by simple menu-cost models, where price reviews occur continuously, nor by simple costly observation models, where each price review is also a price adjustment. More recently several models have been suggested that in a way or another try to overcome these important limitations, by allowing for both types of costs. Two notable examples are Alvarez et al. (2010) and Bonomo et al. (2010).

In their model Alvarez et al. (2010), assume that the firm has to pay an information cost in order to review the price and a menu cost if it decides to change the price. The first order condition for the optimal price-reviewing interval may be approximated by

$$\tau_3 = \sqrt{\frac{2[\rho + \gamma 2(1 - N(x))]}{\theta \sigma^2}} \tag{3}$$

where 2(1-$N(x)$) is the probability of the firm adjusting the price at the end of the review period, and the remaining parameters have the interpretation as above. Equation (3) may be seen as a generalization of the corresponding formulas of the case in which there is only an observation or a menu cost, respectively[9].

[8]For instance, for the Euro Area, Fabiani et al. (2007) document that the frequency of price reviews is generally higher than the frequency of price changes. The surveys show that in most Euro Area countries the modal number of price reviews lies in the range from one to four times a year, but most firms actually change their prices only once a year. In the case of Portugal, these figures are 2 and 1, respectively.

[9]Notice, however, that equation (3) is not a closed form for τ_3, but simply one of a two-equation system, where N(x) also depends on σ, τ_3 and $\overline{p}$, where $\overline{p}$ measures the width of the range of inaction. The authors discuss some sufficient conditions under which the two-equation system yields a unique solution for τ_3 and $\overline{p}$. In particular, under the assumption that the observation costs are sufficiently large relative to the menu costs, the authors are able to show that the optimal price-reviewing interval is increasing on the information costs, ρ, and decreasing on the variability of the underlying optimal price σ^2. On the other hand, the optimal length of time until the next price revision after an adjustment is higher in the model with both costs than in the model with observation costs only. The introduction of the menu-cost increases the cost of one price adjustment, but not the benefit, leading firms to optimally economize on the number of times they pay the observation cost.

In this model price reviews and price changes are separate activities: a firm may assess the adequacy of its current price, i.e., conduct a price review, and decide not adjust if the current price is inside the inaction interval. The timing of each price review is predetermined as it is decided on the previous revision date, but the process of price reviewing is also state-dependent, because the optimal time between price reviews is a function of the expected price gap at the time of price-reviewing. Its value is longest in the range where price adjustments are optimal (i.e., outside the inaction band). In the inaction band, the optimal time has an inverted U-shape: it peaks at a zero price gap and is otherwise decreasing in the size of the gap.[10]

In turn, Bonomo et al. (2010), section 6, develop a model that allows for dissociated menu and information costs, but that in contrast to Alvarez et al. (2010), assumes a continuous flow of partial information which may be factored into pricing decisions costlessly, together with some information that is only incorporated infrequently due, for instance, to gathering and processing costs. The authors further allow for the possibility of the firm to adjust prices without paying the information cost. In this setup firms emerge as conducting both "partially-informed" price adjustments, based on

[10]Bonomo et al. (2010), section 5, develop a model that also allows for separated menu and information costs. However, in contrast to Alvarez et al. (2010), these authors allow for the possibility of the firm to adjust prices without paying the information cost, which may have consequences for the frequency of price changes in the context of significant inflation. The price-reviewing process is however similar to the one in Alvarez et al. (2010).

Abel et al. (2009) address consumption portfolio problems under the assumption of separate observation (information) and adjustment (transaction) costs, which allow them to caracterize the processes of "observation dates" and "transaction dates". In general, as in Alvarez et al. (2010) and Bonomo et al. (2010), on any observation date, the economic agent chooses the length of time until the next observation date, but the length of time may be state-dependent. Thus, in general the model has elements of both state- and time-dependent rules. Interestingly the authors show that for sufficiently small fixed transaction costs the two processes of "observation" and "transaction dates" will eventually converge to pure time-dependent rules. Intuitively, when the fixed transaction costs are not too large compared to the observation costs, the agent will find it optimal to synchronize observation and transaction dates, in order to avoid "wasting" observation costs without using the new information to undertake a transaction. Because of the synchronization, the optimal observation interval is determined as if fixed transaction costs and observation costs were borne together, as in Bonomo and Carvalho (2004).

freely available partial information, as well as "fully-informed" price adjustments when the firm decides to pay the information costs. The price-reviewing process emerges as having both time- and state-dependent components. It is state-dependent because the firm has access to partial information on which it conditions the decision to undertake a price review (and some price changes) and it is time-dependent because the decision to undertake a price review also depends on the time elapsed since the last date when information was fully factored into the pricing decision.

In summary according to the available models in the literature we may aggregate the different price-reviewing strategies into three categories:

1) Pure time-dependent price-reviewing rules where the timing of price reviews is predetermined and independent of the state of the economy (Caballero (1989), Bonomo and Carvalho (2004)).

2) State-dependent price-reviewing strategies where the timing of price reviews is based on (imperfect) information about the current state of the economy and does not depend on the time elapsed since the last price review (Woodford (2009)).

3) Time- and state-dependent price-reviewing strategies, where the timing of price reviews is both time- and state-dependent. Here we include the two distinct cases surveyed above: i) the timing of each price revision is predetermined and decided at the previous revision date, but the length of the optimal interval depends recursively on the state of the economy at the last revision date (Alvarez et al. (2010), Abel et al. (2009), Bonomo et al. (2010), section 5); ii) the firm has access to partial current information on which it conditions the decision to undertake a price review, but the decision to undertake a price review also depends on the time elapsed since the last date when information was fully factored into the pricing decision (Bonomo et al. (2010), section 6).

In the models surveyed above, we have seen that the type of price-reviewing strategy

depends on the existence of menu and information costs, as well as on the assumptions about information availability. But we have also seen that changes in the importance of menu and information costs may change the nature of the price-reviewing strategy. In particular, in the context of the time- and state-dependent model suggested in Alvarez et al. (2010) and Abel et al. (2009) an increase in menu costs (γ) increases the importance of the state-dependent component or, to put it slightly differently, a decrease in the importance of menu costs makes the model to converge towards a pure time-dependent rule as in Caballero (1989). The intuition is that a decrease in menu costs makes the width of the inaction band to converge to zero, making the source of the state-dependent component in the price-reviewing strategy to vanish. In turn, an increase in information or observation costs (ρ) makes the state-dependent model in Woodford (2009) to converge to a pure time-dependent rule with a constant hazard rate as assumed in Calvo (1983) or, in the absence of memory costs, one in which prices are reviewed at predetermined intervals as in Caballero (1989) and Bonomo and Carvalho (2004). The intuition is similar: an increase in the information costs attenuates the dependence of the optimal hazard on the current state, making the optimal time between two consecutive price reviews to converge towards a pure time-dependent rule as information costs become unboundedly large.

In turn, the impact on the optimal price-reviewing strategy of changes in the variability of the optimal price (σ^2) and the sensitivity of firm's profits to sub-optimal prices (θ) may be discussed by noting that an increase in σ^2 or in θ operate in the model by increasing the dependence of the price-reviewing process on the current state. We may also think of an increase in σ^2 or in θ as equivalent to a decrease in the information costs (an increase in the uncertainty about the price gap or on the costs associated to a given price gap makes information more valuable, reducing its relative cost). Thus, we may expect an increase in σ^2 or in θ to increase the probability of a firm following

pure state- or time-and state-dependent price-reviewing strategies as opposed to pure time-dependent rules.

In this paper, we will look into the factors that may explain why firms follow state-dependent, time-dependent or time- and state-dependent price-reviewing strategies. For that purpose, in section 5 we will consider an econometric model that relies on the theoretical approaches presented in this section, but whose relevant factors, in face of the discussion above, include not only the menu (γ) and information costs (ρ), but also the variability of the optimal price (σ^2) and the sensitivity of firm's profits to sub-optimal prices (θ).

Overall, in our estimated model, we expect high menu-costs, small information costs, large variability of the optimal price and high sensitivity of profits to sub-optimal prices, ceteris paribus, to increase the likelihood of state-dependent price-reviewing. Similarly, low menu costs, high information costs, small variability of the optimal price and low sensitivity of profits to sub-optimal prices, are expected to increase the likelihood of time-dependent price-reviewing strategies.

3 The Data

3.1 Data sources

The data used in this study come from a survey about price setting practices carried out by the Banco de Portugal[11]. In this survey, regarding their price reviewing strategies, firms were asked the following question:

The price in your company is reviewed (without necessarily being changed):

1) *at a well-defined frequency (annually, quarterly,..),*

[11]Further details on this survey may be found in Martins (2010).

2) *generally at a defined frequency, but sometimes also in reaction to market conditions (change in the price of raw materials or in demand conditions) or*

3) *without any defined frequency, being reviewed in reaction to market conditions (changes in price of raw materials or in demand conditions).*

The responses to this question, the dependent variable in our model, are interpreted as reproducing time-dependent, time- and state-dependent, and state-dependent price-reviewing practices by Portuguese firms, respectively.

Besides the questions on price-reviewing practices, the survey also contains information on a large set of firms' characteristics. These include information on the size and sector of the firm, its main market (domestic 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 competitiveness (price vs. quality, differentiation vs. after sales service), price discrimination (same price for all customers vs. decided on a case-by-case basis), importance of changes in different factors for price adjustments (price of raw materials, wage costs, demand, competitors' prices), duration of products (short vs. long-duration), information of wage setting practices, 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.).

In total, for estimation purposes, we have detailed information on 906 firms from different areas of economic 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 type of price-reviewing strategy by Portuguese firms is our variable of interest. Table 1 summarises some useful information on this variable by displaying the distribution of the observed price-reviewing strategies in our sample, as well as comparable figures for other European countries taken from Fabiani et al. (2007)[12].

Table 1 reveals that in Portugal 32 percent of the firms in the sample follow time-dependent rules while 43 percent follow state-dependent rules, and the remaining 25 percent follow time- and state-dependent price-reviewing strategies, i.e., generally review prices at a defined frequency, but sometimes also in reaction to market conditions. From Table 1, we can also see that figures for Portugal do not differ significantly from the general picture obtained from several European countries. Even though the distribution of the price-reviewing strategies varies somewhat across countries, we notice that the three alternative price-reviewing strategies are equally important, as none emerges as clearly dominating the others. For instance, from Table 1 we see that the proportion of time-dependent firms is above 25 percent in all cases, and that the importance of time- and state-dependent strategy varies between 18 percent (NL) and 55 percent (DE).

[12]Figures for Portugal in Table 1 do not strictly coincide with those reported in Fabiani et al. (2007) due to differences in the samples used.

Table 1

Price-reviewing strategies - International evidence

Share of firms in percentage*

	PT	ES	DE	NL	BE	IT	AT
Time-dependent	32	33	26	36	26	40	41
Time- and state-dependent	25	28	55	18	40	46	32
State-dependent	43	39	19	46	34	14	27

* PT-Portugal, ES-Spain, DE-Germany, NL-Netherlands, BE-Belgium IT-Italy and AT-Austria; Source: Fabiani et al. (2007).

Table 2

Price-reviewing strategies - Sectoral and size breakdown

Share of firms in percentage

		Sectors		Size	
	Total	Manufacturing	Services	Small	Large
Time-dependent	32	30	47	30	41
Time- and state-dependent	25	25	25	22	35
State-dependent	43	45	28	48	24

Table 2 considers the breakdown by sector and firm size of the different price-reviewing strategies. The Table suggests the existence of strong heterogeneity in these two dimensions. Indeed, the share of firms following time-dependent rules is higher in services than in manufacturing, and tends to increase with the size of the firms.

As in similar studies, the survey data also contains information on the speed of price reaction to shocks. Specifically, firms were asked about the speed of their reaction to

significant positive and negative cost and demand shocks[13]. Simple visual inspection of Table 3, which summarises the responses for positive shocks, suggests that time-, time- and state-, and state-dependent firms have different speeds of price adjustment to shocks. In particular, in both cases, time-dependent firms seem to be slower to adjust than firms following state-dependent price-reviewing strategies. Indeed, 26 percent of firms with state-dependent price-reviewing rules adjust their prices in the first month after a positive cost shock, while 58 percent do it in the first three months. The corresponding figures for time-dependent firms are 14 and 38 percent, respectively. The results for firms with time- and state-dependent rules suggest that the speed of price adjustment is somewhere in between that of time- and state-dependent firms. The analysis based on visual inspection of Table 3 is corroborated by formal non-parametric χ^2 homogeneity tests, which reject the null hypothesis of identical adjustment lags across the three types of firms, at standard significance levels, for the set of adjustment intervals considered[14].

[13]This information was explored by Dias et al. (2010) to study why some firms react to shocks faster than others.

[14]The results for negative cost and demand shocks, as regards the price adjustment lags for the three type of price-reviewing strategies, including the χ^2 homogeneity tests, are qualitatively similar.

Table 3

Speed of price response to positive demand and cost shocks

Share of firms in each category

Price adjustment lag	Time-dependent	Time- and state-dependent	State-dependent
Positive cost shocks:			
1 - Less than one week	3	6	6
2 - From one week to one month	11	16	20
3 - From 1 month to 3 months	24	28	32
4 - From 3 to 6 months	19	21	18
5 - From 6 months to one year	33	24	18
6 - More than one year	10	5	7
Positive demand shocks:			
1 - Less than one week	3	4	4
2 - From one week to one month	7	11	15
3 - From 1 month to 3 months	17	18	23
4 - From 3 to 6 months	13	21	13
5 - From 6 months to one year	22	21	14
6 - More than one year	38	26	31

Table 4 reports the average frequency of price changes as reported by the firms in the sample. From the Table it can be seen that on average time-, time- and state- and state-dependent firms have different frequency of price changes. In particular, state-dependent firms seem to adjust prices more frequently than firms following time-dependent price-reviewing strategies. Indeed, 17 percent of firms following state-dependent rules change their prices at least once in a quarter, while 8 percent do it at least once in a month. On the other hand, only 8 percent of firms following time-dependent rules change their prices at least once in a quarter. The frequency of price changes for time- and state-dependent firms seems to be somewhere in between that of

time- and state-dependent firms. Once again, the analysis based on visual inspection is corroborated by a formal non-parametric χ^2 homogeneity test, which clearly rejects the null hypothesis of equal frequency of price changes across the three types of firms, at standard significance levels, for the set of frequency intervals considered.

Table 4

Frequency of price adjustment

Share of firms in percentage

Frequency of price adjustment	Time-dependent	Time- and state-dependent	State-dependent
1 - Once per month or more	3	5	8
4 - Once per quarter	5	9	9
5 - Twice a year	16	14	17
6 - Once a year or less	76	72	66

Overall, Tables 3 and 4 show that whether firms follow time-, time- and state-, or state-dependent price-reviewing strategies has important consequences for the frequency of price changes and the speed of price reaction to shocks. This, in turn, may be expected to have important consequences for monetary policy, as its effects would depend on the distribution of firms in terms of their price-reviewing strategies. Thus, anything that changes this distribution will affect the speed with which prices react to monetary policy shocks. In particular, one may expect the effects of monetary policy to depend on the firm size distribution or the importance of the services sector in the economy (see Table 2). Countries with a higher share of larger firms and/or with a larger services sector may be expected to display a larger proportion of time-dependent firms and thus to be stickier than otherwise identical countries. But, the factors that may change the effects of monetary policy include monetary policy itself: changes in monetary policy rules involving, for instance, a decrease or an increase in the central

bank inflation target, to the extent that they alter the proportion of firms in each category, will change the frequency of price changes and the speed of price reaction to monetary policy shocks (see, for instance, Bonomo and Carvalho (2004)).

4 An econometric model for the price-reviewing strategies

In order to gauge the impact of the different covariates on the type of price-reviewing strategy, we estimate a multinomial probit model, where the dependent variable, $y_{i,j}$, j=TD, TD-SD, SD indicates one of the three response categories: time-, time- and state- , or state-dependent price-reviewing strategy[15].

The choice of the set of regressors used in the empirical model was guided by the literature on price-reviewing strategies, which we summarized in section 2. As discussed in that section, the relevant factors determining the type of pricing policy may be divided into menu costs, information costs, variability of the optimal price and the sensitivity of profits to sub-optimal prices. As for each of these four categories of factors direct quantitative data is not available, we use proxies as the regressors for each one of the four factors. The different regressors are described in the Appendix together with some summary statistics.

In Table 5, we present the average marginal effects of each of the covariates on the probability of a firm following either a time-, a time- and state- or a state-dependent price-reviewing strategy, computed from the estimated parameters of a multinomial probit model[16].

[15]For a derivation of this model, see Train (2009).

[16]Figures in Table 5 refer to the output of an independent multinomial probit. As a robustness check, we also estimated a multinomial probit allowing for the possibility of correlated errors. However, the estimates for the average marginal effects are virtually unchanged. We note, that by construction the average marginal effects for each regressor in Table 5 add up to zero.

Menu costs

According to the theoretical models surveyed above, we may expect high menu costs to increase the likelihood of state-dependent price-reviewing. However, in our estimated model, menu costs do not emerge as a relevant factor to discriminate among the three alternative price-reviewing strategies. This of course, may stem from the type of regressor we use. In our model, menu-costs are measured by a dummy variable that is equal to one if the firm considers that they are important or very important to explain the existence of price rigidity and is zero otherwise. But, it may well be the case that two firms, with a very different degree of price stickiness attach the same degree of importance to menu costs. Under such circumstances, our measure of menu costs could be unable to discriminate among firms with different price-reviewing strategies. Of course, it may also be the case that in most firms menu costs do not play an important role for the decision on the type of price-reviewing strategy, if they are very small when compared to information costs (see Ball and Mankiw (1994), Zbaracki et al. (2004) and Woodford (2003, 2009)).

Information costs

This category includes a group of variables that may be seen as direct of indirect measures of information costs. According to the models in section 2, we may expect high information costs to increase the likelihood of time-dependent price-reviewing. In this group of regressors, we consider both a direct measure of the information costs, which we label "importance of information costs" and two more indirect measures labeled "price discrimination" and "size". The variable, "importance of information costs" maps directly into the theories presented in section 2. The "price discrimination" variable indicates whether a firm charges different prices to different customers or not. Our assumption is that a firm which price discriminates must be able to process all

the necessary information very cheaply at the time of charging a different price. In that sense, it is expected that, ceteris paribus, firms that price discriminate would tend to prefer state-dependent price-reviewing strategies. With respect to the "size" variable, our assumption is that, in principle, larger firms will tend to have larger product portfolios and also that their decision structure is less centralized than smaller firms. For that reason, we expect larger firms to have higher information costs, and therefore to be more likely to follow time- or time- and state-dependent price reviewing strategies.

Regarding the variable "importance of information costs", we see that firms for which information costs are important, are less likely to follow state-dependent price-reviewing strategies. In particular, these firms are 6.3 percent less likely to follow a state-dependent price-reviewing strategy than otherwise identical firms. Although this result is in line with what is predicted by theory, it lacks some statistical strength.

In the case of the type of pricing policy, namely whether the firm sets a single price or discriminates the price among the customers, we obtain a result that is line with our predictions. That is, we estimate that firms that discriminate prices among their customers are 15.8 percent more likely to follow state-dependent rules than firms that do not.

With respect to the last variable in this group, "size", we find that larger firms tend to prefer time- or time- and state-dependent price reviewing rules in detriment of state-dependent rules. According to our estimates, a large firm is 21.6 percent less likely to follow state-dependent price reviewing rules than a comparable small firm. This results are also in line with the preliminary findings in section 3.

Table 5-Multinomial Probit

Average marginal effects

Regressors	Time-Dependent	Time- and State-Dependent	State-Dependent
Menu costs	0.0204 (0.0341)	−0.0169 (0.0335)	−0.0035 (0.0359)
Information costs			
Importance of information costs	0.0118 (0.0349)	0.0512 (0.0340)	−0.0630* (0.0364)
Price discrimination	−0.1017*** (0.0311)	−0.0562* (0.0295)	0.1579*** (0.0336)
Size	0.0918** (0.0402)	0.1244*** (0.0397)	−0.2162*** (0.0373)
Variability of the optimal price			
Changes in prices of raw materials	−0.1795*** (0.0668)	0.0539 (0.0534)	0.1255** (0.0594)
Changes in wages	0.0798** (0.0401)	−0.0071 (0.0392)	−0.0727* (0.0447)
Changes in demand	0.0001 (0.0383)	0.0284 (0.0379)	−0.0284 (0.0415)
Wage uncertainty	−0.0778** (0.0371)	−0.0190 (0.0361)	0.0968** (0.0402)
Explicit contracts	0.0502 (0.0331)	0.0787** (0.0318)	−0.1289*** (0.0333)
Product lifespan	0.0853** (0.0400)	0.0140 (0.0369)	−0.0993*** (0.0383)
Efficiency loss			
Competition	−0.0734** (0.0365)	0.0087 (0.0334)	0.0647* (0.0371)
Price competitiveness	−0.0518* (0.0318)	−0.0568* (0.0301)	0.1086*** (0.0322)
Changes in competitors' prices	−0.1289*** (0.0396)	0.0886*** (0.0336)	0.0403 (0.0396)
Intermediate goods	−0.0726** (0.0327)	−0.0205 (0.0313)	0.0932*** (0.0354)
Services	0.1405*** (0.0549)	−0.0003 (0.0491)	−0.1402*** (0.0509)

Robust standard errors are in parenthesis; ***,**,* denote significance at 1, 5 and 10 percent level, respectively;

Variability of the optimal price

This category includes a group of variables deemed to affect directly or indirectly the variability of the optimal price of the firm: "changes in the prices of raw materials", "changes in wages", "changes in demand", "wage uncertainty", "explicit contracts" and "product lifespan".

The first three covariates measure the importance of changes in the prices of raw materials, in wages and in demand for the firm's decision of a price change. Estimates in Table 5 show that firms for which raw materials matter more are more likely to follow a state-dependent price-reviewing strategy. In particular, a firm for which changes in the prices of raw materials are important or very important for price changes is about 18 percent less likely to follow a time-dependent price-reviewing strategy, than an otherwise identical firm. In contrast, the more important changes in wages are, the more likely it is that a firm follows a time-dependent price reviewing rule. In both cases the results accord with intuition: in general, the price of raw materials is highly volatile, which will increase the variability of the optimal price and thus, may be expected to increase the likelihood of state-dependent behaviour; in turn, we may expect changes in wages to occur at well-defined frequencies (once a year, usually) and thus, their importance for price changes to be negatively correlated with the uncertainty surrounding the optimal price. For similar but symmetric reasons, the covariate "wage uncertainty" which identifies the firms for which the wages are changed at irregular intervals (more than two times a year or less than once a year), may be expected to be positively correlated with the variability of the optimal price, and thus, to increase the likelihood of state-dependent price-reviewing. Interestingly, the larger importance of changes in demand for the decision of a price change does not seem to have a bearing on the type of price-reviewing strategy followed by Portuguese firms.

The existence of written or "explicit" contracts has been suggested in the literature

as an important explanation for price rigidities at the firm level. With such contracts firms aim at building long-term relationships with their customers 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). According to Table 5, the existence of explicit contracts has also a bearing on the type of price-reviewing strategy followed by Portuguese firms. In particular, we see that firms with a large proportion of sales under written contracts are less likely to follow state-dependent price-reviewing rules and more likely to follow time- or time- and state-dependent rules. This accords with the idea that contracts are in fact also used to reduce the variability of the optimal price.

Finally, the product lifespan also has implications for the type of price-reviewing strategy. From Table 5, we see that firms whose main product has a short lifespan (usually less than one year) are more likely to follow time-dependent price-reviewing rules - according to our model, around 9 percent more likely. Examples of these type of products are products that change collections regularly or seasonally like clothing or footwear.

Efficiency loss

This category includes a group of variables expected to be related to the determinants of the sensitivity of firm's profits to deviations from the optimal price (e.g., demand elasticity or slope of the cost function). In this category, we included the following regressors: "competition", "price competitiveness", "changes in competitor's prices", "intermediate goods" and "services".

The degree of competition[17] may be expected to have a significant impact on the choice of a price-reviewing strategy, because it is known that the more competitive a

[17]We consider a competitive environment if the number of competitors faced by the firm is equal to 5 or more.

sector is, the more sensitive profits are to sub-optimal prices (Gopinath and Itskhoki (2010)). Thus, for the same level of nominal adjustment costs (menu and information costs), firms operating in more competitive environments may be expected to prefer state-dependent practices. Our estimates show that this is indeed the case. From Table 5, we see that a firm operating in a competitive environment is 7.3 percent less likely to follow a time-dependent price-reviewing rule, than an otherwise identical firm.

As it is well known, firms can compete in many different dimensions: price, quality, after-sales service, etc. In that sense, we added to our model a variable that indicates whether the price is the main factor of competitiveness of that firm. The results that we obtain for this variable are that firms which compete in price (as opposed to other dimensions of competition) are 10.9 percent more likely to follow state-dependent price-reviewing strategies. This is the expected result, as the profits of these firms (the ones that compete in price) are more sensitive to deviations from optimal price (the limiting case is perfect competition where small price deviations can have an infinite impact in profits).

As regards the regressor "changes in competitors' prices", we notice that firms for which such changes are important or very important for pricing decisions are less likely to follow time-dependent rules and more likely to follow time- and state-dependent rules, but the likelihood of following state-dependent rules is not affected. This is a very interesting result, which may be explained in a context of strategic complementarities (see, for instance, Bonomo and Carvalho (2004)). In such a context, a firm should not be expected to follow a simple time-dependent rule, as such rule does not accommodate the possibility of a firm reacting to changes in the firms' relevant environment. In contrast, by being time- and state-dependent the firm has the possibility of generally review their prices at well defined frequencies, but sometimes also in reaction to market conditions, namely changes in competitors' prices (see Bonomo et al. (2010)).

As earlier results suggested (see Table 2 in Section 3), from Table 5 we find that firms that operate in the services sector are more likely to follow time-dependent price-reviewing strategies than firms that operate in the manufacturing sector. In fact, the covariate "services" shows up with a very large impact, with estimated positive marginal effects on time-dependent behaviour of around 14 percent. The type of price-reviewing strategy also varies according to type of market for the product. Firms that sell their products to other firms (intermediate goods) are more likely to follow state-dependent rules than firms whose products are mainly for final demand (whose main destinations are wholesalers, retailers or consumers). These results may reflect the fact that services and final goods are typically more differentiated than manufacturing and intermediate goods, and thus face a less elastic demand, which makes profits less sensitive to non-optimal pricing.

Overall, the results in Table 5 show that firms that follow both time- and state-dependent rules are closer to time-dependent than to state-dependent firms. Indeed, changes in regressors that bring about significant changes in the likelihood of time-dependent rules, either bring about a significant change in time- and state-dependent rules of the same sign, or no significant changes at all. In other words, significant increases in the likelihood of state-dependent behaviour are correlated with significant decreases in the likelihood of time-dependent behaviour, of time- and state-dependent behaviour or both. The single exception is the regressor changes in competitors' price, which decreases the likelihood of time-dependent rules at expenses of an increase in the likelihood of time- and state-dependent rules. These results also show that time-dependent and time- and state-dependent behaviour despite being closer in terms of its determinants should be seen and treated as very distinct choices. For many regressors the impact on the two categories is in fact different. For instance, for the covariates aiming at measuring the variability of the optimal price, while 4 out of 6 have a signif-

icant impact on the likelihood of time-dependent behaviour, only one has a significant impact on the likelihood of time- and state-dependent price-reviewing rules.

5 Conclusions

This paper uses firm-level data to look into the factors that may explain why firms follow time-, state-, or time- and state-dependent price-reviewing strategies.

In line with the evidence found in other countries, Portuguese firms are strongly heterogeneous as regards their price-setting/reviewing strategies. In our sample, 32 percent of the firms follow time-dependent, 43 percent state-dependent and the remaining 25 percent time- and state-dependent price reviewing strategies. Importantly, the frequency of price changes and the lags of price adjustments to shocks of time-dependent firms is significantly lower than that of state-dependent firms, while firms that are both time- and state-dependent rank in between.

By estimating a multinomial probit model, we find that the type of price-reviewing strategy varies significantly with those firm characteristics that measure the importance of information costs, the variability of the optimal price and the sensitivity of profits to sub-optimal prices. In particular, we document that factors that increase the costs of information required for the process of price reviewing tend to decrease the likelihood of state-dependent rules or to increase the likelihood of time- and time- and state-dependent price-reviewing strategies. Factors that increase the cost of deviations from the optimal price decrease the likelihood of a firm following time-dependent rules whereas variables that increase the variability of the optimal price increase the probability of a firm following state-dependent price-reviewing strategies. Menu costs do not emerge as playing an important role.

We also find that firms that follow both time- and state-dependent price-reviewing

strategies are closer to time-dependent, than to state-dependent firms, as regards its determinants. Interestingly, however, firms for which changes in competitors' prices are important for pricing decisions are less likely to follow time-dependent rules and more likely to follow time- and state-dependent rules, suggesting that the existence of strategic complementarities plays an important role in discriminating among these two types of firms.

The fact that the proportion of time- and state-dependent firms depends on the state of the economy has important consequences for monetary policy. Monetary policy aimed at stabilizing the economy (by reducing inflation uncertainty, demand variability or the central bank inflation target) might increase the proportion of time-dependent firms, which, in turn, to the extent that such firms display lower frequency of price reviews or of price changes, would tend to increase the real effects of monetary policy (see, for instance, Bonomo and Carvalho (2004)). A simple implication of these results is that DSGE models should be improved in order to account for the heterogeneity and endogeneity of firms' price-setting strategies. Otherwise, the implications of changes in monetary policy rules generated by these models might be very misleading.

Appendix

In this Appendix, we describe the covariates used in the multinomial probit model whose results are presented in section 4, and provide the corresponding summary statistics. All the covariates used in the model are dummy variables. The details are as follows:

Menu costs – Equal to one if the menu costs implied by price changes are ranked as an important or a very important factor, by the firm.

Importance of information costs – Equal to one if the costs involved in collecting the relevant information for price decisions are ranked as an important or a very important factor.

Price discrimination – Equal to one if the price of the firm's product is decided on a case-by-case basis.

Size – Equal to one if the number of employees is larger than 250.

Changes in prices of raw materials – Equal to one if they are considered as important or very important for the firm's decision of a price increase or a price decrease.

Changes in wages – Equal to one if they are ranked as important or very important for the firm's decision of a price increase or price decrease.

Changes in demand – Equal to one if they are ranked as important or very important for the firm's decision of a price increase or price decrease.

Wage uncertainty – Equal to one if the frequency of wage changes is not fixed at regular intervals, i.e., less than once a year or more than 2 times a year.

Explicit contracts – Equal to one if the percentage of sales under written contracts is larger than 25 percent of total sales.

Product lifespan – Equal to one if the good produced has as short duration (usually less than one year), i.e., a product that changes collections seasonally or changes its

models regularly (clothing and footwear, house appliances, etc.)

Competition – Equal to one if the number of firm's competitors is greater than or equal to 5.

Price competitiveness – Equal to one if the firm considers price as a very important factor for competitiveness.

Changes in competitors' price – Equal to one if they are important or very important for the firm's decision of a price increase or price decrease .

Intermediate goods – Equal to one if "other companies" is the main destination of sales (as opposed to wholesalers, retailers, Government, consumers).

Services – Equal to one if the firm operates in the Services sector.

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. For instance, from the Table we see that around 93 percent of the firms consider that changes in prices of raw materials are important or very important for price decisions on either price increases or price decreases, and that the distribution of such firms does not change with firms' size, but varies across sectors, being relatively more frequent in manufacturing than in services. In contrast, only about 30 percent of the firms produce intermediate goods, i.e., sell their main product to other companies (as opposed to wholesalers, retailers or the Government) and are relatively more frequent in the services sector.

Table A1: Main characteristics of the sample

(Share of firms in each category in percentage)

	Total	Sectors		Firms' size	
		Manufacturing	Services	Small	Large
Menu costs	57.1	57.0	57.3	57.9	53.5
Importance of information costs	40.6	41.2	34.8	41.6	36.5
Price discrimination	36.5	36.6	36.0	36.3	37.6
Size (large firms)	18.8	17.9	27.0	–	–
Changes in prices of raw materials	93.4	95.7	71.9	93.8	93.4
Changes in wages	84.8	84.9	83.1	86.3	78.2
Changes in demand	77.7	77.5	79.8	78.0	76.5
Wage uncertainty	17.9	17.4	22.5	19.7	10.0
Explicit contracts	33.0	31.0	51.7	30.8	42.4
Product lifespan	20.2	22.0	3.4	21.2	15.9
Competition	75.7	75.6	76.4	79.9	57.6
Price competitiveness	61.5	62.2	55.1	61.0	63.5
Changes in competitors' prices	74.6	74.3	77.5	73.9	77.6
Intermediate goods	29.9	28.9	39.3	30.8	25.9

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