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WAGE DYNAMICS
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NO 1305 / MARCH 2011

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TIME AND STATE
DEPENDENCE**

**MICRO EVIDENCE
ON FIRMS'
PRICE-REVIEWING
STRATEGIES**

by Daniel A. Dias,
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Wage Dynamics Network

This paper contains research conducted within the Wage Dynamics Network (WDN). The WDN is a research network consisting of economists from the European Central Bank (ECB) and the national central banks (NCBs) of the EU countries. The WDN aims at studying in depth the features and sources of wage and labour cost dynamics and their implications for monetary policy. The specific objectives of the network are: i) identifying the sources and features of wage and labour cost dynamics that are most relevant for monetary policy and ii) clarifying the relationship between wages, labour costs and prices both at the firm and macro-economic level.

The WDN is chaired by Frank Smets (ECB). Giuseppe Bertola (Università di Torino) and Julián Messina (World Bank and University of Girona) act as external consultants and Ana Lamo (ECB) as Secretary.

The refereeing process of this paper has been co-ordinated by a team composed of Gabriel Fagan (ECB, chairperson), Philip Vermeulen (ECB), Giuseppe Bertola, Julián Messina, Jan Babecký (CNB), Hervé Le Bihan (Banque de France) and Thomas Mathä (Banque centrale du Luxembourg).

The paper is released in order to make the results of WDN research generally available, in preliminary form, to encourage comments and suggestions prior to final publication. The views expressed in the paper are the author's own and do not necessarily reflect those of the ESCB.

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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 firms' different strategies is virtually nonexistent. This paper contributes to filling this gap 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 bearing 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: Survey data, price stickiness, menu costs, information costs, multinomial probit.

Non-technical summary

In recent years, a substantial amount of theoretical and empirical research devoted to improving the microeconomic foundations of macroeconomic behaviour has made clear that a thorough understanding of the extent and causes of the sluggish adjustment of nominal prices is crucial to the design and conduct of monetary policy. An important conclusion that emerges from the 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. A second important conclusion is that the effects of monetary policy may depend crucially on the underlying mechanism of firms' price adjustment, namely on whether firms follow state- or time-dependent price-setting rules. Understanding the factors that lie behind firms' choice of different price-reviewing strategies is thus an issue of paramount importance.

This paper adds to this strand of the literature by studying the determinants of the choice of the price-reviewing strategies followed by firms. 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 price-reviewing strategy. Specifically, we explore the information available on firms' pricing decisions to study the link between their price-reviewing strategies and a number of their characteristics. The identification of such characteristics allow us to anticipate changes in firms' behaviour, i.e., changes from time- to state-dependent and vice-versa, as a reaction to changes in economic conditions and therefore to anticipate changes in monetary policy transmission.

In this paper we document that the type of price-reviewing strategy followed by firms 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.

By estimating a multinomial probit model, we conclude 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 increase the likelihood of time- and time- and state-dependent price-reviewing strategies. Factors that increase the variability of the optimal price or the cost of deviations from 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 the time- and state-dependent price-reviewing strategy is closer to the time-dependent, than to the state-dependent strategy. 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 stabilising the economy (by reducing inflation uncertainty) 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. A simple implication of these results is that DSGE models designed for the conduction of monetary policy 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.

1 Introduction

In recent years, a substantial amount of theoretical and empirical research, devoted to improving the microeconomic foundations of macroeconomic behaviour, has made clear that a thorough understanding of the extent and causes of the sluggish adjustment of nominal prices is crucial to the design and conduct of monetary policy.

In this regard, an important conclusion that emerges from the 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 A second important conclusion is that the effects of monetary policy may depend crucially on the underlying mechanism of firms' price adjustment, namely on whether firms follow state- or time-dependent price-setting rules.² Understanding the factors that lie behind firms' choice of different price-reviewing strategies is thus an issue of paramount importance.

This paper adds to this strand of the 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, but a corresponding empirical contribution is virtually nonexistent.

Using the information from a firm-level survey, this paper investigates 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 price-reviewing strategy. Specifically, we explore the information available on firms' pricing decisions using a multinomial probit model to study the link between their

¹For instance, Fabiani et al. (2006) find that in the Euro Area about 34 percent of the firms follow time-dependent rules, 20 percent follow state-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 price-reviewing rules upon the occurrence of specific events.

²See, among many others, Sheshinski and Weiss (1977), Caplin and Spulber (1987), 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).

price-reviewing strategies and a number of their characteristics. The identification of such characteristics will allow us to anticipate changes in firms' behaviour, i.e., changes from time- to state-dependent and vice-versa, as a reaction to changes in economic conditions and therefore to anticipate changes in monetary policy transmission. In addition, our exercise will also allow us to answer several interesting questions, from which the following are just some examples: How do the the frequency of price changes and the lags of price reaction to shocks 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 firm's strategy? How does uncertainty affect firms' choice? Are firms more likely to be state-dependent when they operate in more competitive environments?

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, 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 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 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).³

In this paper we document that the type of price-reviewing strategy followed by firms 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. Menu costs, i.e. costs of changing prices such as the cost of printing and distributing new price lists, do not seem to play a significant role in explaining the different price-reviewing strategies. More specifically, we document that smaller firms, firms for which changes in prices of raw materials are important factors for pricing decisions or that operate in competitive environments are more likely to follow state-dependent price-reviewing rules. In turn, larger firms, firms for which information costs or changes in wages are important factors for pricing decisions, or that operate in the services sector are more likely to follow time- or time- and state-dependent price-reviewing strategies. Interestingly, we also find that the time- and state-dependent strategy is closer to the time-, than to the state-dependent price-reviewing rule. Yet, the two price-reviewing rules are very distinct. In fact, for many regressors, the magnitude of the impact on the likelihood of the two categories is different and, moreover, the probability of a firm

³An 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 may change over time.

choosing between one of the two strategies may go in the opposite direction.

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

The process of charging an optimal price by firms may be thought of as involving price-reviewing and price-setting as two distinct activities. Price reviewing 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 entail different types of costs it may be the case that the firm follows distinct price-reviewing and price-setting strategies.⁴

This section briefly reviews the literature on firms' price-reviewing strategies and discusses the implications for those strategies stemming from changes in the relevant parameters.

Models without costless information

We start by summarizing the implications for the firms' price-reviewing strategies of

⁴Survey data indicate that firms review their prices infrequently, and that not all price reviews yield a price adjustment. 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.

the models suggested in Caballero (1989) and Alvarez et al. (2010), which assume that firms do not have access to costless information about current economic conditions.

In order to make the presentation easier let us start by assuming that: i) the efficiency loss of the firm (out-of-equilibrium cost) may be captured by a quadratic function, $L=\theta[p(t)-p^*(t)]^2$, where θ measures the sensitivity of profits to the price gap, i.e., the deviation of the actual price, $p(t)$, from the optimal price, $p^*(t)$; ii) the optimal price follows a random walk with Gaussian innovations with variance σ^2 per unit of time;⁵ and iii) the firm has to pay a fixed information cost, ρ , in order to review its price. Under these circumstances, it may be shown (see Caballero (1989)) that it is optimal for the firm to follow a time-dependent price-reviewing strategy, where the optimal price-reviewing interval is given by

$$\tau = \sqrt{\frac{2\rho}{\theta\sigma^2}} \quad (1)$$

According to equation (1), 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.⁶

In the model suggested in Caballero (1989) there are no menu costs, i.e., costs of changing prices, so that every price review implies a price change. In a recent contribution, Alvarez et al. (2010) generalise Caballero's model by assuming that the firm has to pay an information cost to review the price and a menu cost if it decides to

⁵Notice that θ depends on the parameters of the demand and cost functions and that, in particular, θ is increasing with the elasticity of demand faced by the firm. The variance σ^2 may be seen as measuring the volatility of demand and cost functions.

⁶The 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 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.



change the price. 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 to adjust if the current price is inside the inaction band (stemming from the presence of menu costs). The timing of each price review is predetermined as it is decided on the previous revision date. Nevertheless 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.⁷

Models with costless information

In contrast to Caballero (1989) and Alvarez et al. (2010), Woodford (2009) and Bonomo et al. (2010) assume that firms have access to partial information at no cost, on which they support the decision to conduct a price review.

In Woodford's (2009) model, which draws on the theory of rational inattention proposed by Sims, the assumptions about information availability have important implications for the strategy of price reviews.⁸ In this model it is assumed 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, which allows firms to decide whether or not to review prices; and *iii*) the memory of the firm (information on the time at which the firm last reviewed its price) is as costly as information about current conditions external to the firm.⁹ Under these circum-

⁷In a similar approach Abel et al. (2009) address consumption portfolio problems under the assumption of separate observation (information) and adjustment (transaction) costs. In general the model has elements of both state- and time-dependent behaviour. 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.

⁸See Sims (1998, 2003, 2006).

⁹This assumption may be justified in the context of the theory of rational inattention: the cost of

stances, it is shown that the optimal timing of price reviews follows a state-dependent rule. However, when the information cost is sufficiently large, the dependence of the optimal hazard (that indicates the probability of a price review) 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).

In the model suggested in Woodford (2009) there are no menu costs dissociated from information costs, so that every price review implies a price change, as in Caballero's model. More recently, Bonomo et al. (2010) developed a model that allows for dissociated menu and information costs and assumes a continuous flow of partial information which may be factored into pricing decisions at no cost, together with some information that is only incorporated infrequently due, for instance, to gathering and processing costs. Nevertheless, the price-reviewing process emerges as having both time- and state-dependent components, as in Woodford (2009)'s memory costless case. It is state-dependent because the firm has access to partial information on which it conditions the decision to undertake a price review, 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.

Impact on the price-reviewing strategy of changes in the relevant parameters

We have seen that in some of the models surveyed above changes in the importance

any kind of information is assumed to be the same as any other, because the relevant bottleneck is limited attention on the part of the decision maker, rather than anything about the structure of the economy that obscures the value of certain variables.

of menu and information costs may alter 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) a decrease in the importance of menu costs makes the model converge towards a time-dependent rule. 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 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). 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.

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 in a context of a model in which firms have access to partial information about current conditions, as in Woodford (2009). In this model, an increase in θ or in σ^2 may be thought of as bringing about both 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) and an increase in the relative cost of firm's memory (the higher is σ^2 or θ the less valuable the memory will be). Thus, an increase in θ or in σ^2 , to the extent that it decreases the information costs on the current conditions and increases the memory costs of the firm, will increase the probability of a firm following state-dependent price-reviewing strategies as opposed to time-dependent or time- and state-dependent rules.

In this article, 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 4 we will consider an econometric model that relies on the theoretical approaches presented in this section, whose relevant factors, in face of the discussion above, include the menu costs, the information costs, the variability of the optimal price and the sensitivity of firm's profits to sub-optimal prices. 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 or, more precisely, the likelihood of a state-dependent component in the firm's price-reviewing strategy. 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 a time-dependent component in the firm's price-reviewing strategy.

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.¹⁰ 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,..),*

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*

¹⁰Further details on this survey may be found in Martins (2010).

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), destination of sales (wholesalers vs. retailers, private vs. public sector), number of competitors, type of relation with customers (long-term vs. short-term), factors 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).¹¹

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 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

¹¹Figures for Portugal in Table 1 do not strictly coincide with those reported in Fabiani et al. (2007) due to differences in the samples used.

proportion of time-dependent firms is above 25 percent in all cases, and that the importance of the time- and state-dependent strategy varies between 18 percent (NL) and 55 percent (DE).

Table 2
Price-reviewing strategies - Sectoral and size breakdown

Share of firms in percentage

	Total	Sectors		Size*	
		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

* Small and large firms are firms with up to 250 employees and more than 250 employees, respectively.

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 frequency of price changes and the speed of price reaction to shocks. Table 3 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 emerge as adjusting 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 per quarter, while 8 percent do it at least once a month. On the other hand, only 8 percent of firms following time-dependent rules change their prices at least once

per 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. The analysis based on visual inspection of Table 3 is corroborated by a formal non-parametric χ^2 homogeneity test, which rejects the null hypothesis of equal frequency of price changes across the three types of firms.¹²

Table 3
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
2 - Once per quarter	5	9	9
3 - Twice a year	16	14	17
4 - Once a year	61	57	40
5 - Less than once a year	16	15	26

Table 4 reports the lags or price reaction to significant positive cost and demand shocks.¹³ Simple visual inspection of the table suggests that the speed of price adjustment to shocks varies according to the type of price-reviewing strategy. 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

¹²The outcome of the test is $\chi^2(8)=42.4$, so that the null hypothesis is rejected at 1 percent level.

¹³This information was explored by Dias et al. (2010) to investigate the firms' characteristics that explain why some firms react to shocks faster than others.

in between that of time- and state-dependent firms. Once again, the analysis based on visual inspection is corroborated by formal non-parametric χ^2 homogeneity tests, which clearly reject the null hypothesis of identical adjustment lags across the three types of firms.¹⁴

Table 4
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
<i>Positive cost shocks:</i>			
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
<i>Positive demand shocks:</i>			
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

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

¹⁴For the positive cost and demand shocks the results of the tests are $\chi^2(10) = 34.26$ and $\chi^2(10) = 32.65$, respectively, so that the null hypothesis is rejected at 1 percent level for the two tests. 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.

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. For instance, if the choice of price-reviewing strategy varies with firm size (as suggested by Table 2), then, it may be expected that the effects of monetary policy will be different in countries with different firm size distribution as the masses of time- and state-dependent firms will also be different. But not only structural characteristics of an economy may influence monetary policy. The type of monetary policy may also have an impact on the effects of monetary policy: monetary policy rules aimed at stabilising the economy, to the extent that they alter the proportion of firms in each category, will change the frequency of price changes and consequently the speed of price reaction to monetary policy shocks.¹⁵

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, $y_{i,j}$, $j=1, 2, 3$ indicates one of the three response categories: time-, time- and state- , or state-dependent price-reviewing strategy.¹⁶

The choice of the set of regressors used in the empirical model was guided by the literature on price-reviewing strategies, summarised in section 2. As discussed there, the relevant factors determining the type of pricing policy may be divided into four

¹⁵For instance, by reducing inflation uncertainty it is likely that monetary policy will reduce the variability of firms' optimal price, which, according to the discussion in section 2, is likely to increase the probability of firms following time- or time- and state-dependent rules.

¹⁶For a derivation of this model, see Train (2009).

categories: menu costs, information costs, variability of the optimal price and the sensitivity of profits to sub-optimal prices. As direct quantitative data is not available, we use proxies as the regressors for each one of the four categories. The different regressors are described in the Appendix together with some summary statistics.

Table 5 presents 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 the multinomial probit model.¹⁷

Menu costs

According to the theoretical models surveyed above, we may expect high menu costs to increase the likelihood of a state-dependent component in a firm's price-reviewing strategy. 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 covariate we use. In our model, the regressor "importance of menu costs" is a dummy variable that equals one if the firm considers that those costs are important or very important to explain the existence of price rigidity, and is zero otherwise. But, it might be the case that two firms, with a very different degree of price stickiness attach the same degree of importance to menu costs. In this case, our measure of menu costs would be unable to discriminate among firms with different price-reviewing strategies. Of course, it may also be the case that menu costs, if they are very small when compared to information costs, do not in fact play an important role for the decision on the type of price-reviewing strategy (see Ball and Mankiw (1994), Zbaracki et al. (2004) and Woodford (2003, 2009)).

¹⁷Figures 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.

Information costs

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 labelled "price discrimination" and "size".

According to the theoretical literature reviewed in section 2, we may expect high information costs to increase the likelihood of time- or time- and state-dependent price-reviewing strategies, as opposed to state-dependent rules. 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 discriminates prices must be able to process all the necessary information very cheaply at the time of charging a different price. In that sense, firms that price discriminate may be expected 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, as opposed to state-dependent ones.

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, for a firm for which information costs are important or very important, the probability of following a state-dependent price-reviewing strategy is 6.9 percentage points (pp) lower than the probability for an otherwise identical firm. This result is in line with what is predicted by theory, but it lacks some statistical strength.

Table 5-Multinomial Probit
Average marginal effects

Regressors	Time- Dependent	Time- and State-Dependent	State- Dependent
<i>Menu costs:</i>			
Importance of menu costs	0.0165 (0.0344)	-0.0176 (0.0335)	0.0011 (0.0362)
<i>Information costs:</i>			
Importance of information costs	0.0165 (0.0352)	0.0526 (0.0338)	-0.0691* (0.0367)
Price discrimination	-0.0889*** (0.0313)	-0.0540* (0.0297)	0.1429*** (0.0339)
Size	0.0972** (0.0407)	0.1243*** (0.0394)	-0.2215*** (0.0374)
<i>Variability of the optimal price:</i>			
Changes in prices of raw materials	-0.1769*** (0.0675)	0.0512 (0.0539)	0.1257** (0.0611)
Changes in wages	0.0883** (0.0395)	-0.0065 (0.0389)	-0.0818* (0.0446)
Changes in demand	-0.0047 (0.0387)	0.0287 (0.0380)	-0.0239 (0.0420)
Explicit contracts	0.0446 (0.0331)	0.0794** (0.0318)	-0.1240*** (0.0336)
<i>Efficiency loss:</i>			
Number of competitors	-0.0722** (0.0365)	0.0086 (0.0333)	0.0637* (0.0372)
Price competitiveness	-0.0536* (0.0318)	-0.0586* (0.0302)	0.1121*** (0.0323)
Changes in competitors' prices	-0.1398*** (0.0396)	0.0864*** (0.0336)	0.0534 (0.0395)
Intermediate goods	-0.0895*** (0.0321)	-0.0237 (0.0310)	0.1132*** (0.0351)
Services	0.1247** (0.0548)	-0.0031 (0.0485)	-0.1216** (0.0520)

Number of observations: 906

Log pseudo-likelihood: -894.88897

Wald $\chi^2(26)=148.80$ (P=0.000); MacFadden's Pseudo $R^2=0.0791$.

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

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, for a firm that discriminates prices among their customers, the probability of following a state-dependent rule is 14.3 pp higher than the corresponding probability for a firm that does not.

With respect to "size", the last variable in this group, 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, the probability of a large firm following a state-dependent price-reviewing rule is 22.2 pp lower than the probability for a comparable small firm. This result is also in line with the preliminary findings in section 3.¹⁸

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" and "explicit contracts".

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 where the prices of raw materials are considered important or very important for price changes are more likely to follow a state-dependent price-reviewing strategy. In particular, the probability of such firms following a time-dependent price-reviewing strategy is 17.7 pp lower, than the probability for 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

¹⁸The variable "size" may also be seen as a measure of the firm's market power. In that sense, it could equally be considered in the group of variables aimed a measuring the "efficiency loss". Larger firms, *ceteris paribus*, have a higher degree of price setting power (through a higher market share) and thus, face a less elastic demand, which makes profits less sensitive to non-optimal pricing, increasing the likelihood of a time-dependent component in the firm's price-reviewing strategy.

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. 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- and state-dependent rules. This accords with the idea that contracts are in fact also used to reduce the variability of the optimal price.

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: "number of competitors", "price competitiveness", "changes in competitor's prices", "intermediate goods" and "services".

The number of competitors, which is used to measure the degree of competition faced by firms, 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 sector is, the more sensitive profits are to sub-optimal prices (Gopinath and Itskhoki (2010)). Thus, *ceteris paribus*, 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, for a firm operating in a competitive environment, the probability of following a time-dependent price-reviewing rule is 7.2 pp lower than the probability for 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 are that firms which compete in price (as opposed to other dimensions of competition) are more likely to follow state-dependent price-reviewing strategies. According to Table 5, the probability for such a firm of following a state-dependent rule is 11.2 pp higher than for an otherwise identical firm. This is the expected result, as the profits of firms that compete in price are more sensitive to deviations from optimal price.

As regards the regressor "changes in competitors' prices", we notice that a firm for which such changes are important or very important for pricing decisions is less likely to follow a time-dependent rule and more likely to follow a time- and state-dependent rule, but the likelihood of following a state-dependent rule 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.

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 12.5 pp. The type of price-reviewing strategy also varies according to the 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 the time- and state-dependent strategy is closer to the time-dependent than to the state-dependent strategy, in the sense that changes in regressors that bring about significant changes in the likelihood of one of the two strategies usually also bring about changes of the same sign in the likelihood of the other (even though in some cases not statistically different from zero). However, the results also show that time- and time- and state-dependent behaviour are to be seen as two distinct choices. Indeed, for many regressors, the magnitude of the impact on the likelihood of the two categories differs from each other and, moreover, the probability of a firm choosing between the two strategies sometimes goes in the opposite direction as, for instance, in the case of a firm for which changes in competitors' prices are important or very important for pricing decisions.

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-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 speed of price reaction 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 the time- and state-dependent price-reviewing strategy is closer to the time-dependent, than to the state-dependent strategy. 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 stabilising the economy (by reducing inflation uncertainty) 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. A simple implication of these results is that DSGE models designed for the conduction of monetary policy 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:

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

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

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.

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

Number of competitors – 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 the 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 covariates defined above. 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
Importance of 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
Explicit contracts	33.0	31.0	51.7	30.8	42.4
Number of competitors	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
Services	9.8	-	-	8.8	14.1

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