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Price and Wage Rigidities
Microeconomic Evidence

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Our lives begin to end the day we become silent about things that matter
Martin Luther King, Jr. (1929-1968)

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Chapter 1

Introduction

1.1 What I learned from my research

At least since the publication of Keynes's General Theory in 1936, a recurrent topic in macroeconomics has been whether the adjustment of prices and wages is sufficiently fast to allow an efficient allocation of resources. Nominal rigidities are regarded as the cornerstone of New Keynesian models which are widely used for macroeconomic analysis. In recent years, a substantial amount of theoretical research devoted to improving the microeconomic foundations of macroeconomic behaviour has shown that the nature of nominal rigidities plays a central role in determining the effects of different shocks on the economy. This research has made clear that a thorough understanding of the extent and causes of the sluggish adjustment of nominal wages and prices is crucial *inter alia* to the design and conduct of economic policies and of monetary policy in particular.

The objective of this dissertation was to deepen the understanding about the sources and implications of nominal price and wage rigidities in Portugal. It comprises four essays based on microeconomic evidence. The first two investigate firm-level price rigidities by using survey data; the third also on the basis of survey data but from a different source examines the implications for employment of base-wage rigidity in a context where several labour-cost adjustment margins are available; and finally the fourth explores a rich matched employer-employee dataset to estimate the impact on hirings and separations stemming from increases in the bargained wage floors. These four essays that are pre-

sented in chapters 2 to 5. They were written in such a way that allows each of them to be read autonomously. In this context, there will be some unavoidable overlapping between some chapters in particular regarding the background sections (description of the database, wage institutional setting,)

I can synthesize the main findings from these four essays in eight main stylised results.

Result 1

The lags of price reaction to shocks adjustments, a direct measure of price rigidity, varies with the market, product, and firm characteristics, such as the cost structure of the firm, the type of pricing policy, the competitive environment, the different factors of competitiveness, or the type of good. In particular, firms which discriminate prices, do quantity discounts or operate in more competitive environments react faster to shocks than otherwise similar firms. These findings can be seen as supporting of the predictions of models of optimal price setting like the ones suggested in Barro (1972), Caballero (1989) orAlvarez et al. (2011).

Result 2

The evidence collected supports the existence of asymmetries in the speed with which firms adjust their prices in response to positive and negative demand or costs shocks. Firms seem to react faster to positive than to negative cost shocks, and more quickly to negative than to positive demand shocks. However, there is a significant degree of heterogeneity in the asymmetry of firm's responses to shocks which seems to have gone unnoticed so far. Moreover, the direction and magnitude of these asymmetries depend on the characteristics of the firms and of the market in which they operate. For example, firms operating in more competitive markets respond to different shocks more symmetrically.

Result 3

Portuguese firms are strongly heterogeneous as regards their price-reviewing strategies. The results show that 32 percent of the firms follow time-dependent, 43 percent follow state-dependent and the remaining 25 percent follow 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.

Result 4

Those factors that affect the choice of firms' price-reviewing strategies are also the factors that explain why some firms change prices more frequently than others or why firms react to shocks with different lags. Given that the frequency of price changes and the speed of price reaction to shocks of time-dependent firms are significantly lower, the factors that increase the probability of a firm following a time-dependent price-reviewing strategy are also the factors that reduce the frequency of price changes and decrease the speed of price reaction to shocks. In contrast, the factors that increase the probability of a firm following a state-dependent price-reviewing rule also increase the frequency of price changes or the speed of price reaction to shocks.

Result 5

Reducing the number of employees is the most common strategy pursued by the Portuguese firms to reduce their labour costs in the face of adverse shocks. Other important strategies are the reduction or elimination of bonus payments and other monetary benefits, the reduction or elimination of non-monetary benefits and the slowdown or freezing of the rate at which promotions are filled. There is heterogeneity in the use of each of these strategies across firms. It depends on several workers' and/or firms' attributes such as the tenure and skills distribution, measures of the unions' bargaining power, as well as some indicators of the economic environment in which firms operate.

Result 6

Given that the Portuguese labour legislation strictly forbids cuts in base wages, in a context of a common shock those firms that are able to freeze their base wages (i.e. those that exhibit the highest degree of base wage flexibility) tend to use the strategy "reduce employees" less frequently. The strong positive impact of base-wage flexibility on employment is significantly strengthened by the possibility of firms resorting to alternative margins of labour cost adjustment, like more flexible compensation components (bonuses, benefits and promotions) and the recruitment of new employees at wages lower than those received by the employees that have left the firm.

Result 7

Every year in Portugal collective agreements update the wage floors of around 30,000 job titles. Given the widespread use of extension mechanisms, the coverage of these "minimum wages" is close to 90 percent of all dependent workers in the private sector. The evidence shows firms which are more strongly affected by the change in the bargained wage floors increase their separation rates and, more importantly, significantly decrease their hiring rates, leading to fairly sizeable higher job destruction rates. If we restrict the analysis to the newly-hired workers, we also observe that the role of external wages is more intense among (lower) worker accessions.

Result 8

Externally driven wage increases have also a sizeable effect on the probability of firm closure. In particular, the results indicate a quasi-elasticity of labour demand through firm closure of 0.67, meaning that a 1 percent increase in the wage bill generated by the increase in the bargained wage floor increases the probability of firm closure by 0.67 percentage points. This appears to be a fairly sizeable effect, since the average failure rate in the sample used is around 11 percent.

In the next section, I will make a short summary of each of the four essays.

1.2 Summary of the studies

This section summarises the main findings of each of the four essays to be presented in chapters 2 to 5.

1.2.1 Understanding price stickiness: firm-data evidence on price adjustment lags[1]

This work investigates firm-level price rigidities by using survey data to look into the length of lags of price adjustments in reaction to positive and negative demand and cost shocks. Price adjustment lags are a direct measure of price rigidity and therefore may be

[1]Published in the Oxford Bulletin of Economics and Statistics, Volume 77, Issue 5, pages 701-718, October 2015.

seen as a better measure of price stickiness than the commonly used frequency of price changes, which is expected to also depend on the frequency and magnitude of the shocks to the optimal price.

The evidence shows that the lags of price adjustments vary with the market, product, and firm characteristics, such as the cost structure of the firm, the type of pricing policy, the competitive environment, the different factors of competitiveness, or the type of good. In particular, firms which discriminate prices, do quantity discounts or operate in more competitive environments react faster to shocks than otherwise similar firms. These findings can be seen as supporting of the predictions of models of optimal price setting like the ones suggested in Barro (1972), Caballero (1989) or Alvarez et al. (2011).

The results are support the existence of asymmetries in the speed with which firms adjust their prices in response to positive and negative demand or costs shocks. In line with similar evidence reported in the empirical literature, most firms in the sample seem to react faster to positive than to negative cost shocks, and more quickly to negative than to positive demand shocks. However, there is a significant degree of heterogeneity in the asymmetry of firm's responses to shocks which seems to have gone unnoticed so far. Moreover, the direction and magnitude of these asymmetries depend on the characteristics of the firms and of the market in which they operate. For example, firms operating in more competitive markets respond to different shocks more symmetrically.

Some results on asymmetric price responses are individually consistent with some of the theoretical models suggested in the literature, but, overall, the results can only be explained by a combination of the models purporting to explain asymmetric behaviour in response to different shocks. This fact illustrates the complexity of the problem and suggests that further research will be needed to better understand the conditions under which different kinds of asymmetries will be observed.

The findings presented in this work have important implications for macroeconomic models. Based on the evidence presented it is proposed that monetary models should try to accommodate the fact that the degree of price stickiness varies across firms and that firms react differently to different types of shocks. The findings suggest that models of optimal price setting which take into account various characteristics of the firm and of the markets where this firm operates are a good way to model these heterogeneities in a

micro-founded way.

The existence of asymmetries in the speed of price responses to shocks may also have important implications for monetary policy. Indeed, the existence of firm-level asymmetric price rigidity has the implication that the relationship between inflation and aggregate demand (Phillips curve) might be non-linear, calling for asymmetric monetary policy rules. However, in contrast to most of the theoretical literature which tends to favour the idea that prices are stickier downwards than upwards in response to demand shocks, the evidence obtained suggests that the type of asymmetry prevailing at the aggregate level depends on the relative importance of different types of firms in the economy and on the type of shock. Therefore, whether the relation between inflation and aggregate demand is linear, convex or concave is still an open issue and thus more empirical evidence is required before definite conclusions can be drawn on this matter.

1.2.2 Choosing between time and state dependence price-reviewing strategies[2]

This work 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 follow state-dependent and the remaining 25 percent follow 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.

The results from a multinomial probit model show 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, factors which increase the costs of information required

[2]Published in The Scandinavian Journal of Economics, Volume 115, Issue 3, pages 756–780, July 2013.

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, i.e., the costs of changing prices such as the cost of printing and distributing new price lists, do not emerge as playing a significant role. However, more and better data is required before definite conclusions may be drawn on the importance of this factor for the choice of the price-reviewing strategies by Portuguese firms.

The factors that affect the choice of firms' price-reviewing strategies may also be seen as the factors that explain why some firms change prices more frequently than others or why firms react to shocks with different lags. Given that the frequency of price changes and the speed of price reaction to shocks of time-dependent firms are significantly lower, the factors listed above that increase the probability of a firm following a time-dependent price-reviewing strategy are also the factors that reduce the frequency of price changes and decrease the speed of price reaction to shocks. In contrast, the factors that increase the probability of a firm following a state-dependent price-reviewing rule also increase the frequency of price changes or the speed of price reaction to shocks.

The fact that the frequency of price changes and the speed of price reaction to shocks depend on whether firms follow time-dependent, time- and state-dependent, or state-dependent price-reviewing strategies may be expected to have important consequences for monetary policy, as it implies that monetary policy effects will depend on the distribution of firms in terms of their price-reviewing strategies. In particular, anything that changes this distribution is likely to affect the speed of price reaction to monetary policy shocks. For instance, if, in line with what was found for Portugal, the choice of a price-reviewing strategy varies with firm size in other countries, then it may be expected that the effects of monetary policy will be different in countries with different firm-size distributions as the masses of time- and state-dependent firms will also be different. Similarly, because firms in the services sector are more prone to follow time-dependent price-reviewing rules, changes in the structure of the economy that affect its composition (manufacturing versus services)

will have the implication of changing the effects of monetary policy. This idea that firms rationally choose their price-reviewing strategy may help to understand the cross-sectional variation of monetary shocks (different countries/states are affected differently by the same type of monetary shock) and, at the same time, may also explain why the same monetary shock may affect the same country differently in different periods of its development path.

But not only structural characteristics of an economy may influence monetary policy. The fact that the proportion of time- and state-dependent firms depends on the state of the economy implies that different monetary policy regimes may affect 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 price-reviewing category, will be likely to modify the frequency of price changes and thus the speed of price reaction to monetary policy shocks. For instance, by reducing inflation and/or demand uncertainty, monetary policy will reduce the variability of firms' optimal price which, according to the evidence presented, is likely to increase the probability of firms following time-dependent or time- and state-dependent rules as opposed to state-dependent rules. This, *ceteris paribus*, may be expected to reduce the frequency of price reviews (and of price changes) or the speed of price reaction to shocks and thus to increase the real effects of monetary policy.

1.2.3 Wage rigidity and employment adjustment at the firm level[3]

Most of the studies aimed at assessing the extent and the effects of nominal wage rigidities have focused mainly on base wages or permanent wages (base wages plus the other components that are paid regularly on a monthly basis, such as meals allowances, tenure-related components, etc.), leaving aside potentially more flexible pay-components such as performance related bonuses and other monetary and non-monetary benefits which may strongly attenuate the negative impact on employment of base-wage rigidities.

Using survey data, this work investigates the implications for employment of base-wage rigidities together with other strategies that Portuguese firms have used to cut

[3]Published in Labour Economics, Elsevier, vol. 23(C), pages 40-49, August 2013.

labour costs in the event of exogenous negative labour demand or supply shocks.

The sample results show that, among the firms that have reduced labour-costs, the reduction in the number of employees ("reduce employees") was by far the most commonly used strategy (around 72 percent of the firms) followed by the strategy "flexible margins", which includes the reduction or elimination of bonus payments and other monetary benefits, the reduction or elimination of non-monetary benefits and the slowdown or freezing of the rate at which promotions are filled (around 45 percent of the firms). The recruitment of new employees with a wage lower than the one of those who left the firm ("cheaper hires") was used by around 30 percent of the firms and around 26 percent of the firms have resorted to "base-wage freezes".

The evidence also shows that there is a significant heterogeneity in the use of each of these strategies across firms. The use of each margin depends on several workers' and/or firms' attributes such as the tenure and skills distribution, measures of the unions' bargaining power, as well as some indicators of the economic environment in which firms operate. In particular, firms operating mainly in the foreign market, a more competitive environment, tend to use some of these strategies more heavily.

The econometric results suggest that the strategy "cheaper hires" is used as a substitute for "base-wage freezes" by Portuguese firms, i.e., it is predominantly used in situations in which firms do not freeze base wages after a negative labour demand shock or to compensate abnormal or unexpected base-wage increases after a negative labour supply shock. In contrast, the relationship between the strategies "flexible margins" and "base-wage freezes" is positive (even though not significantly so) which suggests that the "flexible margins" are predominantly used as a complement to "base-wage freezes" in reaction to negative labour demand shocks.

The results uncovered a clear negative association between the margin "base-wage freezes", which is taken as a measure of base-wage flexibility, and the strategy "reduce employees". In particular, the probability of a firm reducing employment is around 21 percentage points lower for a firm that has frozen base wages than for an otherwise identical firm. The ability to use the "flexible margins" or "cheaper hires" also decreases the probability of a firm reducing employment (between 6 and 7 percentage points). Together, the probability for a firm of reducing employment if it uses the strategies "base-

wage freezes", "flexible margins" and "cheaper hires" is around 35 percentage points lower than for an otherwise identical firm.

Overall, the main conclusion of this study is that base-wage flexibility has a strong positive impact on employment, and that such positive impact has been significantly strengthened by the possibility of firms resorting to alternative margins of labour cost adjustment, like more flexible compensation components (bonuses, benefits and promotions) and the recruitment of new employees at wages lower than those received by the employees that have left the firm.

1.2.4 Upward nominal wage rigidity

Every year in Portugal collective agreements update the wage floors of around 30,000 job titles. Given the widespread use of extension mechanisms ("*portarias de extensão*"), the coverage of those "minimum wages" is close to 90 percent of all dependent workers in the private sector. This occurs despite the fact that the union density rates are very low (around 10 percent according to Portugal and Vilares (2013)).

This means that in the Portuguese labor market firms confront not only severe downward nominal wage rigidity because nominal wage cuts are forbidden (Dickens et al. (2007)), but also what is tentatively call "upward nominal wage rigidity". This phenomenon is similar in nature to the frictions generated by nationwide mandatory minimum wages, in the sense that many firms are forced to increase their wages to comply with the updated wage agreements.

In this work it is explored an unusually rich matched employer-employee data set, one that provides for each worker the identification of the collective agreement (and the corresponding job title) binding the formation of base wages. In this setup it is estimated for each firm the wage bill growth that is implied by the signature of a new contract. The evidence shows that the firms that are more strongly affected by the change in the bargained wage floors increase their separation rates and, more importantly, significantly decrease their hiring rates, leading to fairly sizeable higher job destruction rates. Furthermore, higher wage impacts are also associated with greater failure rates of firms.

When the focus is on the stock of employed workers, we observe that the impact of externally driven wage increases is being largely concentrated on (higher) worker separations, but when we look at the determinants of the wages of new hires, what we see is that the role of external wages is more intense among (lower) worker accessions.

The set of empirical results collected in the current essay call into question the functionality of the architecture of the Portuguese wage setting system. In particular, it raises very serious concerns with respect to the widespread use of extension mechanisms. Also, the limited role played by the workers councils in the Portuguese legal framework seriously dampens any moves toward a decentralized (firm based) system of wage negotiations. Furthermore, given the low representativeness of the unions and of the employer associations, it may well be possible that higher wage firms and higher wage workers engage in a strategic behavior, seeking to avoid the competition of lower wage firms and lower wage workers.

Chapter 2

Understanding price stickiness: firm-data evidence on price adjustment lags[4]

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2.1 Introduction

Most of the literature aimed at identifying the reasons of price stickiness has focused on the frequency of price changes.[5] However, an important issue that arises when using observed price changes to measure price rigidity at the micro-level is that the differences in the frequency of price changes across products are not expected to strictly correspond

[4]Published in the Oxford Bulletin of Economics and Statistics, Volume 77, Issue 5, pages 701-718, October 2015.

[5]See among others, Bils and Klenow (2004), Alvarez and Hernando (2005), Dhyne et al. (2006), Munnik and Xu (2007), Klenow and Kryvtsov (2008), Nakamura and Steinsson (2008), Druant et al. (2012), Gopinath and Itskhoki (2010), andVermeulen et al. (2012).

to differences in firm specific characteristics, like the costs of adjusting prices or the sensitivity of profits to sub-optimal prices. Rather, the frequency of price changes is likely to also depend, in a significant way, on the frequency and magnitude of the shocks that hit the firms in the period under consideration. This suggests that the frequency of price changes might not be the best variable to be used in empirical studies aimed at identifying the reasons of price rigidity. As Blinder (1991, p. 94) puts it: "From the point of view of macroeconomic theory, frequency of price change may not be the right question to ask, for it depends as much on the frequency of shocks as on the firms' pricing strategies. We are more interested to know how long price adjustments lag behind shocks to demand and cost."

Therefore, rather than looking into the reasons for infrequent price changes, in this work we directly investigate the deeper and more meaningful question of the determinants of the speed of price adjustments to demand and cost shocks. In particular, we use survey data on price adjustment lags reported by Portuguese firms to investigate how fast they adjust their prices in response to changes in market conditions.

The contributions of this work are twofold. First, we identify firm-, product- and market-level characteristics that are important to explain why some firms react faster than others to demand or cost shocks. As a guide to our empirical exercise we follow the theoretical literature on optimal price setting rules (e.g., Barro (1972), Caballero (1989) and Alvarez et al. (2011)), which relates the degree of price stickiness to the sensitivity of firm's profits to sub-optimal prices, to the volatility of the optimal price, and to the costs of reviewing and adjusting prices (information and menu costs).

Second, exploring the fact that our data set contains information on firms reactions to different types of shocks (cost vs demand or negative vs positive), we investigate whether firms react asymmetrically to shocks, i.e., if there are significant differences in the speed of price reaction to positive and negative demand or cost shocks, and evaluate which theoretical models suggested in the literature are able to account for such asymmetries. This is a very important issue because the existence of firm-level asymmetric price rigidity may have important implications for the conduct of monetary policy. Based on the argument that wages are flexible upwards but rigid downwards, the literature on this matter seems to favour the idea that prices are stickier downwards than upwards. If this

is the case, output will be more sensitive to negative than to positive monetary policy shocks (see, for instance, Ball and Mankiw (1994*a*) and Ravn and Sola (2004)). Moreover, the relationship between inflation and aggregate demand (Phillips curve) must be non-linear, calling for asymmetric monetary policy rules. In particular, negative monetary policy shocks (interest rate increases) must be larger when inflation is above target than positive shocks (interest rate cuts) when inflation is below target (see, for instance, Laxton et al. (1994), Laxton et al. (1999), Juan et al. (2004), Dolado et al. (2005),Dobrynskaya (2008)). However, if prices react faster to negative than to positive demand shocks, things may be expected to work the other way around. The conclusions in Buckle and Carlson (2000), as well as in Fabiani et al. (2006) favour this alternative assumption.

Other works have studied the speed of price reactions to demand and costs shocks; see, e.g., Kwapil et al. (2010) for Austria, Loupias and Ricart (2004) for France, Alvarez and Hernando (2005) for Spain, Fabiani et al. (2004) for Italy, and Small and Yates (1999) for the United Kingdom. However, a major distinguishing feature of our approach is that we use much more detailed information on the speed of price adjustments, and consequently we are able to identify more precisely the effect of the covariates in our model. Specifically, we explore the available information on price adjustment lags using a six-category random effects ordered probit model to study the link between price adjustment lags and various firm characteristics.

There are also other dimensions in which our dataset set is richer than those previously used to investigate price-stickiness. In particular, we have detailed data on an extensive list of characteristics of more than 900 firms and on the reaction time of each firm to four types of shock. In total, therefore, we can use more than 3600 observations on a varied set of firms.

A potential disadvantage of the type of data we use is that it does not distinguish between aggregate and idiosyncratic shocks. Indeed, the economic literature has stressed that the reaction of firms to shocks may depend on whether these are aggregate or idiosyncratic (Lucas Jr (1973)), and recently Mackowiak and Wiederholt (2009) developed a model in which prices react quickly to idiosyncratic shocks, but only slowly to aggregate shocks (see also Dhyne et al. (2011)). The fact that our data has no information on

whether the firm sees the shock as aggregate or idiosyncratic is an important limitation.[6] In any case, we do not expect this fact to seriously limit the interpretation of our results because, since we have four observations for each firm, our panel data model will to some extent account for the heterogeneity resulting from firms interpreting the nature of the shock in different ways.

We find that adjustment lags to cost and demand shocks (either positive or negative), vary significantly with some firm characteristics such as the cost structure, type of pricing policy, and the type of good. In particular, we conclude that firms for which intermediate inputs represent a relatively high share of total costs, discriminate prices or do quantity discounts on a regular basis, or face more elastic demand curves (i.e., operate in a competitive environment or consider price an important factor of competitiveness), react faster to demand or cost shocks than otherwise identical firms. Overall, these results are consistent with the optimal price setting models put forward in the literature.

The evidence also suggests that firms react differently to demand and cost shocks, as well as to positive and negative shocks. In line with similar evidence reported in the literature, most firms in our sample seem to react faster to positive than to negative cost shocks, and more quickly to negative than to positive demand shocks. However, the more detailed analysis carried out in this work uncovered a significant degree of heterogeneity in firm's responses to shocks. Indeed, in our dataset, some firms react symmetrically but others react asymmetrically to positive and negative demand or cost shocks. Importantly, the direction and magnitude of this asymmetries vary with the characteristics of the firms and of the market in which they operate. In particular, price adjustment lags are more symmetric when firms operate in more competitive environments or have less price setting power.

Some results on asymmetric behaviour are individually consistent with some of the theoretical models suggested in the literature, but none of these models seems to be able to explain the full set of empirical results found in the chapter. This suggests that the issue of asymmetric responses by firms to the different types of shocks is a complex

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

phenomenon requiring further theoretical as well as empirical investigation before definite implications for monetary policy can be drawn.

The rest of the chapter is organised as follows. Section 2.2 presents the theoretical background which underlies the estimated model and the analysis of asymmetry in the lags of adjustment. Section 2.3 describes the novel dataset used in the chapter and presents the results of a preliminary data analysis. Section 2.4 presents the econometric model and Section 2.5 presents and discusses the estimation results. Section 2.6 contains some concluding remarks and, finally, the Appendix provides information on how the different variables were constructed.

2.2 Theoretical background

Models of optimal price setting and the factors behind price rigidity

Firms do not continuously adjust their prices in response to shocks. To model this fact, the literature has focused on two costs: the "information cost", the cost of reviewing the price, and the "menu cost", the cost of actually changing the nominal price.

Formal models with menu costs date back at least to Barro (1972).[7]By assuming that firms face menu costs for changing their prices, Barro is able to show that it is optimal for a firm to change prices only infrequently by following a state-dependent price setting strategy: due to the existence of fixed costs of changing prices, firms change their prices only when the difference between the actual and the optimal price is sufficiently large.

One alternative to assuming menu costs is to assume that when firms review their price they incur in an information cost. In this case, Caballero (1989) showed that the optimal rule for the firm is to review the price at fixed time intervals. Because there are

[7]There is now an extensive theoretical literature aiming at explaining why prices at the micro level may remain unchanged for large periods of time. Here, we focus mainly on the contributions by Barro (1972), Caballero (1989) and Alvarez et al. (2011), as these deliver closed- or almost closed-form solutions for the average optimal time between consecutive price changes or consecutive price reviews. Other relevant contributions in this field include, for instance, Dixit (1991), Bonomo and Carvalho (2004), Reis (2006), Woodford (2009), Gopinath and Itskhoki (2010) and Bonomo et al. (2010).

no costs to adjust prices, every time a firm reviews the price it also changes it. These are known as time-dependent price setting rules.

More recently, Alvarez et al. (2011) studied the case where a firm faces simultaneously menu and information costs. In this case, like in the previous two, the optimal rule is also to only change the price infrequently, but the optimal price setting rule is both time-dependent and state-dependent. It is state-dependent in the sense that, after reviewing the price, the firm also chooses when is optimal to review the price again and that interval depends on the state of the economy. It is time-dependent because the firm will not review its prices until the date set for doing so.

In order to derive the relevant implications for our work stemming from this literature, we focus on the model of Alvarez et al. (2011) which assumes that: *i*) the 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 (log) price, $p(t)$, from the optimal (log) price, $p^*(t)$; *ii*) the optimal (log) price follows a random walk with Gaussian innovations with variance σ^2 per unit of time; *iii)* the firm incurs in a fixed information cost, ρ, in order to determine the optimal price and on a fixed menu cost, γ, in order to change the price; and iv) the rate of inflation, or the drift of the stochastic process ruling $p^*(t)$, is 0 or approximately 0.[8] Under these hypotheses, Alvarez et al. (2011) showed that the expected time between price reviews - τ - can be approximated by

$$\tau = \sqrt{2\frac{\left(\rho + 2\gamma\left(1 - \Phi\left(\frac{\overline{p}}{\sigma\sqrt{\tau}}\right)\right)\right)}{\theta\sigma^2}}, \tag{1}$$

where $\overline{p}$ is some threshold such that the firm opts for not adjusting the price if $-\overline{p} < p(t) - p^*(t) < \overline{p}$, and $\Phi(\cdot)$ denotes the CDF of the standard normal distribution.

Because the variable of interest in (1), τ, is on both sides of the equation, and also because $\overline{p}$ depends on some of the parameters, obtaining comparative statics is not a straightforward task. However, using some of the results and assumptions in Alvarez

[8]Note that θ depends on the parameters of the demand and costs functions, and that, in particular, it 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.

et al. (2011), it is possible to show that:

- $\frac{\partial \tau}{\partial \rho} > 0$, that is, the average time between price reviews increases with the information cost;
- For small values of the menu cost γ, $\frac{\partial \tau}{\partial \gamma} > 0$. In words, when the menu costs are small, a marginal increase of these increases the average time between price reviews;
- $\frac{\partial \tau}{\partial \theta} < 0$, that is, the average time between price reviews decreases with the sensitivity of profits to the price gap;
- For small values of the variance of the optimal price, σ^2, $\frac{\partial \tau}{\partial \sigma^2} < 0$. This means that the more volatile the optimal price is the shorter is the average time between price reviews.

These results are intuitive and generalise the predictions of the conventional menu-cost model developed in Barro (1972) and of the simple information-cost model suggested in Caballero (1989).[9] If we make the additional assumption that price adjustment lags are positively correlated with the average time between price reviews, then the results above give us a set of predictions that we can test with our data. In particular, we will look into the factors that might reflect differences in the firm's information or menu costs, that might be expected to make profits more or less sensitive to sub-optimal prices, or that might affect the uncertainty surrounding the optimal price of the firm, and will test whether this set of covariates has the impact on the lag of price adjustment that is predicted by the optimal price setting theories.

2.2.1 Links between price adjustment lags and the type of shock

The models discussed in the previous sub-section do not explicitly account for the possibility that firms may react with different lags to different types of shocks. However, there

[9] In Barro (1972), the average time between price adjustment is given by $\tau = \sqrt{\frac{6\gamma}{\theta\sigma^2}}$ and it is easy to verify that $\frac{\partial \tau}{\partial \gamma} > 0$, $\frac{\partial \tau}{\partial \theta} < 0$ and $\frac{\partial \tau}{\partial \sigma^2} < 0$. In the case of Caballero (1989), the average time beween price reviews is given by $\tau = \sqrt{\frac{2\rho}{\theta\sigma^2}}$ and the resulting comparative statics are: $\frac{\partial \tau}{\partial \rho} > 0$, $\frac{\partial \tau}{\partial \theta} < 0$ and $\frac{\partial \tau}{\partial \sigma^2} < 0$.

is now a vast theoretical literature that focuses on the question of whether prices are more sticky in response to a shock that warrants a price decrease or to shocks in the opposite direction, or whether prices react more quickly to cost than to demand shocks. A brief survey of this literature tells us two things: There are many possible justifications for the existence of differences between the speed of adjustment to different types of shocks; there is no consensus about the sign and magnitudes of these differences.

Tsiddon (1993), Ball and Mankiw (1994*a*) and Ellingsen et al. (2006) noted that the coexistence of menu costs and positive trend inflation may lead firms to react differently to positive and negative shocks. Positive trend inflation implies that, in real terms, the price set by the firm falls continuously. Therefore, the firm may not need to react to a shock leading to a price decrease because the inflation will automatically adjust the price without the need for the firm to incur in the menu costs. On the contrary, if the shock warrants a price increase the firm has an additional incentive to make the adjustment because inflation will systematically increase the price gap. Our data, and consequently our empirical results, are obtained in the context of positive inflation and therefore we can directly test the prediction of these models.

Models considering the existence of search costs (e.g., Yang and Ye (2008), Tappata (2009), Lewis and Noel (2011) and Cabral and Fishman (2012)), or of inattentive consumers (e.g., Chen et al. (2008)) also predict that prices rise faster than they drop, at least in reaction to cost shocks. Search costs and inattentive consumers create rigidities on the side of consumers that firms take into consideration when they set their prices.In particular, the demand elasticities faced by firms depend on whether costs fall or rise and therefore, prices react asymmetrically to positive and negative cost shocks.

The existence of asymmetries is also predicted by models considering firms' strategic behaviour (e.g., Devereux and Siu (2007), Bhaskar (2002), Kovenock and Widdows (1998), Hansen et al. (1996) and Maskin and Tirole (1988)). However, the predictions of these models are not clear-cut. In the context of a state-dependent price setting model, with menu costs, Devereux and Siu (2007) conclude that firms have more incentive to increase prices following a positive cost shock than to lower prices following a negative cost shock. The idea is that with a positive cost shock prices are strategic complements, so that a firm has more incentive to increase its price when other firms increase theirs,

while for a negative cost shock prices are strategic substitutes, so that the firm has less incentive to lower its price when other firms lower theirs.

This result stands in stark contrast to the conventional model of oligopoly with kinked demand curves described in Maskin and Tirole (1988), which suggests that prices may be more rigid upwards than downwards. That is, firms adjust their prices to negative demand and cost shocks because downward adjustments are not costly, whereas prices may be left unchanged or adjustments delayed in the face of positive shocks because raising prices involves a loss in market share. Another reason why prices may be more rigid upwards than downwards, especially in response to demand shocks, is provided by the consideration that customer antagonization might be higher for price increases than for price decreases (Okun (1981), Rotemberg (2005) and Anderson and Simester (2010)).

Fairness and customers' anger considerations may also give rise to different responses to demand and cost shocks. Okun (1981) distinguishes between price increases due to cost shocks and those that are due to demand shocks. The author argues that higher costs are an accepted rationale for raising prices, i.e., price increases that are based on cost increases are "fair", while those based on demand increases often are viewed as unfair. Consequently, firms may hold prices constant in the face of demand shocks because they do not want to jeopardise customer relations, and this would explain why firms in some sectors adjust their prices more promptly in response to changes in costs than in response to changes in demand. In a slight abuse of terminology, we also refer to these differences as asymmetries.

Most of these results, albeit diverse and sometimes even contradictory, can be related to the price-setting models introduced in the previous subsection. In particular, the asymmetries can be interpreted as letting the values of the parameters depend on the sign and type of shocks. Moreover, the asymmetries can vary across firms because the way the parameters depend on the shocks may be a function of the characteristics of the firm and of the market in which it operates. For example, the degree of competition faced by a firm may be related to the magnitude of search costs and to the degree of inattentiveness of the consumers, implying that there should be less asymmetries when markets are more competitive because in this case search costs are smaller and consumers are more attentive. Our results in Section 2.5 will be used to shed some light on which

of these predictions are supported by the data.

2.3 The Data

2.3.1 Data sources

Most of 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, firms were asked how long they would take to react to significant cost and demand shocks. More specifically, they were asked the following four questions: 1) "After a significant increase in demand how much time on average elapses before you raise your prices?"; 2) "After a significant increase in production costs how much time on average elapses before you raise your prices?"; 3) "After a significant fall in demand, how much time on average elapses before you reduce your prices?"; and 4) "After a significant decline in production costs how much time on average elapses before you reduce your prices?". The responses to these questions, which will be the dependent variable in our model, are recorded as continuous interval data with six categories: 1 - less than one week; 2 - from one week to one month; 3 - from one month to three months; 4 - from three to six months; 5 - from six months to one year; 6 - the price remained unchanged. With the expression "significant increase" or "significant decline" the authors of the survey had in mind inducing respondents to interpret the shock as significant enough to lead firms to react to it by changing their price. Therefore, we interpret option 6 as indicating that the price will eventually change, but the adjustment lag is longer than one year.[11]

Besides the questions on price adjustments lags, the survey also contains information on a large set of firms' characteristics. These include information on the main market of the firm (internal vs. external market), main destinations of sales (wholesalers vs. retailers, private vs. public sector), number of competitors, relations with customers (long-term vs. short-term), type of product competition (price vs. quality, differentiation vs. after sales service), price discrimination (same price for all customers vs. decided

[10] For further details on this survey, see Martins (2010).

[11] As a robustness check, we also estimated models grouping categories 5 and 6 together and found that the results of the next section change very little.

on a case-by-case basis), price setting decisions (own company vs. external entity, main customers vs. main competitors), and reasons for postponing price changes (the risk that competitors do not follow, existence of implicit or written contracts, cost of changing prices, costs of collecting information, absence of significant changes in variable costs, preference for maintaining prices at psychological thresholds, etc.).

The information from the survey is supplemented with data from two other sources. From *Central de Balanços*, a comprehensive dataset maintained by Banco de Portugal in which the balance sheets and income statements of most Portuguese firms are registered, we obtain data on the number of employees, the share of sales that are made abroad, and the shares of labour, inputs, and financial costs. Finally, we obtain information about the proportion of domestic and foreign capital of the firm from *Quadros de Pessoal*, a large administrative database collected by the Portuguese Ministry of Employment and Social Security, which, among other, includes information about all the Portuguese firms with wage earners (size, ownership, location, etc.).

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

2.3.2 Preliminary data analysis

As mentioned above, the four survey questions about price adjustment lags are our variates of interest. Table 2.1 summarises the information on these variables by displaying the distribution of the observed price adjustment lags for each type of shock. These results suggest that, in general, firms in the sample are quicker to react to cost shocks, in particular when they are positive, than to demand shocks. For example, only around 10 percent of the firms keep their prices unchanged in the first year after a positive cost shock, while the fraction of firms that hold their prices unchanged in response to a positive

Table 2.1: Distribution of the price responses to demand and cost shocks

	Cost shocks		Demand shocks	
Price adjustment lag	Positive	Negative	Positive	Negative
1 - less than one week	4.7	3.5	2.8	4.8
2 - from one week to one month	16.8	15.2	12.2	16.8
3 - from 1 month to 3 months	25.0	25.7	19.3	23.4
4 - from 3 to 6 months	17.6	15.0	13.4	13.7
5 - from 6 months to one year	26.3	21.2	17.7	14.0
6 - the price remained unchanged	9.6	19.5	34.7	27.4
Total	100.0	100.0	100.0	100.0

demand shock is around 35 percent. Interestingly, firms in the sample seem to react more quickly to positive than to negative cost shocks, but to be slower to react to positive than to negative demand shocks.[12]. Formal tests for the hypotheses that the reaction time is the same both for positive and negative shocks, and for demand and cost shocks, will be performed in Section 2.5.

The results in Table 2.1 are not informative about the possible effect of the characteristics of the firms on the speed of adjustment, and may hide important heterogeneity in firms' responses to shocks. As an illustration of the importance of this heterogeneity, Table 2.2 gives the breakdown by sector and firm size of the proportion of firms that do not adjust the price in the first year after the shock. Clearly, the speed of price adjustment varies with firm sizes and across sectors.

2.4 An econometric model for price adjustment lags

The econometric model we use to gauge the impacts of the different covariates on the lags of price adjustments takes into account both the interval nature of the data and the fact

[12]Similar results concerning the relative speed of price adjustment to cost and demand shocks using survey data were obtained for Austria, Italy, France, Luxembourg, Spain and the US (see, respectively, Kwapil et al. (2010), Fabiani et al. (2004), Loupias and Ricart (2004), Lünnemann and Mathä (2006), Alvarez and Hernando (2005), Blinder et al. (1998)). Comparable results for positive and negative cost shocks are obtained in Peltzman (2000) from quantitative data for the U.S.

Table 2.2: Percentage of firms that do not change their prices in the first year after the shock

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

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

that each firm contributes to the sample with four observations. These four responses are likely to depend on common unobserved firm characteristics, suggesting the use of a panel data set-up, with random effects representing the unobserved firm characteristics. Besides providing potential efficiency gains, the inclusion of the random effects with a flexible distribution makes the model more general and therefore less sensitive to distributional assumptions.

Formally, we model the latent variable $y_{i,j}$, which represents the time firm i takes to react to a shock of type j, as a function of a set of firm characteristics and of a firm-specific random-effect. Because the preliminary data analysis suggests that the speed of price adjustment is shock specific and depends on the firms' characteristics, we estimate a model which allows for the possibility of different coefficients for each type of shock. This is almost equivalent to estimating four different models, one for each type of shock, with the difference being that in our case the four seemingly unrelated equations are linked by the unobserved heterogeneity component, which is assumed to be common to the four shocks.[13]

[13]Qualitatively, the results do not change if the model is estimated without the random effects or assuming that the random effects are independent across the four equations.

Therefore, we assume that $y_{i,j}$ is related to a set of firm characteristics by

$$y_{i,j} = \Lambda_j \left(x_i' \beta_j + \omega_j v_i + \varepsilon_{i,j} \right), \tag{2}$$

where $\Lambda_j(\cdot)$ is a strictly increasing invertible function that is specific to shocks of type j; x_i is a set of firm characteristics whose impact, measured by vectors β_j, is shock specific; v_i is a non-observed firm-effect whose impact, measured by ω_j, is shock specific; and $\varepsilon_{i,j}$ is a non-observed stochastic term that is firm and shock specific.

Equation (2) implies that $z_{i,j} = \Lambda_j^{-1}(y_{i,j})$ is related to the firm characteristics by the linear model

$$z_{i,j} = x_i' \beta_j + \omega_j v_i + \varepsilon_{i,j}.$$

In our data, $y_{i,j}$ is not fully observed and instead we observe $\widetilde{y}_{i,j}$, which is related to $z_{i,j}$ as follows. For $m = 1, 2, ..., 6$,

$$\widetilde{y}_{i,j} = m \qquad if \quad \phi_{m-1,j} < z_{i,j} < \phi_{m,j}, \tag{3}$$

where the constants $\phi_{m,j}$ are the limits of the intervals into which the domain of $z_{i,j}$ is partitioned due to the fact that $y_{i,j}$ is observed as interval data. That is, the dependent variable in our model is $\widetilde{y}_{i,j} = m$, where $m = 1, 2, .., 6$ indicates one of the six possible response categories.

At this point two approaches can be followed. Because the price lags are reported in the form of known time intervals, we could specify the form of $\Lambda_j(\cdot)$ and use this information to determine the cut-off parameters $\phi_{m,j}$. Alternatively, we can estimate the cut-off parameters, which avoids the need to specify $\Lambda_j(\cdot)$. This is the approach we follow because by not specifying $\Lambda_j(\cdot)$ the model gains an interesting degree of flexibility.[14] Specifically, for identification purposes, we set $\phi_{0,j} = -\infty$, $\phi_{1,j} = 0$, and $\phi_{6,j} = +\infty$, estimating freely the remaining four cut-off parameters.

In order to be able to estimate the parameters of the model we need to make distributional assumptions on the unobserved random components. We start by assuming that $\varepsilon_{i,j} | x_i, v_i \sim N(0,1)$, where the normalization of the variance to 1 implies no loss of

[14]The fact that we only use the ordinal information provided by the firms has the additional benefit of giving some protection against the likely presence of reporting errors.

generality. Then, based on (3), the conditional probability of observing $\widetilde{y}_{i,j} = m$ is given by

$$\begin{aligned}
\Pr\left(\widetilde{y}_{i,j} = m | x_i, v_i\right) &= \Pr\left(\phi_{m-1,j} < z_{i,j} < \phi_{m,j} | x_i, v_i\right), \\
&= \Pr\left(z_{i,j} < \phi_{m,j} | x_i, v_i\right) - \Pr\left(z_{i,j} < \phi_{m-1,j} | x_i, v_i\right), \\
&= \Phi\left\{\phi_{m,j} - \left(x_i'\beta_j + \omega_j v_i\right) | x_i, v_i\right\} - \\
&\quad \Phi\left\{\phi_{m-1,j} - \left(x_i'\beta_j + \omega_j v_i\right) | x_i, v_i\right\}, \\
&= h_j\left(\widetilde{y}_{i,j} | x_i, v_i\right),
\end{aligned}$$

where, as before, $\Phi(\cdot)$ denotes the standard normal CDF. Furthermore, assuming that the disturbances $\varepsilon_{i,j}$ are conditionally independent (given x_i and v_i) across i and j, we can write the probability that for a certain firm we observe $(\widetilde{y}_{i,1} = m_1, \widetilde{y}_{i,2} = m_2, \widetilde{y}_{i,3} = m_3, \widetilde{y}_{i,4} = m_4)$ as

$$\Pr\left(\widetilde{y}_{i,1} = m_1, \widetilde{y}_{i,2} = m_2, \widetilde{y}_{i,3} = m_3, \widetilde{y}_{i,4} = m_4 | x_i, v_i\right) = \prod_{j=1}^{4} h_j\left(\widetilde{y}_{i,j} | x_i, v_i\right).$$

Since we also do not observe v_i, we need to integrate it out of $h_j\left(\widetilde{y}_{i,j} | x_i, v_i\right)$ in order to obtain an expression of the individual contribution to the likelihood that can be used for estimation. This leads to

$$L_i(\lambda) = \int_{-\infty}^{+\infty} \prod_{j=1}^{4} h_j\left(\widetilde{y}_{i,j} | x_i, v_i\right) g(v_i)\, dv_i,$$

where λ denotes the vector of parameters of the model and $g(\cdot)$ is the density function of v_i. Following Dhaene and Silva (2012), we assume that $g(v_i)$ is such that $\sinh^{-1}(\delta v_i)/\delta$ has a standard normal distribution.[15] That is, the shape-parameter δ introduces additional flexibility in the model by allowing the distribution of the random effect component to have an unspecified degree of excess kurtosis.[16] The integration in $L_i(\lambda)$ is performed using 50-point Gauss-Hermite quadrature.

Finally, it is necessary to define the set of regressors to use. This choice was guided

[15]The use of this sort of transformation was pioneered by Burbidge et al. (1988) and MacKinnon and Magee (1990).

[16]For the empirical model presented in the next section the estimate of δ is -0.5740, indicating that the random-effects have a distribution with substantial excess kurtosis.

by the literature briefly reviewed in Section 2.2. In the absence of direct quantitative measures for some of the expected relevant factors, we have chosen as regressors sectoral, product, and firm-level characteristics that may be related to the importance of menu and information costs, the variability of the optimal price, and the sensitivity of profits to sub-optimal prices. To conserve space, the particular set of regressors that is used and the motivation to use them are presented in the next section, along with the estimation results. The Appendix gives further details on the regressors and provides some summary statistics.

2.5 Empirical results

2.5.1 What factors explain why some prices are stickier than others?

Tables 2.3 and 2.4 summarize the main estimation results. In particular, Table 2.3 presents the results of the estimated model, and Table 2.4 reports the marginal effects of the covariates on the probability that the price adjustment does not take place in the first year after the shock.[17] Specifically, the first line of Table 2.4 reports the estimated probability, for a firm in the reference group, that the price adjustment does not take place in the first year after the shock, and the remaining lines give the change to this probability from setting to 1 the corresponding regressor. These differences to the baseline group, for a generic covariate d and shock j ($j = 1, \ldots, 4$), are computed as $\Pr[\widetilde{y}_{i,j} = 6|\ \overline{x} = 0, d = 1] - \Pr[\widetilde{y}_{i,j} = 6|\ \overline{x} = 0, d = 0]$, where $\overline{x}$ denotes the fixed values of all other covariates in the model.

For ease of presentation, and following the theory surveyed in Section 2.2, we grouped

[17] It is well-known (see, e.g., Winkelmann and Boes (2006)) that in models for ordered data the signs of the partial effects of the covariates are unambiguous only for the first and last category ($\widetilde{y}_{i,j} = 1$ and $\widetilde{y}_{i,j} = 6$, in our case). For the intermediate categories, it is possible to see how a covariate changes the probability of a firm being in a given category, but that is not informative about whether that variable has a positive or negative impact on the value of the underlying latent variable. We focus on the category $\widetilde{y}_{i,j} = 6$ (i.e., price adjustment does not take place in the first year after the shock), as it is more meaningful than the category $\widetilde{y}_{i,j} = 1$ (i.e., price adjustment takes place in the first week after the shock).

the covariates in our model into the following three categories: 1) Menu and information costs, 2) Variability of the optimal price, and 3) Sensitivity of profits to sub-optimal prices.[18]

Menu and information costs

The models reviewed in Section 2.2 imply that, *ceteris paribus*, firms with higher menu and/or information costs are expected to display longer price lags in reaction to demand and cost shocks.

Given the lack of direct quantitative information on these costs, we included in the model four regressors which may be expected to have a bearing on the importance of menu and/or information costs at the firm level: information on whether the firm practices price discrimination and/or quantity discounts, information on the capital structure, and information on the size of the firm. Using size to proxy the importance of firms' menu an/or information costs may be seen as a controversial assumption because this regressor could also be used as a measure of the firms' market power and thus be included in the group of regressors that have a bearing on the sensitivity of the profits to sub-optimal prices. Moreover, there seems also to be some controversy on whether one should expect information costs to be higher in large or in small firms (see, for instance, Buckle and Carlson, 2000). Here, we follow the evidence in Zbaracki et al. (2004), which suggests that information costs are likely to be higher in larger firms.

The type of pricing policy (single price versus price discrimination and existence of quantity discounts) emerges as playing an important role in determining the speed of price adjustments. Firms that decide the price on a case-by-case basis, or do quantity discounts, tend to be faster to adjust to both cost and demand shocks. For example, from

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

Table 2.3: Panel-ordered probit estimates for the price adjustment lags

	Cost shocks		Demand shocks	
Covariates	Positive	Negative	Positive	Negative
Constant	3.455** (0.325)	4.639** (0.444)	3.327** (0.318)	3.555** (0.379)
Price discrimination	−0.395** (0.163)	−0.386* (0.198)	−0.568** (0.160)	−0.633** (0.190)
Quantity discount	−0.428** (0.152)	−0.304* (0.184)	−0.405** (0.149)	−0.440** (0.176)
Size	0.356** (0.158)	0.525** (0.193)	−0.131 (0.152)	0.174 (0.181)
Capital structure	−0.392** (0.171)	−0.448** (0.208)	−0.119 (0.165)	−0.174 (0.195)
Labour costs	0.417** (0.122)	0.394** (0.149)	0.411** (0.119)	0.508** (0.141)
Intermediate input costs	−0.253** (0.126)	−0.292* (0.153)	−0.052 (0.122)	0.036 (0.144)
Explicit contracts	0.044 (0.127)	−0.033 (0.154)	0.075 (0.123)	0.124 (0.146)
Implicit contracts	−0.142 (0.148)	−0.113 (0.180)	0.102 (0.143)	−0.195 (0.171)
Competition	−0.358** (0.136)	−0.365** (0.165)	−0.304** (0.132)	−0.409** (0.157)
Domestic market	−0.032 (0.127)	−0.071 (0.154)	0.043 (0.123)	0.223 (0.146)
Price competitiveness	−0.026 (0.113)	−0.239* (0.137)	−0.213* (0.110)	−0.409** (0.131)
Quality competitiveness	0.271** (0.130)	0.204 (0.157)	0.313** (0.125)	0.488** (0.150)
Delivery competitiveness	−0.091 (0.111)	−0.106 (0.134)	0.268** (0.108)	0.302** (0.128)
Price set by customers	0.417** (0.181)	−0.214 (0.219)	0.113 (0.174)	−0.137 (0.206)
Price set by competitors	0.315* (0.163)	−0.079 (0.197)	−0.408** (0.156)	−0.673** (0.187)
Services	1.031** (0.205)	1.108** (0.253)	0.559** (0.199)	0.949** (0.238)
Intermediate goods	−0.262** (0.124)	−0.423** (0.151)	−0.418** (0.120)	−0.419** (0.143)
$\phi_{2,j}$	1.443** (0.113)	1.793** (0.166)	1.367** (0.126)	1.586** (0.131)
$\phi_{3,j}$	2.605** (0.139)	3.263** (0.221)	2.418** (0.148)	2.873** (0.174)
$\phi_{4,j}$	3.386** (0.158)	4.064** (0.256)	2.994** (0.159)	3.578** (0.200)
$\phi_{5,j}$	4.973** (0.206)	5.302** (0.308)	3.675** (0.173)	4.304** (0.227)
ω_j	1.060** (0.087)	1.429** (0.129)	0.964** (0.081)	1.304** (0.111)
δ			−0.574** (0.094)	

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

Table 2.4: Probability estimates for the category $\widetilde{y}_{ij} = 6$

	Cost shocks		Demand shocks	
Covariates	Positive	Negative	Positive	Negative
Baseline group	0.161^{**} (0.026)	0.357^{**} (0.072)	0.405^{**} (0.044)	0.331^{**} (0.042)
Price discrimination	-0.053^{**} (0.020)	-0.075^{*} (0.039)	-0.141^{**} (0.037)	-0.119^{**} (0.032)
Quantity discount	-0.057^{**} (0.018)	-0.060 (0.037)	-0.103^{**} (0.036)	-0.086^{**} (0.032)
Size	0.062^{**} (0.036)	0.113^{**} (0.420)	-0.035 (0.040)	0.038 (0.040)
Capital structure	-0.053^{**} (0.021)	-0.086^{**} (0.041)	-0.032 (0.043)	-0.036 (0.039)
Labour costs	0.074^{**} (0.025)	0.084^{**} (0.032)	0.113^{**} (0.033)	0.113^{**} (0.032)
Intermediate input costs	-0.036^{**} (0.017)	-0.058^{*} (0.031)	-0.014 (0.032)	0.008 (0.031)
Explicit contracts	0.007 (0.020)	-0.007 (0.031)	0.020 (0.033)	0.027 (0.032)
Implicit contracts	-0.021 (0.021)	-0.023 (0.037)	0.028 (0.039)	-0.040 (0.034)
Competition	-0.049^{**} (0.017)	-0.071^{**} (0.032)	-0.079^{**} (0.328)	-0.081^{**} (0.029)
Domestic market	-0.005 (0.019)	-0.015 (0.031)	0.012 (0.033)	0.048 (0.032)
Price competitiveness	-0.004 (0.017)	-0.048^{*} (0.027)	-0.056^{**} (0.028)	-0.080^{**} (0.024)
Quality competitiveness	0.046^{*} (0.024)	0.043 (0.033)	0.086^{**} (0.035)	0.109^{**} (0.035)
Delivery competitiveness	-0.014 (0.016)	-0.022 (0.027)	0.073^{**} (0.030)	0.066^{**} (0.029)
Price set by customers	0.074^{**} (0.036)	-0.043 (0.043)	0.031 (0.047)	-0.028 (0.042)
Price set by competitors	0.054^{*} (0.031)	-0.016 (0.04)	-0.104^{**} (0.038)	-0.126^{**} (0.031)
Services	0.212^{**} (0.052)	0.241^{**} (0.053)	0.154^{**} (0.054)	0.216^{**} (0.055)
Intermediate goods	-0.037^{**} (0.016)	-0.082^{**} (0.028)	-0.107^{**} (0.029)	-0.082^{**} (0.026)

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

Table 2.4 we see that for a firm that sets its price on a case-by-case basis, the probability of adjusting its price in response to a demand shock more than one year after the shock is 12 to 14 percentage points (pp) lower than the probability for an otherwise identical firm (approximately 8 to 10 pp lower in the case of a firm that does quantity discounts). These results can be interpreted as reflecting the fact that firms with such flexible pricing practices are likely to face relatively low information, managerial, or menu costs, which also allow them to react more quickly to shocks.

We see from Table 2.4 that size matters for the speed of price adjustment. In the face of cost shocks, large firms tend to be slower at adjusting their prices than small firms. However, for the reaction to demand shocks, the size of the firm does not seem to matter.

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

Variability of the optimal price

This category includes four regressors deemed to affect directly or indirectly the variability of the firm's optimal price: two variables related to the cost structure of the firm (shares of labour and intermediate input costs), and two variables related to the relation between the firm and its customers (explicit contracts, i.e., the proportion of sales under written contracts, and implicit contracts, i.e., whether the relation with the customers is essentially of a long- or short-term nature).

If prices of different factors of production have different volatilities, it is expectable that the cost structure of a firm will matter for the speed with which it adjusts its prices. If input costs are relatively stable, such as wages which are changed on average once a year, firms can be expected to review and/or change their prices only infrequently, thus exhibiting longer price durations and larger price adjustment lags.[19] On the contrary, if input costs are highly volatile, as it is the case of some raw materials, prices are likely

[19]This is a very robust result that has been extensively documented in the literature for the frequency of price adjustments (see, among other,Altissimo et al. (2006) and the references therein). Our results show that the same result is valid for the speed with which firms react to shocks.

to be reviewed and/or changed more frequently, on average, allowing faster reaction to shocks. Thus, ceteris paribus, one may expect firms with higher labour cost shares to react more slowly to shocks than firms with higher shares of intermediate inputs. This is confirmed by our findings. From Table 2.4 we see that, for a firm with a share of labour costs above the median, the probability of taking more than one year to adjust its price after a cost shock is about 7 to 9 pp higher than the corresponding probability for an otherwise identical firm. This difference in the probabilities increases to 11 pp in the face of demand shocks.

Economic theory suggests that the existence of explicit and/or implicit contracts may be an important source of price stickiness at the firm level (see, for instance, Fischer (1977) and Okun (1981)). With explicit contracts, firms aim at building long-term relationships with their customer in order to stabilise their future sales. Customers, on the other hand, are attracted by a constant price because it makes their future costs more predictable and helps to minimize transaction costs (e.g., shopping time). In turn, the theory of implicit contracts is based on the idea that firms try to win customer loyalty by changing prices as little as possible. Overall, the presence of explicit and/or implicit contracts may be expected to reduce firm's demand variability and thus to have implications for firms' reactions to shocks. The results in Table 2.3 show, however, that the coefficients on "Explicit contracts" and "Implicit contracts" are not statistically different from zero for either of the four shocks, suggesting that these variables do not have a bearing on the length of these lags.[20]

Sensitivity of profits to sub-optimal prices

This group of variables includes the remaining regressors that appear in Tables 2.3 and 2.4, which we see as having implications for firms' price elasticity of demand and thus for the sensitivity of firms' profits to sub-optimal prices.

It is known that the more competitive a sector is, the more sensitive profits are to sub-optimal prices. Thus, for given nominal adjustment costs (due to the presence of information or menu costs), stronger competition may be expected to translate into

[20]The variables conveying information on whether explicit and/or implicit contracts are present may also be understood as providing information on the costs of changing prices, but in view of our results this question is immaterial.

quicker responses to shocks (see, for instance, Martin (1993)). Our results confirm that firms in more competitive environments tend to be faster to react to shocks. From Table 2.4 we see that, in the face of a demand shock (either positive or negative), the probability of a firm adjusting the price more than one year after the shock is reduced by around 8 pp for firms operating in more competitive markets (firms with five or more competitors).

Regarding the market destination variable, we find that the coefficients of the covariate that measures the importance of the domestic market are not statistically significant for any of the four shocks. Thus, whether the firm sells their products in the domestic market or abroad does not seem to make a difference for the speed with which firms react to shocks.

In order to investigate if the different competitiveness factors affect the speed with which firms respond to shocks, we distinguish between price, quality, and delivery period as alternative sources of competitiveness. We may think of these factors as reflecting different product characteristics which translate into different demand elasticities (higher demand elasticity for firms for which price is an important factor, and lower elasticity for firms that value more the quality of the product or the delivery period).[21] The results in Tables 2.3 and 2.4 suggest that firms that consider price as an important factor of competitiveness tend to adjust prices more quickly, while firms that value more the quality of the product or the delivery period as competitiveness factors tend to adjust their prices at a slower pace in response to shocks (specially so, in face of demand shocks).

In order to characterise firms price setting autonomy we consider two variables related to the firms' lack of autonomy in setting their own prices (as opposed to cases in which the price is set by the firm itself). We find that the "price set by customers" variable has a positive and significant impact only in the case of positive cost shocks, suggesting that for these firms customers have enough power to delay the firms' reaction when costs push prices up. Regarding the "price set by competitors" variable, our results show that firms that have their prices significantly affected by the main competitors are faster to respond to demand shocks than firms that set their own prices. The results in Table 2.4

[21] Martin (1993) showed that the speed of price adjustment increases with the elasticity of demand, that is, firms react faster to shocks when the demand schedule facing them is flatter. This same idea was used by Gopinath and Itskhoki (2010) to show the link between the frequency of price adjustment and exchange rate pass-through.

show that the probability of such a firm adjusting the price more than one year after the shock is 10 to 13 pp lower than for a firm in the reference category. This suggests that firms whose prices are set by the main competitors may be acting as market followers in a market where the presence of market leaders helps reducing, or even eliminating, potential coordination problems.

Finally, in order to characterise the type of product we use information regarding the sector where firms operate (manufacturing or services), and the destination of the product (final vs. intermediate consumption). As earlier results suggested (see Table 2.2), from Table 2.3 and 2.4 we find that firms that operate in the services sector are substantially slower to react to shocks than firms that operate in the manufacturing sector.In fact, for each of the four shocks, the covariate "Services" shows up in Table 2.4 as the one with the largest impact on the estimated probabilities, with marginal effects ranging from 15 to 24 pp. These results are consistent with previous evidence on the frequency of price changes which suggested a significantly higher degree of price stickiness in the services sector.

The speed of price adjustment also varies according to the type of market for the product. Firms that sell their products to other firms (intermediate goods) tend to be quicker to adjust their prices than firms whose products are mainly for final demand (whose main destinations are wholesalers, retailers or consumers). These results possibly reflect the fact that services and final goods are typically more differentiated than manufacturing and intermediate goods, respectively, and thus face a less elastic demand.

2.5.2 Symmetric or asymmetric price adjustment lags?

The results in Section 2.3, as well as those found in other countries, suggest that firms react more quickly to positive than to negative cost shocks, and more slowly to positive than negative demand shocks. However, formal tests of possible asymmetric reaction times were not performed in Section 2.3, and therefore it is important to investigate this issue formally. In the context of our model, testing for symmetry entails comparing not only the coefficients of the different covariates in the equations for the different shocks, but also all other parameters that are shock specific.

Table 2.5: Tests of symmetry

Symmetry within shocks		Symmetry between shocks	
Positive and negative cost shocks	Positive and negative demand shocks	Positive cost and demand shocks	Negative cost and demand shocks
$\chi^2(23) = 88.33$ ($p = 0.000$)	$\chi^2(23) = 78.29$ ($p = 0.000$)	$\chi^2(23) = 300.0$ ($p = 0.000$)	$\chi^2(23) = 95.88$ ($p = 0.000$)

$\chi^2(23)$ stands for the Wald test statistic with 23 degrees of freedom and p for the corresponding p-value.

Table 2.5 presents the results of the two tests for symmetry within shocks – positive and negative cost shocks, and positive and negative demand shocks. In both cases the null of symmetry is rejected at all usual significance levels, suggesting that firms react differently to negative and positive shocks. Table 2.5 also reports the results of two tests for symmetry between shocks – positive shocks to costs and demand, and negative shocks to costs and demand. Again, the null of symmetry is rejected at the usual significance levels, suggesting that firms adjust differently to positive cost and demand shocks, as well as to negative cost and demand shocks.

Combining the results of these formal tests with the evidence in Section 2.3, one may be led to conclude that prices adjust more quickly upwards than downwards following cost shocks, but more slowly upwards than downwards in reaction to demand shocks. However, the results in Section 2.3 revealed strong heterogeneity in the way firms react to shocks and therefore the direction of the asymmetry may vary with the characteristics of the firms. In order to investigate this issue, we computed for firms in the baseline group the differences between the probability that the adjustment to different shocks will take more than a year, as well as the differences-in-differences for each covariate relative to the baseline group (obtained from Table 2.4). These results, which are displayed in Table 2.6, allow us to discuss the sources and direction of asymmetries within shocks (positive vs. negative cost or demand shocks) and between shocks (cost vs. demand positive or negative shocks).

Starting with the results for cost shocks - positive vs negative - we find that for the baseline group there is evidence that firms adjust faster to positive than to negative cost shocks: the difference between the probability that the adjustment takes more than a year for positive and negative shocks is equal to -0.1955, and significantly different from zero. This result is consistent with the predictions of a model with menu costs and trend inflation and with a model that incorporates search costs or consumer inattentiveness, as well as with the predictions of some models considering firms' strategic behaviour (e.g., Devereux and Siu (2007)), but it is at odds with the predictions of the oligopoly models with kinked demand curves of the type considered by Maskin and Tirole (1988).

However, it is interesting to notice that this result vanishes for some firms. For example, if we consider firms whose price is set by customers, consider price as an important factor of competitiveness, and produce intermediate goods, we obtain a value for the difference between probabilities of adjustment after 1 year very close to zero: $0.0094 = 0.1162 + 0.0437 + 0.0450 - 0.1955$. Therefore, the asymmetry all but disappears for firms that face more competitive markets or have less price setting power. Again, this is something that is consistent with menu-cost models with positive trend inflation and with models where consumers face search costs or are inattentive. Indeed, it is more costly to maintain a sub-optimal price in more competitive markets and therefore firms may be expected to react faster, irrespective of the direction of the price change. In the limit, if there are no lags of adjustment, there cannot be asymmetries in the speed of adjustment.

For demand shocks the asymmetry tests in Table 2.5 above, combined with the evidence in Table 2.2, suggest that prices move more quickly in response to negative than to positive shocks. This is something that would be consistent with a model where customer anger is taken into consideration, under the assumption that customer antagonization is higher for price increases than for price decreases (Okun (1981) and Anderson and Simester (2010)), but could have not be anticipated, for instance, by menu-cost models with positive trend inflation. However, the results in Table 2.6 do not provide clear evidence to support this asymmetry, and do not identify covariates with a strong effect on it, and therefore further research on the determinants of this kind of asymmetry is needed.

Table 2.6: Estimates of the difference between probabilities for the category $\widetilde{y}_{ij} = 6$ for the baseline group, and differences with respect to this group

	Within shocks Positive - Negative		Between shocks Cost -Demand	
	Cost shock	Demand shock	Positive shock	Negative shock
Baseline group	−0.1955** (0.0763)	0.0740 (0.0535)	−0.2431** (0.0545)	0.0263 (0.0828)
Price discrimination	0.0223 (0.0322)	−0.0218 (0.0334)	0.0882** (0.0323)	0.0440 (0.0318)
Quantity discount	0.0033 (0.0307)	−0.0172 (0.0329)	0.0467 (0.0319)	0.0263 (0.0301)
Size	−0.0510 (0.0349)	−0.0720* (0.0379)	0.0963** (0.0361)	0.0752** (0.0350)
Capital structure	0.0338 (0.0341)	0.0040 (0.0391)	−0.0210 (0.0377)	−0.0508 (0.0343)
Labour costs	−0.0103 (0.0268)	−0.0003 (0.0312)	−0.0392 (0.0299)	−0.0292 (0.0275)
Intermediate input costs	0.0220 (0.0255)	−0.0216 (0.0301)	−0.0218 (0.0281)	−0.0654** (0.0264)
Explicit contracts	0.0137 (0.0252)	−0.0063 (0.0312)	−0.0134 (0.0290)	−0.0334 (0.0268)
Implicit contracts	0.0020 (0.0294)	0.0674* (0.0347)	−0.0485 (0.0333)	0.0169 (0.0298)
Competition	0.0227 (0.0272)	0.0017 (0.0300)	0.0302 (0.0291)	0.0093 (0.0271)
Domestic market	0.0096 (0.0251)	−0.0366 (0.0312)	−0.0166 (0.0286)	−0.0628** (0.0269)
Price competitiveness	0.0437** (0.0221)	0.0245 (0.0254)	0.0520** (0.0242)	0.0328 (0.0228)
Quality competitiveness	0.0029 (0.0269)	−0.0229 (0.0329)	−0.0401 (0.0308)	−0.0658** (0.0286)
Delivery competitiveness	0.0079 (0.0218)	0.0071 (0.0280)	−0.0868** (0.0257)	−0.0876** (0.0239)
Price set by customers	0.1162** (0.0360)	0.0588 (0.0423)	0.0430 (0.0425)	−0.0145 (0.0355)
Price set by competitors	0.0698** (0.0332)	0.0216 (0.0339)	0.1578** (0.0349)	0.1096** (0.0323)
Services	−0.0282 (0.0490)	−0.0628 (0.0536)	0.0589 (0.0546)	0.0243 (0.0471)
Intermediate goods	0.0450* (0.0237)	−0.0242 (0.0265)	0.0697** (0.0254)	0.0005 (0.0244)

Standard errors computed from analytical second derivatives are in parenthesis; ** and * marks significance at 5% and at 10%, respectively.

Turning, finally, to the difference between cost and demand shocks (see the last two columns in Table 2.6), we conclude that the probability of a firm in the baseline group adjusting the price more than one year after the shocks is significantly lower for a positive cost shock than for a positive demand shock, but that the difference is not significant in the case of negative shocks.

The fact that firms react faster to positive cost shocks than to positive demand shocks is consistent with models of customer anger or fair pricing. These models predict that consumers will more easily accept a price increase caused by a change in costs than a price increase that is caused by an increase in demand. However, once again, the result depends on the characteristics of the firms. In particular, for large firms who practice price discrimination, whose prices are set by competitors, consider price as an important factor of competitiveness, and produce intermediate goods, we obtain a positive and large value for the difference between probabilities of adjustment after 1 year: $0.2209 = 0.0882 + 0.0963 + 0.1578 + 0.0520 + 0.0697 - 0.2431$. That is, not only the magnitude but also the sign of the asymmetry depends on the characteristics of the firms.

The last set of results concerns the difference in the response to negative cost and demand shocks. For the baseline group, there is no evidence of asymmetric behaviour, but there are several characteristics of the firm that induce significant asymmetries. In particular, we find that large firms and firms that have their prices set by competitors react faster to negative demand shocks than to negative cost shocks. Conversely, firms that state that intermediate input costs are important, firms that operate in the domestic market, and firms that compete in quality or in the speed of delivery, adjust faster to negative cost shocks than to negative demand shocks. This heterogeneity across firms is hard to explain by any single model.

In short, three main conclusions emerge from the analysis regarding the existence of asymmetries in the speed with which prices adjust to shocks: 1) there is evidence of the existence of asymmetries in the speed of price responses to positive and negative demand and cost shocks; 2) the magnitude and direction of these asymmetries vary with the characteristics of the firm and of the market in which the firm operates; 3) there does not seem to be a single theoretical model that can explain all the different results we obtained, suggesting that more eclectic models are needed to better understand this

phenomenon.

2.6 Conclusions

This work investigated firm-level price rigidities by using survey data to look into the length of lags of price adjustments in reaction to positive and negative demand and cost shocks. Price adjustment lags are a direct measure of price rigidity and therefore may be seen as a better measure of price stickiness than the commonly used frequency of price changes, which is expected to also depend on the frequency and magnitude of the shocks to the optimal price.

We find that the lags of price adjustments vary with the market, product, and firm characteristics, such as the cost structure of the firm, the type of pricing policy, the competitive environment, the different factors of competitiveness, or the type of good. In particular, firms which discriminate prices, do quantity discounts or operate in more competitive environments react faster to shocks than otherwise similar firms. We interpret these findings as support of the predictions of models of optimal price setting like the ones suggested in Barro (1972), Caballero (1989) or Alvarez et al. (2011).

We also find evidence of the existence of asymmetries in the speed with which firms adjust their prices in response to positive and negative demand or costs shocks. In line with similar evidence reported in the empirical literature, most firms in our sample seem to react faster to positive than to negative cost shocks, and more quickly to negative than to positive demand shocks. However, we have uncovered a significant degree of heterogeneity in the asymmetry of firm's responses to shocks which seems to have gone unnoticed so far. Moreover, the direction and magnitude of these asymmetries depend on the characteristics of the firms and of the market in which they operate. For example, we find that firms operating in more competitive markets respond to different shocks more symmetrically.

Some results on asymmetric price responses are individually consistent with some of the theoretical models suggested in the literature, but, overall, our results can only be explained by a combination of the models purporting to explain asymmetric behaviour in response to different shocks. This fact illustrates the complexity of the problem and

suggests that further research will be needed to better understand the conditions under which different kinds of asymmetries will be observed.

Our results have important implications for macroeconomic models. Based on the evidence presented here we propose that monetary models should try to accommodate the fact that the degree of price stickiness varies across firms and that firms react differently to different types of shocks. Our findings suggest that models of optimal price setting which take into account various characteristics of the firm and of the markets where this firm operates are a good way to model these heterogeneities in a micro-founded way.

The existence of asymmetries in the speed of price responses to shocks may also have important implications for monetary policy. Indeed, the existence of firm-level asymmetric price rigidity has the implication that the relationship between inflation and aggregate demand (Phillips curve) might be non-linear, calling for asymmetric monetary policy rules. However, in contrast to most of the theoretical literature which tends to favour the idea that prices are stickier downwards than upwards in response to demand shocks, the evidence obtained in this study suggests that the type of asymmetry prevailing at the aggregate level depends on the relative importance of different types of firms in the economy and on the type of shock. Therefore, whether the relation between inflation and aggregate demand is linear, convex or concave is still an open issue and thus more empirical evidence is required before definite conclusions can be drawn on this matter.

2.7 Appendix

In this Appendix, we describe the covariates used in the ordered probit model whose results are presented in Section 2.4, and provide the corresponding summary statistics. All the covariates used in the model are dummy variables. The details are as follows:

Explicit contracts – Equal to one if the percentage of sales under written contracts is larger than 50 percent of total sales.

Implicit contracts – Equal to one if the relationship with customers is essentially a long-term one (more than one year).

Price discrimination – Equal to one if the price of the firm's product is decided on a

case-by-case basis.

Quantity discount – Equal to one if the price depends on the quantity sold but according to a uniform price list.

Price set by customers – Equal to one if the price of the product is set by the firm's main customer(s).

Price set by competitors – Equal to one if the price of the product is set by the firm's main competitor(s).

Labour costs – Equal to one if the labour cost share is above the median of the sample.

Intermediate input costs – Equal to one if the other input costs share is above the median of the sample.

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

Domestic market – Equal to one if Portugal is the main destination market for the firm's product.

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

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

Delivery competitiveness – Equal to one if the firm considers delivery period as a very important factor for competitiveness.

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

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

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

Capital structure – Equal to one if the share of domestic capital (owned by Portuguese entrepreneurs) is larger than 50 percent.

Table 2.7 summarizes the relative importance in the sample of the above defined covariates. The entries in the Table record the share of firms in each category, with the exception of the labour and intermediate input costs, which represent the corresponding average shares, and the capital structure, which represents the share of firms whose

Table 2.7: Main characteristics of the sample:
Share of firms in each category in percentage

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

[(a)] Average of labour or intermediate input cost share (percent);

[(b)] Share of firms whose national capital accounts for 50 percent or more of total capital.

national capital accounts for 50 percent or more of total capital. For instance, from the Table we see that around 83 percent of firms have implicit contracts, i.e., they have an essentially long-term relationship with customers, and that the distribution of implicit contracts is relatively homogeneous across sectors and do not vary much with the size of firms. In contrast, only in about 25 percent of the firms do formal contracts account for 50 percent or more of total sales (explicit contracts), and its distribution varies significantly across sectors and firms' size.

Chapter 3

Choosing between time and state dependence price-reviewing strategies[22]

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3.1 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,

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and that the different strategies are widespread throughout the economy.[23] 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.[24] Understanding the factors that underlie firms' choice of different price-reviewing strategies is thus an issue of paramount importance.

This work 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 information from a firm-level survey for Portugal, this chapter investigates the main reasons that lead Portuguese 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 price-reviewing strategies and a number of their characteristics. The identification of such characteristics allows 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.

As a byproduct, this work also contributes with additional evidence on the factors that may explain why some firms change prices more frequently than others. The initial literature on this issue, mainly due to the lack of firm level detailed information, was unable to identify a relevant set of covariates that significantly correlates with the frequency of price changes at the micro level (see, for instance, Bils and Klenow (2004) and Gopinath and Itskhoki (2010)). More recently, the availability of firm-level survey data allowed the identification of some factors (that basically include measures of firms' cost structure and the degree of competition faced by firms) that correlate significantly with the frequency

[23]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 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.

[24]See, 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) and Woodford (2009).

of price changes.[25] This work, by identifying a number of significant correlations between the different price-reviewing strategies and a large set of firm characteristics on the one side, and by establishing a clear relation between such strategies and the frequency of price changes on the other side, is able to provide additional evidence on this issue.

Finally, our exercise allows us to answer several interesting questions from which the following are just some examples: How do 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' price-reviewing strategies 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 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 for the examination of 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 work. 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 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 a time-dependent, a state-dependent or a combination of both price-reviewing strategies (see Blanchard and Fischer (1989), chapter 8).[26]

[25] See, for instance, Alvarez and Hernando (2005) and Druant et al. (2009) for research based on firm-level survey data, and Vermeulen et al. (2012), which summarise evidence for some European countries, for research based on sectoral data.

[26] 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

In this work, we document that the type of price-reviewing strategy followed by firms has important consequences for the frequency of price changes and for 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 do firms that follow time-dependent strategies.

We also find that the type of price-reviewing strategy varies significantly with the 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. More specifically, we document that smaller firms, firms for which changes in the 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 and firms 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-dependent, 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, for some of them, the probability of a firm choosing between one of the two strategies may even go in the opposite direction.

The fact that the frequency of price reviews and the speed of price reaction to shocks vary with firms' price-reviewing strategies, together with the fact that the distribution of firms' price-reviewing strategies depends on the state of the economy is expected to have important consequences for monetary policy. In particular, anything that changes this distribution is likely to affect the speed with which prices react to monetary policy shocks. For instance, if, in line with what we find for Portugal, the choice of a price-reviewing strategy also varies with firm size in other countries, then the effects of monetary policy will be different in countries with different firm-size distributions as the masses of time- and state-dependent firms will also be different. Similarly, because firms in the services

policy rules. Notable examples of these, sometimes called exogenous time-dependent models, include Taylor (1980) and Calvo (1983). In this work, 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 (see, for instance, Caballero (1989)).

sector are more prone to follow time-dependent price-reviewing rules, changes in the structure of the economy that alter the relative importance of the services sector will change the impact of monetary policy. But, and maybe even more interestingly, the type of monetary policy may have an impact on the effects of monetary policy: monetary policy aimed at stabilising the economy by reducing the variability of firms' optimal price (through the reduction of inflation or demand uncertainty) is likely to increase the proportion of time-dependent firms which, in turn, to the extent that such firms display a lower frequency of price changes or a lower speed of price reaction to shocks, will 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-reviewing or price-setting strategies. Otherwise, the implications of changes in monetary policy rules generated by these models might be misleading.

The rest of the chapter is organised as follows. Section 3.2 presents the theoretical background which underlies the estimated model. Section 3.3 describes the dataset and presents some preliminary results. Section 3.4 presents the estimated model and discusses the main results. Section 3.5 provides some concluding remarks and, finally, an Appendix presents an explanation of how the different variables were constructed.

3.2 Theoretical background

The process by which firms determine an optimal price may be thought of as involving two distinct activities: price-reviewing and price-setting. 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.[27]

[27]Survey 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,

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 the models suggested in Caballero (1989) and Alvarez et al. (2011), which assume that firms do not have access to costless information about current economic conditions.

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=θ[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;[28] 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

$$\tau = \sqrt{\frac{2\rho}{\theta\sigma^2}} \tag{1}$$

According to equation (1), the optimal length for price-reviewing is increasing with information costs and decreasing with the parameters that measure the efficiency loss from sub-optimal prices and the variability of the underlying optimal price.[29]

In the model suggested in Caballero (1989) there are no menu costs, i.e., costs of

but most firms actually change their prices only once a year. In the case of Portugal, these figures are 2 and 1, respectively.

[28]Notice 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.

[29]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 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.

changing prices, so that every price review implies a price change. In a recent contribution, Alvarez et al. (2011) 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 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 has been 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.[30]

Models with costless information

In contrast to Caballero (1989) and Alvarez et al. (2011), 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 (see Sims (1998, 2003, 2006)), the assumptions about information availability have important implications for the strategy of price reviews. 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.[31] Under

[30]In 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.

[31]This assumption may be justified in the context of the theory of rational inattention: the cost of any kind of information is assumed to be the same as any other because the relevant bottleneck is limited

these circumstances, 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 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. (2011) 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 converge to zero, which makes

attention on the part of the decision maker, rather than anything about the structure of the economy that obscures the value of certain variables.

the source of the state-dependent component in the price-reviewing strategy vanish. In turn, an increase in information or observation costs makes the state-dependent model in Woodford (2009) 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 that changes in the variability of the optimal price (σ^2) and the sensitivity of firm's profits to sub-optimal prices (θ) have on the optimal price-reviewing strategy may be discussed in a context of a model in which firms have access to partial information about current conditions (as in Woodford (2009)).[32] 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 look into the factors that may explain why firms follow state-dependent, time-dependent or both time- and state-dependent price-reviewing strategies. For that purpose, in section 3.4 we 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.

[32]Notice that changes in σ^2 and θ do not alter the mode of price reviewing in the context of the models developed in Caballero (1989) and Alvarez et al. (2011), as in these models firms are not assumed to have access to partial information about current conditions that they could use to decide whether or not to undertake a price review.

3.3 The Data

3.3.1 Data sources

The data used in this study come from a survey of price setting practices carried out by the Banco de Portugal in 2004.[33] In this survey firms were asked the following question concerning their price-reviewing strategies:

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*

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 firms, respectively.

Besides the questions on price-reviewing practices, the survey also contained information on a large set of firms' characteristics. These included information on the size and sector of the firm, its main market (domestic versus external market), the 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.). Finally, the survey also contained information

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

Table 3.1: Price-reviewing strategies (Country evidence):
Share of firms in percentage

	PT	ES	DE	NL	BE	IT	AT	EA
Time-dependent	32	33	26	36	26	40	41	34
Time- and state-dependent	25	28	55	18	40	46	32	46
State-dependent	43	39	19	46	34	14	27	20

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

on the frequency of price adjustment and the speed of price responses to demand and costs shocks by Portuguese firms.

In total, for estimation purposes, we have detailed information on 906 firms with 20 or more employees, from Manufacturing (NACE - classification of economic activities - 15 to 37) and Services (NACE 60 to 64, 80 and 85 - Transport, Storage and Communication, Education and Healthcare).

3.3.2 Preliminary data analysis

As mentioned above, the type of price-reviewing strategy by Portuguese firms is our variable of interest. Table 3.1 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 and the Euro Area taken from Fabiani et al. (2007).[34]

Table 3.1 reveals that in Portugal 32 percent of the firms in the sample follow time-dependent rules, 43 percent follow state-dependent rules while 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

[34]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 3.2: 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

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

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 3.1 we see that the 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 3.2 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.[35] Table 3.3 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

[35]Firms in the survey were asked the following questions: a) On average, at what frequency is the price changed?; b) After a significant positive demand shock how much time on average elapses before you change your price? (and similar questions for a significant negative demand shock and for a significant positive or negative cost shock). The answers in the form of quantity or time intervals are summarised in Tables 3.2 and 3.3.

Table 3.3: 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 or less	76	72	66

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 3.3 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.[36]

Table 3.4 reports the lags or price reaction to significant positive cost and demand shocks, reported by the firms in the survey.[37] 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 in between the speed of time-dependent and the speed of 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

[36]The outcome of the test is $\chi^2(6)=15.1$, so that the null hypothesis is rejected at 5 percent level.

[37]This information was explored by Dias et al. (2011) to investigate the characteristics that explain why some firms react to shocks faster than others.

Table 3.4: 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
Positive cost shocks:			
1 - Less than one week	3	6	6
2 - From one week to one month	11	16	20
3 - From one to three months	24	28	32
4 - From three to six months	19	21	18
5 - From six 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 one to three months	17	18	23
4 - From three to six months	13	21	13
5 - From six months to one year	22	21	14
6 - More than one year	38	26	31

identical adjustment lags across the three types of firms.[38]

Overall, Tables 3.3 and 3.4 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 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. In particular, anything that changes this distribution is likely to affect the speed of price reaction to monetary policy shocks.

[38]For 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 5 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.

3.4 An econometric model for the price-reviewing strategies

In order to understand what makes firms choosing one price-reviewing strategy over the others, we specify and estimate a multinomial probit choice model. Given that the firm has 3 choices we can define the latent variable $y^*_{i,j} = x'_i\beta_j + \varepsilon_i$ to denote the gain for firm i stemming from choosing the price-reviewing strategy $j = \{1, 2, 3\}$. It is further assumed that the residuals ε_i have a multivariate normal distribution. The observed dependent variable y_i is defined as:

$$y_i = \begin{cases} j & if \quad y^*_{ij} = max(y^*_{i1}, y^*_{i2}, y^*_{i3}) \\ 0 & otherwise \end{cases}$$

i.e., strategy j is chosen if y^*_{ij} is highest for j. The multinomial probit model allows us to model probabilities of the three different outcomes of the dependent variable y_i in such a way that they sum up to unity: P(y_i=1)+P(y_i=2)+P(y_i=3)=1. The probability of firm i choosing price-reviewing strategy k is given by

$$P\left(y_i = k \,|x_i\right) = P\left(y^*_{ik} > y^*_{ij},\ j = \{1, 2, 3\}, j \neq k\right)$$

These probabilities can be easily obtained given the normality assumption for the error terms.[39]

The choice of the set of regressors, x_i, used in the empirical model was guided by the literature on price-reviewing strategies, summarised in section 3.2. As discussed there, the relevant factors determining the type of pricing policy may be divided into four categories: menu costs, information costs, variability of the optimal price and the sensitivity of profits to sub-optimal prices. We use proxies as the regressors for each one of the four categories whenever direct quantitative data are not available.[40] The different

[39]For further details see, for instance, Maddala (1983) or Train (2009).

[40]We also use binary dummy variables as regressors in the few cases where quantitative data were available because we believe that the use of such variables, on the one hand, greatly reduces the importance of potential reporting errors that may emerge with survey data and, on the other hand, makes it easier to extract the information from the regressors by increasing the contrast between the groups of firms defined by the binary dummy variables.

regressors are described in the Appendix together with some summary statistics.

Table 3.5 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.[41]

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. However, 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*b*), Zbaracki et al. (2004) and Woodford (2003, 2009)). Overall, we believe that more and better data on menu costs is required before definite conclusions may be drawn on the importance of this factor for the the type of price-reviewing strategy.

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 3.2, we may expect high information costs to increase the likelihood of time- or time- and state-dependent price-

[41] Figures in Table 3.5 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 3.5 add up to zero.

Table 3.5: Multinomial Probit:
Average marginal effects

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

Number of observations: 906
Log pseudo-likelihood: -894.889
Wald $\chi^2(26)$=148.80 (P=0.000); MacFadden's Pseudo R^2=0.079.

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

reviewing strategies, as opposed to state-dependent rules. The variable, "importance of information costs" maps directly into the theories presented in section 3.2. 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 structures are less centralized as compared to 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 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.[42]

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 in line with our predictions. That is, we estimate that, for a firm that price discriminates the probability of following a state-dependent rule is 14.3 percentage points 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 to the 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 percentage points lower than the probability

[42]The variable "importance of information costs" is defined in a similar way to the "importance of menu costs". Thus, similarly to what was suggested for the latter, it might be the case that our direct measure of information costs is unable to fully discriminate among firms with different price-reviewing strategies. The fact that the other (indirect) measures of information costs have very significant impacts on the estimated model suggests that this may in fact be the right explanation for the absence of statistically strong results for the "importance of information costs".

for a comparable small firm. This result is also in line with the preliminary findings in section 3.3.[43]

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 3.5 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 percentage points 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 strategy. 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.[44] 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

[43]Using "size" as proxy for information costs may be seen as a controversial assumption. This variable 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 at 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.

In the model, "size" is defined as dummy variable that equals 1 if the firm is a large firm (i.e., the number of employees is larger than 250) and is zero otherwise (see Appendix). Some sensitivity tests showed that the results in the model do not qualitatively change if "size" is defined as the number of employees.

[44]In the survey, firms were asked at what frequency wages are normally changed and slightly more than 80 percent (736 in our sample of 906 firms) answered "once a year". Among these, about 70 percent answered that they adjust wages in a specific month of the first quarter of the year (January, February or March).

followed by Portuguese firms.

The existence of "explicit" or written 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 3.5, 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 made using 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 (Martin (1993) and 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 percentage points lower than the probability for and otherwise identical firm.

As it is well known, firms can compete in many different dimensions: price, quality, after-sales service, etc. We may think of these factors as reflecting different product characteristics which translate into different demand elasticities. In that sense, we added to

our model a variable that indicates whether price is a very important factor of firm's competitiveness. We find 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 3.5, the probability for such a firm of following a state-dependent rule is 11.2 percentage points higher than for an otherwise identical firm. This is the expected result, as firms that compete in price may be expected to display higher demand elasticity and thus their profits to be more sensitive to deviations from the optimal price.

As regards the effects of "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 reviewing 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 3.2 in Section 3.3), from Table 3.5 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 percentage points. 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.

Finally, the results in Table 3.5 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 the changes are not statistically different from zero). However, the results also show that time-dependent 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.

3.5 Conclusions

This work 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 follow state-dependent and the remaining 25 percent follow 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 which 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, i.e., the costs of changing prices such as the cost of printing and distributing new price lists, do not emerge as playing a significant role. But, we believe that more and better data is required before definite conclusions may be drawn on the importance of this factor for the choice of the price-reviewing strategies by Portuguese firms.

The factors that affect the choice of firms' price-reviewing strategies may also be seen as the factors that explain why some firms change prices more frequently than others or why firms react to shocks with different lags. Given that the frequency of price changes and the speed of price reaction to shocks of time-dependent firms are significantly lower, the factors listed above that increase the probability of a firm following a time-dependent price-reviewing strategy are also the factors that reduce the frequency of price changes and decrease the speed of price reaction to shocks. In contrast, the factors that increase the probability of a firm following a state-dependent price-reviewing rule also increase the frequency of price changes or the speed of price reaction to shocks.

The fact that the frequency of price changes and the speed of price reaction to shocks depend on whether firms follow time-dependent, time- and state-dependent, or state-dependent price-reviewing strategies may be expected to have important consequences for monetary policy, as it implies that monetary policy effects will depend on the distribution of firms in terms of their price-reviewing strategies. In particular, anything that changes this distribution is likely to affect the speed of price reaction to monetary policy shocks. For instance, if, in line with what was found for Portugal, the choice of a price-reviewing strategy varies with firm size in other countries, then it may be expected that the effects of monetary policy will be different in countries with different firm-size distributions as the masses of time- and state-dependent firms will also be different. Similarly, because firms in the services sector are more prone to follow time-dependent price-reviewing rules, changes in the structure of the economy that affect its composition (manufacturing versus services) will have the implication of changing the effects of monetary policy. This idea that firms rationally choose their price-reviewing strategy may help to understand the cross-sectional variation of monetary shocks (different countries/states are affected differently by the same type of monetary shock) and, at the same time, may also explain why the same monetary shock may affect the same country differently in different periods of its

development path.

But not only structural characteristics of an economy may influence monetary policy. The evidence shown in this chapter that the proportion of time- and state-dependent firms depends on the state of the economy implies that different monetary policy regimes may affect 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 price-reviewing category, will be likely to modify the frequency of price changes and thus the speed of price reaction to monetary policy shocks. For instance, by reducing inflation and/or demand uncertainty, monetary policy will reduce the variability of firms' optimal price which, according to the evidence presented, is likely to increase the probability of firms following time-dependent or time- and state-dependent rules as opposed to state-dependent rules. This, *ceteris paribus*, may be expected to reduce the frequency of price reviews (and of price changes) or the speed of price reaction to shocks and thus to increase the real effects of monetary policy.

Appendix

In this Appendix, we describe the covariates used in the multinomial probit model whose results are presented in section 3.4, 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 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 of 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 services.

Table 3.6: 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

Table 3.6 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.

Chapter 4

Wage rigidity and employment adjustment at the firm level[45]

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4.1 Introduction

Understanding the interaction between wage and employment adjustments is very important for the design of monetary or fiscal policies aiming to stabilise the economy. This work contributes to this literature by analysing how firms, in the presence of wage rigidity, combine different channels of labour-cost adjustment in response to adverse shocks.

Wage rigidity is expected to have implications for unemployment because, in the face of negative shocks, employment adjustment is likely to be larger when wages are rigid downwards. Wage rigidity is also thought to have important implications for monetary policy, as it may condition the inflation target that monetary authorities should pursue. If nominal wages were perfectly flexible it would be optimal to aim at zero inflation but,

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in the presence of downward nominal wage rigidity, a certain amount of inflation may be required to "grease the wheels" of the labour market by easing reductions in real wages.[46]

The bulk of the empirical literature aimed at assessing the extent and the effects of nominal wage rigidities has focused on base wages or permanent wages (base wages plus other components that are paid on a permanent or regular basis, such as meals allowances, tenure-related components, etc.), leaving aside potentially more flexible pay components, such as performance-related bonuses, commissions and other benefits, which may strongly attenuate the negative impact on employment of strict downward base-wage rigidity.[47] Exceptions are the contributions by Lebow et al. (2003), Dwyer (2003) and Oyer (2005) who look at the role played by benefits in reducing nominal wage rigidity. They conclude that firms seem to be able to partly circumvent wage rigidity by varying benefits so that total compensation displays less rigidity than do wages alone.

This work extends the existing literature by discussing the implications of wage rigidity in a context where several labour-cost adjustment margins are available to firms. Since firms are primarily concerned with total compensation per employee, the assessment of the importance of these alternative labour cost adjustment strategies is crucial to evaluate the overall degree of labour cost flexibility and its implications. Based on firm-level survey data for a sample of Portuguese firms, this work investigates whether these alternative margins of labour cost adjustment have been used as substitutes or complements to base wages and, most importantly, whether their utilisation has significantly reduced the detrimental impact on employment of base-wage rigidities in the Portuguese labour market.

Overall, the analysis carried in this chapter shows that base-wage flexibility has a strong positive impact on employment in the face of negative shocks, and that such impact is significantly reinforced by the existence of alternative margins of labour cost adjustment. In particular, the availability of compensation components (bonuses, benefits and promotions) that firms can freeze or cut in bad times, and the possibility of recruiting

[46]For a discussion, see, among many others, Akerlof et al. (1996), Gordon (1996), Mankiw (1996), Dwyer (2003), Fehr and Goette (2005), Carlsson and Westermark (2007), Elsby (2009), Messina and Sanz-de Galdeano (2011) and Stüber and Beissinger (2012).

[47]For empirical evidence on downward wage rigidity see, for instance, Altonji and Devereux (2000), Knoppik and Beissinger (2006), Dickens et al. (2007), Goette et al. (2007), Holden and Wulfsberg (2008, 2009), Behr and Pötter (2010) and Messina et al. (2010).

new employees at a wage lower than the one of those who have recently left the firm contribute to partly offset the negative impact of base-wage rigidities on employment.

The rest of the chapter is organised as follows. Section 4.2 describes the dataset. Section 4.3 provides the institutional and theoretical background for the econometric model used in the empirical section of the chapter. Section 4.4 presents some preliminary analysis of the data. Section 4.5 discusses the econometric methodology, presents the estimated models and discusses the main results. Section 4.6 provides some concluding remarks. Finally, the Appendix describes how the different variables were constructed.

4.2 Data sources

Most of the data used in this study come from a survey on wage and price setting practices carried out by Banco de Portugal in 2008 on a sample of Portuguese firms[48].

In this survey, firms were asked two questions pertaining to the different margins of labour cost adjustments, including base-wage freezes, reduction or elimination of other compensation components and reduction of employment.

As regards base-wage freezes firms were asked the following question: "*Over the last five years, has the base wage of some workers in your firm ever been frozen*?". Under the assumption of a common negative shock, and in the absence of nominal wage cuts, wage freezes identify those firms in the sample where base wages exhibit the lowest degree of real downward rigidity. Thus, for the purposes of the present work, we look at base-wage freezes as a measure of downward wage flexibility.[49]

In the second question, firms were asked if they had ever used ways of cutting labour costs other than changing their base wages. In particular, they were asked the following question: "*Have you ever used any of the following strategies to reduce labour costs*?"

[48]Details on the sample selection method, as well as a copy of the full questionnaire can be found in Martins (2011).

[49]Information on wage freezes has been used in the literature as a measure of the degree of downward nominal wage rigidity (see, for instance, Babecký et al. (2009, 2010)). In our view, however, wage freezes can be seen as a measure of downward nominal wage rigidity only if the analysis is restricted to the population of firms where wages have been frozen or cut (see for instance, Holden (2004), Dickens et al. (2007) and Holden and Wulfsberg (2008)). Radowski and Bonin (2008) have also used the frequency of wage freezes or wage cuts as a proxy for wage flexibility in Germany.

Firms participating in the survey were allowed to choose as many options as they wished from the list below:

1) *Reduce or eliminate bonus payments and other monetary benefits*;

2) *Reduce or eliminate non-monetary benefits*;

3) *Slow or freeze the rate at which promotions are filled.*

4) *Recruit new employees at a wage lower than the one of those who left the firm*;

5) *Reduce the number of employees.*

These five strategies together with wage freezes summarise the main labour cost-cutting strategies available to Portuguese firms in the face of negative shocks.[50] Wage freezes and strategies 1 to 4 may be seen as affecting the average price of labour. Further below, for estimation purposes and tractability reasons, strategies 1 to 3 (the reduction or elimination of monetary and non-monetary benefits and the slowdown or freezing of promotions) will be aggregated in a single margin and denoted together as "flexible margins" as they are usually seen as more flexible than base wages. The reduction in the number of employees affects the quantity of labour and will be denoted simply as "reduce employees".

Besides the questions on base-wage freezes and on the alternative margins of labour cost reduction, the survey also contains information on a large set of firms' characteristics. These include information on the composition of the labour force (share of white collar vs. blue collar workers; share of low skilled vs. high skilled workers; share of workers with permanent contracts), the percentage of workers covered by collective wage agreements, the share of exports in firms' total sales, and the relevance of some factors as obstacles to wage cuts/freezes in a context where firms may desire to reduce their labour costs, such as the constraints imposed by collective wage agreements, the negative impact on firms' reputation or the difficulties in attracting new workers in the future.

After excluding from the sample those firms that have not fully answered the two

[50]The original question in the survey included also the option *"Change the policy of shifts (reducing the number of hours and or shift premia)"*. The answers to this option are not analised in this work because they involved a small number of firms and because we also believe that such option is basically used by firms whose product has very specific characteristics, making it difficult to find a meaningful set of regressors capable of explaining why some firms use that option with higher probability than others.

questions on the alternative strategies to reduce labour costs, we were able to obtain detailed information on 1319 firms from different branches of activity. More specifically, our sample includes firms with 10 or more employees, covering manufacturing (38 percent), energy (3 percent), construction (11 percent), retail and wholesale trade (17 percent), and other business services (31 percent).

However, for estimation purposes, and for reasons that will become clear further below, we restrict the analysis to firms that have reduced costs, i.e., that have used at least one cost-cutting strategy. This reduces the original sample to 757 firms. Also for estimation purposes, the information from the survey was supplemented with data from *Quadros de Pessoal*, a large administrative database collected by the Ministry of Employment and Social Security, which, among other, includes information about all the Portuguese firms with wage earners (size, ownership, location, etc.). From this database, we obtained information on size (number of employees) and workers' tenure.

By combining these two datasets through the individual tax identification number of each firm and after excluding the firms that have not answered to all the questions that are used as regressors in the estimated model the initial sample is further reduced to 635 firms. This constitutes the final sample retained for estimation purposes.

4.3 Institutional and theoretical background

4.3.1 Institutional background

In the face of negative labour demand or supply shocks, firms are expected to reduce labour costs. This can be achieved by reducing employment and/or the average labour costs. In the real economy, however, firms face restrictions in terms of the channels of adjustment they can use, so that the way in which they distribute shocks across the various labour-cost adjustment channels is expected to depend not only on the technological and market restrictions, but also on the institutional and structural constraints of the economy, including wage rigidity and employment protection legislation.

As regards nominal wage rigidity, many studies place the Portuguese labour market among the most rigid countries in Europe (see, Behr and Pötter (2010), Messina et al.

(2010), Holden and Wulfsberg (2008), Dickens et al. (2007) and Knoppik and Beissinger (2006)). Such rigidity stems above all from the fact that labour legislation forbids nominal wage cuts. According to the Portuguese law, a firm cannot reduce contracted wages, including other regular and periodic monetary or non-monetary pay components, unless this is permitted by collective agreements. As a general rule, only bonuses, commissions and other monetary or non-monetary benefits associated to the worker's performance, not included in the collective agreement, may legally be reduced (Portuguese Labour Code, art. 129, 258 and 260). Also, collective negotiations are usually conducted at the industry or occupation level, and collective agreements stipulate minimum working conditions, like the monthly minimum wage for each category of workers, overtime pay and the normal duration of work. Such collective bargaining covers a large part of the workforce resulting both from the presence of labour unions and the existence of mechanisms of contract extension, i.e., the Government normally uses extension mechanisms to broaden the coverage of the collective bargaining agreement to workers not covered by unions. This largely regulated institutional framework, as well as the existence of a compulsory minimum wage, which establishes a wage floor for many workers, introduce strong additional rigidity in the wage-setting process.[51]

In contrast, the Portuguese labour market is usually seen as displaying a very low level of real wage rigidity. This conclusion emerges not only from the literature that uses micro data on the distribution of wage changes to compute measures of downward real wage rigidity (see Dickens et al. (2007) and Messina et al. (2010)), but also from the literature that looks at the wage supply curve using micro or macro data, where real wages appear as highly responsive to the unemployment rate (see OECD (1992), Luz and Pinheiro (1993), Gaspar and Luz (1997), Dias et al. (2004) and Marques (2008)). Estimates based on more recent data, however, suggest that things may have changed significantly during the last decade or so. According to Portugal et al. (2010), the large cyclical sensitivity of real wages, prevailing in the 1980s and the 1990s, has basically vanished in the most recent period.[52]

[51] In recent years, however, the number of firm-level agreements, which are supposed to allow greater wage flexibility, has increased. According to our survey, they are present in around 10 percent of the firms.

[52] According to the authors' estimates, the semi-elasticity of real wages to changes in the unemployment rate dropped from -2.46 in the 1986-2000 period to about zero in the 2002-2007 period for job-stayers,

The Portuguese labour market is also seen as displaying a high level of employment rigidity among European economies mainly due to legislation that protects employees with permanent contracts against individual dismissal (see Venn (2009)). Nevertheless, the typical Portuguese firm appears to have more control over employment than it has over contracted wages, namely because it has the possibility of resorting to collective dismissals and temporary contracts or finding ways to get around individual dismissals regulation by negotiating voluntary quits.

4.3.2 Theoretical background

Given the characteristics of the Portuguese labour market, we assume a "*right to manage*" situation where base wages are bargained collectively but other components of total compensation and employment are chosen optimally by firms subject to adjustment costs (namely hiring and firing costs), as well as to institutional constraints.

In order to discuss the impact of negative labour demand and supply shocks on wages and employment, we start with a very stylised model where it is assumed that firms do not pay bonuses or any other monetary or non-monetary benefits, so that total compensation coincides with base wages. To maximise profits in a "*right to manage*" situation firms must choose employment so as to equate the wage, which they take as given, to labour's marginal impact on firm's revenues. Let us assume that the inverse labour demand schedule of firm i may be written as:

$$w_i = -\theta_i l_i + d_i \tag{1}$$

where w is the log of firm's labour cost, l_i is the log of employment, d_i measures other factors that affect labour demand (marginal revenues) and θ_i is the inverse of the elasticity of the labour demand schedule.

Similarly, let us assume that firm i faces the following inverse log-linear labour supply schedule:

$$w_i = \lambda_i l_i + s_i \tag{2}$$

and from -0.955 to -0.343 for new-hires.

where λ_i is the inverse of labour supply elasticity and s_i measures other factors that affect labour supply. Solving the two equations for wages and employment, we get:

$$w_i = \frac{\theta_i}{\lambda_i + \theta_i} s_i + \frac{\lambda_i}{\lambda_i + \theta_i} d_i, \quad (3)$$

$$l_i = \frac{1}{\lambda_i + \theta_i} (d_i - s_i) \quad (4)$$

In this simple framework, a labour demand shock may be represented by Δd_i and a labour supply shock by Δs_i.

From equation (4), we see that the response of employment to labour demand shocks is small when the labour supply curve is inelastic, i.e., λ_i is large. In contrast, if wages do not change, i.e., λ_i is very small, possibly because they are set by binding collective wage agreements, then employment responds strongly to labour demand shocks. Thus, in the face of a negative labour demand shock several final adjustments are possible. If the firm is not able to freeze nominal wages (the most likely situation under downward wage rigidity), it will likely reduce employment and answer in the survey that it has reduced employment but not frozen wages. If, by negotiating with the workers' representatives, the firm manages to freeze nominal wages (the best it can aim at, given the existence of strict base-wage nominal downward rigidity), the firm will answer in the survey that it has frozen wages and reduced employment (if freezing wages was not enough to prevent employment reduction) or that it has frozen wages and not reduced employment, otherwise.

In the case of a labour supply shock, employment responses are expected to be larger when θ_i is small, i.e., labour demand is more elastic, which in turn reflects the degree of market competition, as well as the substitutability of labour with other factors. In the face of a negative labour supply shock (for instance, an unexpected base-wage increase imposed by collective agreements), the most likely final outcome (in the absence of other adjustment mechanisms) is a reduction in employment, so that the firm will answer in the survey that it has reduced employment but has not frozen wages.

The role played by the alternative mechanisms investigated in this work, like the flexible components of total compensation (such as bonuses and other monetary and non-monetary benefits) and the possibility of recruiting new employees at a lower wage than the one of those who have left the firm, may be discussed by noting that they

operate in the model by affecting total compensation and thus the labour supply and demand curves. In the context of downwardly rigid base wages, the negative impact on employment of a negative labour demand shock will be lower if the firm has the possibility of resorting to other total compensation components (i.e., freezing or reducing bonuses and other monetary or non-monetary benefits, freezing or slowing down the rate at which promotions are filled or recruiting new employees at wages lower than those received by the employees that have recently quit). Similarly, in the face of a negative labour supply shock, these margins may be used to attenuate the increase in total compensation, reducing the negative impact on employment. In the case of a negative labour demand shock, these margins will emerge in the sample either as complements to base-wage freezes (if firms manage to freeze wages), or as substitutes (if firms are unable to freeze base wages) while, in the case of a negative supply shock, they will emerge as substitutes to (unexpected) base-wage increases.

4.4 Preliminary data analysis

Table 4.1 summarises some information on the different cost-cutting strategies used by Portuguese firms in our sample. From the table, we see that the reduction in the number of employees ("reduce employees") is by far the most used strategy. Indeed, around 72 percent of the firms in the sample answered that they had used this margin in the past. The "flexible margins", which aggregate the reduction or elimination of bonus payments and other monetary benefits ("reduce bonuses"), the reduction or elimination of non-monetary benefits ("reduce benefits") and the slowdown or freezing of promotions ("slowdown promotions"), ranks second with around 45 percent of the firms, and the recruitment of new employees with a wage lower than the one of those who left the firm ("cheaper hires") ranks third with around 30 percent of the firms.

Table 4.1 also shows that the use of the different strategies by Portuguese firms does not vary much across sectors, with the possible exception of energy and construction. The energy sector displays a slightly lower usage of "base-wage freezes" and "flexible margins" and a relatively higher usage of "cheaper hires" and "reduce employees", while firms in the construction sector also use the "reduce employees" strategy more frequently

Table 4.1: Labour cost-cutting strategies:
Share of firms that have used each margin at least once

Sectors and firm sizes	Base wage freezes	Flexible wage margins			Flexible margins	Cheaper hires	Reduce employees
		Reduce bonuses	Reduce benefits	Slowdown promotions			
Total	0.258	0.243	0.148	0.246	0.454	0.297	0.715
Manufacturing	0.284	0.254	0.167	0.227	0.448	0.284	0.732
Energy	0.190	0.190	0.095	0.238	0.333	0.333	0.857
Construction	0.254	0.127	0.127	0.282	0.423	0.282	0.803
Trade	0.252	0.289	0.111	0.163	0.422	0.274	0.681
Business services	0.234	0.242	0.156	0.307	0.502	0.329	0.671
Large firms	0.244	0.269	0.154	0.260	0.474	0.349	0.724
Small firms	0.276	0.208	0.140	0.227	0.429	0.277	0.702

"Flexible margins" is the aggregation of "slowdown promotions", "reduce bonuses" and "reduce benefits". Large firms are those firms with 100 or more employees, while firms with less than 100 employees are considered as small firms. Number of observations: 757.

than the average firm.

As regards the distribution by firm size, Table 4.1 does not reveal strong asymmetries. Nevertheless, large firms seem more likely to use the "flexible margins" and "cheaper hires", as opposed to small firms which seem to make a more extensive use of "base-wage freezes".

According to the discussion in Section 4.3, we may expect the detrimental implications for employment of base-wage rigidity to be partly offset by the availability of other mechanisms through which firms can reduce their labour costs, such as the "flexible margins" and/or the "cheaper hires". In order to investigate whether some of these relationships are apparent in the data, we computed some sample conditional proportions, as well as tetrachoric correlation coefficients for pairings of different margins (see Tables 4.2 and 4.3, respectively).

From Table 4.2, we see that around 72 percent of the firms in the sample have reduced employment but only around 26 percent have frozen wages, which suggests that a large proportion of firms has reduced employment without freezing wages. However, among

Table 4.2: Sample conditional proportions

	Reduce employees	Cheaper hires	Flexible margins	Base-wage freezes
P(.)	0.715	0.297	0.454	0.258
P(. | Base-wage freezes=1)	0.564	0.215	0.503	1
P(. | Flexible margins=1)	0.657	0.305	1	-
P(. | Cheaper hires=1)	0.680	1	-	-

P(Y | X=1) stands for the proportion of firms that used strategy Y among those firms that have used strategy X. Number of observations: 757.

Table 4.3: Tetrachoric correlation coefficients between different pairs of labour cost-cutting strategies

	Reduce employees	Cheaper hires	Flexible margins	Base-wage freezes
Base-wage freezes	-0.330***	-0.195***	0.097	1.000
Flexible margins	-0.193***	0.027	1.000	
Cheaper hires	-0.086	1.000		
Reduce employees	1.000			

***,** and * stand for significance at 1, 5 and 10 percent level, respectively. Number of observations: 757.

the firms that have frozen base wages only around 56 percent have also reduced employment. In turn, from Table 4.3, we see that the correlation coefficient between "base-wage freezes" and "reduce employees" is significantly negative (-0.330). Thus, overall, the sample evidence suggests that "base-wage freezes" might have been used as a substitute to employment reduction.

A similar picture emerges for "cheaper hires". Conditional on having frozen wages, only around 22 percent of the firms have used "cheaper hires", compared to around 30 percent in the full sample. The correlation between "base-wage freezes" and "cheaper hires" is also significantly negative (-0.195) .

In contrast, there is no indication that "flexible margins" could have been used as a

substitute for "base-wage freezes". If anything, the data suggest that firms that managed to freeze wages also tended to use the "flexible margins". In other words, flexibility in the total compensation components ("base-wage freezes" and "flexible margins") seems to be positively correlated, even though not significantly so (Table 4.3).

As regards the other strategies, Table 4.2 suggests that "flexible margins" or "cheaper hires" could also have been used as substitutes to employment reduction, but according to Table 3 only the correlation between "flexible margins" and "reduce employees" appears as significantly different from zero. Finally, according to Tables 4.2 and 4.3, there seems to be no relationship whatsoever between the "flexible margins" and the "cheaper hires".

Overall, Table 4.2 and Table 4.3 suggest that in the sample some margins were used as substitutes for other margins ("base-wage freezes" for "reduce employees" and for "cheaper hires", and "flexible margins" for "reduce employees"), but no significant evidence emerges as regards complementarity relationships. In the next section these relationships will be further characterised using an appropriate econometric model.

4.5 Empirical Analysis

4.5.1 An econometric model for the cost-cutting strategies

In the face of negative shocks firms are expected to respond through adjustments that affect directly their demand (price of the product) and/or their supply (costs of production). For reasons of data availability and econometric tractability, this work focuses on the labour-cost adjustment strategies that Portuguese firms have used in the face of negative labour demand and supply shocks. Thus, implicitly, we assume that the degree of price stickiness and the costs of wage and employment adjustment determine the relative importance of the price versus the cost channel, but that the relationship among the different labour-cost margins is chiefly determined by their relative adjustment costs. This allows a two-stage approach where it is assumed that firms first decide whether to reduce prices and/or costs and then, conditional on having decided to reduce costs, they determine which type of costs they are going to cut, subject to technical or institutional

restrictions.[53]

Against this background, we model firms' cost-cutting strategies by assuming the following multivariate recursive probit model:

$$y_{i1}^* = x_{i1}'\beta_1 + \epsilon_{i1} \quad (5)$$

$$y_{i2}^* = x_{i2}'\beta_2 + \alpha_1 y_{i1} + \epsilon_{i2} \quad (6)$$

$$y_{i3}^* = x_{i3}'\beta_3 + \delta_1 y_{i1} + \delta_2 y_{i2} + \epsilon_{i3} \quad (7)$$

$$y_{i4}^* = x_{i4}'\beta_4 + \gamma_1 y_{i1} + \gamma_2 y_{i2} + \gamma_3 y_{i3} + \epsilon_{i4} \quad (8)$$

where y_{ij}^* (i=1,..N; j=1,...4) represents a latent variable which measures the amount of margin j used by firm i and $x_{ij}^{'}$ is a set of regressors whose impacts are measured by vector β_j. As y_{ij}^* is not observed, we define, as usually:

$$y_{ij} = 1 \quad if \quad y_{ij}^* > 0; \quad y_{ij} = 0 \quad if \quad y_{ij}^* \leq 0, \quad i = 1, ..N; j = 1, ...4. \quad (9)$$

Equations (5)-(8) describe the most general recursive triangular model that complies with the *condition for logical consistency*. It has been shown in the literature that such a model allows for causal interpretations enabling us to understand the underlying mechanisms generating the observations (see Maddala (1983)). It has also been shown that such a model does not suffer from identification problems.[54]

We define the 4 variables as follows: y_{i1}="base-wage freezes", y_{i2}="flexible margins", y_{i3}="cheaper hires" and y_{i4}="reduce employees". By ordering "base-wage freezes" first,

[53]Ideally, in order do draw conclusions on the impacts of the different regressors on the alternative adjustment channels, we would like to have detailed data on the reaction of firms to the different shocks. Our sample, has information on whether a given margin was used, but is mute on the frequency and timing of its utilisation. Thus, we proceed under the implicit identifying assumption that the data on the labour cost-cutting strategies is the result of a single reaction by the firm to a negative labour demand or labour supply shock (or a single reaction to the accumulation of several negative labour demand or supply shocks). This qualification requires, of course, that the estimated parameters be interpreted with some caution.

[54]Wilde (2000) has shown that the identification of the model is achieved if the same exogenous regressors appear in all equations, provided these regressors are sufficiently variable, so that theoretical identification does not require availability of additional instruments. See also Freedman and Sekhom (2010). Still, equations (5) and (6) in the estimated model include three additional regressors in order to ensure proper empirical identification of the model.

we are assuming that base wages are basically negotiated outside the firm, through collective agreements, such that they are not significantly affected by adjustments in the other cost margins, in line with a *right-to-manage* approach. In turn, by ordering "reduce employees" last, we are assuming that the probability of employment reduction may depend on whether the remaining margins are also used. *Ceteris paribus*, employment adjustment is expected to be lower when base wages are flexible and the firm has the possibility of using the "flexible margins" or the "cheaper-hires".

In model (5)-(8) it may further be assumed that:

$$corr(\epsilon_{ij}, \epsilon_{ik}) = \rho_{jk} \neq 0 \quad \forall j,k = 1,2,3,4 \quad (j \neq k) \tag{10}$$

Under assumption (10), the dependent variables y_{ij} (j=1,2,3) in the right-hand side of equations (6)-(8) are endogenous for the equations where they appear as regressors, and the four equations of model (5)-(8) must be estimated jointly. But if $\rho_{jk} = 0, \quad \forall j,k \quad (j \neq k)$, the dependent variables y_{ij} in the right-hand side of equations (6)-(8) become exogenous for estimation purposes and each equation in (5)-(8) may be estimated separately.

Given that our purpose is to identify the relationships among the different cost-cutting strategies, model (5)-(8) is estimated by restricting the original sample to firms that have reduced labour costs, i.e., that have used at least one cost-cutting strategy. Restricting the sample to firms that have reduced costs may raise sample selection issues because the restricted sample becomes endogenously determined. However, sample selection will only be a problem if the residuals in the selection equation are correlated with the residuals of the model estimated over the restricted sample. In order to handle this situation, we start by estimating model (5)-(8) together with a selection equation which, in our case, is an equation for the "cost margin" defined over the full sample:

$$w_i^* = z_i'\delta + v_i, \quad w_i = 1[(w_i^* > 1], \tag{11}$$

where $w_i = 1$ if the firm has reduced costs (has used one cost margin at least), and $w_i = 0$ otherwise; $z_i^{'}$ is a vector of exogenous regressors. From this model we may proceed by testing the joint hypothesis of endogeneity of the y_{ij} variables (j=1,2,3) in equations

(6)-(8) and the existence of sample selection problems, i.e.,:

$$H_0 : \rho_{jk} = \theta_r = 0, \quad j,k,r = 1,2,3,4 \quad (j \neq k) \tag{12}$$

where $\theta_r = corr(v_i, \epsilon_{ir}), r = 1,2,3,4$.

According to the likelihood ratio (LR) test, the null hypothesis in equation (12) is not rejected at standard significance levels. More specifically, from the estimated model we get LR(10)=4.943 with P-value=0.895, so that the test suggests the absence of any significant correlation among the residuals of the recursive triangular model (5)-(8), as well as among those residuals and the residuals of the selection equation, suggesting that endogeneity and sample selection are not relevant issues in our case.[55]

It is well-known that inference on multivariate binary models is very demanding in terms of sample sizes (see, for instance, Fabbri et al. (2004)). Thus, in the absence of endogeneity and sample selection problems, we proceed by estimating each equation of the model separately, as this is is likely to imply strong estimation efficiency gains.[56]

4.5.2 Estimation results

Table 4.4 presents the results of the estimated model and Table 4.5 reports the average total marginal effects of each of the covariates on the probability of a firm using each

[55]The sample selection model is estimated by maximum likelihood methods using the mvprobit Stata routine with some modifications. The vector of exogenous regressors, $z_i^{'}$, includes a set of variables aimed at explaining why firms adjust prices and not costs in reaction to negative labour demand and supply shocks. Thus, besides the regressors $x_i^{'}$ considered in the triangular model (5)-(8), and described in the next section, $z_i^{'}$ includes 5 additional regressors aimed at capturing the degree of price rigidity/flexibility: "price autonomy", "domestic competition","share of temporary employees", "cost price rigidity" and "demand price rigidity". See the Appendix for the description of these regressors.

[56]As a robustness check, we also conducted a single exogeneity test for the dependent variables y_{ij} (j=1,2,3) that appear as regressors in equations (6)-(8) by testing the correlation among the residuals of model (5)-(8). This hypothesis was tested using both the likelihood ratio (LR) test and the conditional moments (CM) test. The first one requires estimating the full model jointly by maximum likelihood methods, but the second one is particularly attractive as it is based on univariate probit estimation of the four equations. Simulations performed in Monfardini and Radice (2008) in a bivariate context show that the size of these two tests is not very sensitive to misspecification errors (omission of a relevant variable). For the two tests we get LR(6)=3.207 with P-value=0.783 and CM(6)=2.531 with P-value=0.865. Thus, both tests suggest the absence of any significant correlation involving the residuals of the recursive triangular model.

labour cost-cutting strategy.[57]

The choice of the exogenous regressors, x_{ij}, to be used in the empirical model was guided by the literature on downward wage rigidity. These include regressors aimed at measuring the importance of workers' and firms' attributes such as tenure, the proportion of high-skilled blue- and white-collar workers, the proportion of permanent employees or of employees covered by collective wage agreements, the importance of competition, etc. The Appendix describes how they were constructed.

We start by investigating how the exogenous regressors affect the use of the labour cost-cutting strategies, and then proceed by analysing the relationships among these strategies, with a special focus on wage-freezes and employment.

Effects of the exogenous regressors

For ease of presentation, we grouped the exogenous regressors into the following four categories: 1) labour force composition, 2) union activity, 3) barriers to wage freezing and 4) other characteristics.

Labour force composition

This group includes the regressors that provide information about the labour force composition of the firm: proportion of workers with less than 5 years of tenure, the proportion of high-skilled blue- and white-collar workers, and the share of permanent employees.

According to the turnover model (Stiglitz (1974)), wages of high-tenured workers are expected to be more rigid downwards than those of low-tenured workers, but it may also be argued that high-tenured workers are more likely to face higher costs of job loss and thus might be expected to have lower bargaining power and thus lower degree of

[57]The average marginal effects were calculated from the difference in the predicted probabilities conditional on marginal changes for continuous regressors and zero and one changes for discrete variables in each equation. We notice that in our triangular model the total marginal effect on y_j from a covariate x_k may be decomposed into the sum of a direct effect (the partial effect computed directly from the equation for y_j) and an indirect effect coming from the contribution of the equations that precede y_j in the triangular model. For instance the impact of x_k on the probability of "reduce employees" involves a direct effect through the "reduce employees" equation and an indirect effect from the use of the other margins: "base-wage freezes", "flexible margins" and "cheaper hires" (provided x_k enters those equations as a regressor). Figures in Table 4.5 refer to the total marginal effects with bootstrapped standard errors.

Table 4.4: Labour cost-cutting strategies:
Probit estimates

Regressors	Base-wage freezes	Flexible margins	Cheaper hires	Reduce employees
constant	-0.5240^{**} (0.2561)	-0.1761 (0.2371)	-1.1774^{***} (0.2092)	1.3367^{***} (0.2353)
tenure less than 5 years	-0.1335 (0.2805)	0.0106 (0.2281)	0.3553^{*} (0.2228)	-0.7819^{***} (0.2241)
high-skilled blue-collar	0.0055^{***} (0.0019)	0.0005 (0.0018)	0.0045^{***} (0.0018)	-0.0036^{*} (0.0019)
high-skilled white-collar	0.0059^{**} (0.0026)	0.0041^{*} (0.0025)	0.0078^{***} (0.0023)	-0.0054^{**} (0.0027)
permanent employees	0.0831 (0.1751)	-0.2539^{*} (0.1316)	-0.2184 (0.1718)	-0.2217 (0.1725)
coverage	-0.0397 (0.1114)	-0.0081 (0.1115)	0.0716 (0.1190)	0.2859^{**} (0.1208)
legislation	-0.1866 (0.1343)	0.1291 (0.1363)	–	–
reputation of the firm	-0.4855^{***} (0.1254)	-0.2232^{*} (0.1201)	–	–
workers attraction	0.1392 (0.1240)	-0.2188^{*} (0.1281)	–	–
openness	-0.0447 (0.1685)	0.2649^{*} (0.1481)	0.3044^{**} (0.1481)	0.1105 (0.1665)
size	-0.0381 (0.1311)	0.0110 (0.1140)	0.1484 (0.1276)	0.0828 (0.1304)
energy	-0.1919 (0.3816)	-0.3255 (0.3376)	0.2247 (0.3788)	0.2675 (0.4056)
construction	-0.0780 (0.2121)	0.0954 (0.1947)	0.0974 (0.2327)	0.2908 (0.2278)
trade	-0.2370 (0.1811)	-0.0677 (0.1552)	0.0828 (0.1656)	0.0283 (0.1915)
business services	-0.0882 (0.1611)	0.2014 (0.1544)	0.0605 (0.1635)	-0.0116 (0.1586)
wage freezes	–	0.1552 (0.1107)	-0.3621^{***} (0.1330)	-0.6208^{***} (0.1288)
flexible margins	–	–	0.0343 (0.1088)	-0.2055^{*} (0.1120)
cheaper hires	–	–	–	-0.2137^{*} (0.1256)
Number of observations	χ^2= 37.20 (P=0.00)	χ^2= 26.26 (P=0.04)	χ^2= 44.9 (P=0.00)	χ^2= 67.60 (P=0.00)
N=635	R^2 =0.047	R^2 =0.036	R^2 =0.045	R^2 =0.083

Bootstrapped standard errors in parentheses.

Table 4.5: Labour cost-cutting strategies:
Probit Model - Average marginal effects

Regressors	Base-wage freezes	Flexible margins	Cheaper hires	Reduce employees
tenure less than 5 years	-0.0410	0.0016	0.1211^{*}	-0.2371^{***}
	(0.0841)	(0.0857)	(0.0717)	(0.0669)
high-skilled blue-collar	0.0017^{***}	0.0003	0.0013^{**}	-0.0015^{***}
	(0.0006)	(0.0007)	(0.0005)	(0.0006)
high-skilled white-collar	0.0018^{**}	0.0017^{*}	0.0023^{***}	-0.0023^{***}
	(0.0008)	(0.0009)	(0.0007)	(0.0008)
permanent employees	0.0260	-0.0946^{*}	-0.0748	-0.0638
	(0.0551)	(0.0483)	(0.0509)	(0.0552)
coverage	-0.0122	-0.0038	0.0254	0.0893^{**}
	(0.0337)	(0.0417)	(0.0398)	(0.0368)
legislation	-0.0594	0.0456	0.0075	0.0089
	(0.0424)	(0.0509)	(0.0058)	(0.0098)
reputation of the firm	-0.1544^{***}	-0.0953^{**}	0.0170^{**}	0.0368^{***}
	(0.0388)	(0.0451)	(0.0082)	(0.0110)
workers attraction	0.0424	-0.0817^{*}	-0.0059	-0.0033
	(0.0369)	(0.0486)	(0.0063)	(0.0092)
openness	-0.0136	0.1007^{*}	0.1085^{**}	0.0227
	(0.0496)	(0.0555)	(0.0503)	(0.0542)
size	-0.0117	0.0035	0.0511	0.0241
	(0.0395)	(0.0429)	(0.0418)	(0.0398)
base-wage freezes	–	0.0596	-0.1158^{***}	-0.2023^{***}
		(0.0417)	(0.0393)	(0.0423)
flexible margins	–	–	0.0115	-0.0636^{*}
			(0.0359)	(0.0333)
cheaper hires	–	–	–	-0.0663^{*}
				(0.0388)

The average marginal effects include both the direct and indirect effects (see footnote 13). Bootstrapped standard errors in parentheses.

downward wage rigidity.[58] Whether higher tenure is associated with higher or lower wage rigidity is therefore an empirical matter.

The results for this regressor indicate that it does not have a significant impact on the two compensation related margins, suggesting that it is not a relevant variable as regards firms' decisions on freezing base-wages or reducing the "flexible margins". In contrast, firms with a higher proportion of less experienced or younger workers are more likely to use the margin "cheaper hires". This result suggests that firms with a higher proportion of less experienced or younger workers are also the ones where quits are more frequent, allowing firms to reduce labour costs by paying lower wages to new employees. This result may be due to the prevailing dual labour market in Portugal which provides very high protection to older workers with open-ended contracts and very little to the younger ones with fixed-term contracts (see Centeno and Novo (2012)). In the case of "reduce employees", however, the coefficient is negative suggesting that firms with higher proportion of high-tenured workers are more likely to reduce employment in the face of negative shocks. This effect may stem from the fact that the proportion of high-tenured workers is proxying the age of the firm and collective dismissals being more frequent in older firms.[59]

The literature also suggests that wages of high-skilled or white-collar workers are likely to display higher downward rigidity than those of low-skilled or blue-collar workers either because the effort of high-skilled workers is more valuable and more difficult to monitor or

[58] If we consider the tenure profile of wages predicted by Lazear (1979), who suggests that workers are likely to earn less than the value of their marginal productivity (VMP) when they are young and to earn more than their VMPs when they are old, together with the shirking model (see Shapiro and Stiglitz (1984)), we conclude that the cost of job loss may be higher for older workers and workers with higher tenure. In fact, it is typically more difficult for older workers to find a new job and workers with long tenure often lose their tenure component of wages when changing jobs.

[59] Tenure is usually seen as an endogenous variable in wage or dismissals equations defined at the worker level, where tenure endogeneity is due to unobserved worker's match and/or heterogeneity effects. However it is unclear whether one should expect tenure endogeneity to be an important issue for equations defined at the firm level and pertaining not to wage or unemployment levels equations, but to the probability of a firm freezing wages or reducing employment. Yet, to see whether tenure endogeneity could be a problem in our equation for "reduce employees" (tenure is not significant in the equations for "base-wage freezes" and "flexible margins"), we carried out a simple endogeneity test by estimating a bivariate probit model involving the equation for "reduced employees" (which includes tenure as a regressor) and an equation for tenure, but the test results clearly suggested the absence of any significant endogeneity problem.

because costs of hiring and training costs are higher for high-skilled and/or white-collar workers making firms more reluctant to cut their wages (see, for instance, Shapiro and Stiglitz (1984), Akerlof (1982) and Akerlof and Yellen (1990)).

From Tables 4.4 and 4.5, we see that, in comparison to low-skilled workers (blue- and white-collar), firms with more high-skilled workers are more likely to use the first three margins of adjustment: "base-wage freezes", "flexible margins" and "cheaper hires", but less likely to "reduce employees". These results, apparently not in line with most theories, are likely to reflect a greater use of flexible pay components among high-skilled workers.[60]

To the extent that workers with permanent contracts have more bargaining power in the wage-setting process than workers with temporary contracts, the "insider-outsider model" (Lindbeck and Snower (1988)) will imply higher wage rigidity for the former group of workers. From Tables 4.4 and 4.5, we see that the impact of the share of permanent employees on each of the margins tends to be negative (the exception is "base-wage freezes"), even though not statistically significant for most of the margins. In line with the theory, this result suggests that the higher the share of permanent workers, the harder it is, in general, to use the adjustment margins.

Union activity

The role played by labour unions in the wage setting process and the employment protection legislation is also likely to have strong implications for wage rigidity and for employment responses to shocks. The higher is the unions' bargaining power, the more rigid wages are expected to be and thus changes in employment are also likely to be higher. For instance, in the model developed in Holden (2004), downward wage rigidity is likely to be stronger the higher the coverage of collective agreements and the stricter the employment protection legislation. The idea is that with collective wage agreements wage cuts need the consent of employees and such cuts are more difficult to implement under stricter employment protection legislation.

[60]In practice, the sign and magnitude of the estimated parameters for some regressors, in the model for a given margin, are likely to depend not only on workers' relative bargaining power but also on how widespread that margin is across the different type of workers. For instance, the use of the "flexible margin" (bonuses, benefits or promotions) is likely to be more widespread among the class of high-skilled and/or white-collar workers. Under these circumstances, firms with higher proportion of high-skilled and/or white-collar workers may emerge in the estimated models as displaying higher probability of reducing the flexible margin, in contrast to what the theory would suggest.

In order to capture the role played by unions in the wage setting process, we included the variables "coverage" and "legislation" in the model. The first measures the proportion of workers covered by collective agreements and the second is a dummy variable which equals one if the firm considers labour regulation or the collective wage agreement as a relevant or very relevant factor that prevents wages from being cut or frozen.[61] From Tables 4.4 and 4.5, we see that the two regressors, with the exception of "reduce employees" are not very relevant to explain differences across firms in the use of the different cost-cutting strategies. In the case of coverage, we see that it increases the likelihood of a firm reducing employment, which suggests that the presence of unions does not limit the firms' ability to adjust the quantity margin.

Barriers to wage freezing

Efficiency wage theories and, in particular, the adverse selection model or the sociological models suggested in the literature may also explain why some firms do not freeze or cut wages in the event of negative shocks (see Katz (1986) and Campbell and Kamlani (1997)). According to these models, firms may be very reluctant to cut back wages or other compensation components if they think that would reduce workers effort and/or induce workers to shirk or to leave the firm, consequently increasing monitoring, supervising and/or turnover costs. In order to capture these ideas, we included in the model the variables "reputation of the firm" and "workers attraction". These are dummy variables which equal one if the firm considers that the negative consequences for the reputation of the firm and the difficulties in attracting new employees are relevant or very relevant factors that prevent cutting or freezing their nominal wages. From Tables 4.4 and 4.5, we see that the impact of these two regressors is negative both for "base-wage freezes" and "flexible margins", which means that these two obstacles to reducing or freezing base wages are also obstacles to reducing the "flexible margins". Interestingly, we notice that these two regressors do not enter the equations for "cheaper hires" and "reduce employees" directly, but they exert an indirect effect on these two margins, which is particularly significant in the case of "reputation of the firm". By reducing the probability of a firm

[61] Notice that "legislation", "reputation of the firm" and "workers attraction" are included only in the first two equations. On the one hand, we believe that these regressors are capturing firm's characteristics that are expected to be more relevant for compensation related components and, on the other, by excluding them from the other two equations, we intend to ensure proper empirical identification of the model. See also footnote 9.

freezing base wages or using the "flexible margins", this regressor indirectly increases the probability of a firm using the margins "cheaper hires" and "reduce employees".[62]

Other characteristics

International economic integration is likely to increase both competition and factor substitutability, thus increasing the elasticity of labour demand and labour productivity. Firms operating in such an environment should also feel stronger pressure to reduce costs and thus one may expect a more intense adjustment of wages and employment in reaction to shocks. But wage rigidity may also vary with firm size, as well as with the type of sector in which the firm operates. If monitoring costs and/or turnover costs are higher in larger firms (Oi (1983) and Barron et al. (1987)) such firms are more likely to pay efficiency wages in order to reduce the probability of shirking or to avoid the hiring and training costs and thus to exhibit stronger downward wage rigidity.

In order to account for these possibilities we included in the model the regressors openness, size and four sectoral dummies. Openness measures the importance of exports for the firm (is a dummy variable that equals one if the share of exports on total sales is 50 percent or higher). From Tables 4.4 and 4.5, we see that firms where exports account for a higher share of total sales are also firms that adjust more their "flexible margins" and take advantage of existing "cheaper workers", in line with what could be expected.

From Tables 4.4 and 4.5, we conclude that large firms do not make more intensive use of the labour cost-cutting strategies than small firms. A similar conclusion holds for the sectoral dummies in Table 4.4, suggesting that the use of labour cost-cutting strategies does not vary significantly across sectors, as the analysis in Section 4.4 suggested.

[62]In this work, we assume that bonuses and other monetary and non-monetary benefits are more flexible than base wages. This seems a reasonable hypothesis for countries like Portugal where base wages cannot be cut for legal reasons. However, in general, this is as debatable assumption. On the one hand, it may be argued that benefits over which the firm has at least some discretion are likely to be less rigid than wages because firms have more (and more subtle) ways to lower benefits than to lower wages. It has also been suggested that one of the reasons firms provide some benefits to employees is to reduce nominal wage rigidity (see Oyer (2005)). But, on the other hand, it may be claimed that many of the theories suggested in the literature to justify the presence of downward nominal wage rigidity are likely to apply to benefits too. In particular, efficiency wage theories would suggest that firms may be very reluctant to cut back bonuses and other benefits for the reasons presented above. The estimated results for the covariates "reputation of the firm" and "workers attraction" show that this type of effect is indeed present in data. Thus, in general, whether bonuses and benefits are significantly less rigid downwards than base wages is to be seen as an empirical matter.

Relationships among the labour-cost cutting strategies

In general, we may expect the adjustment of a given margin to depend on the degree of rigidity of the other margins. For instance, the probability of a firm using employment adjustment as a reaction to a negative labour demand shock is expected to be higher when base wages are rigid and smaller if alternative more flexible margins are available.

We start by noticing that the estimated results in Tables 4.4 and 4.5 are consistent with the preliminary analysis presented in section 4.4. From the probit equation for "reduce employees", we see that "base-wage freezes", "flexible margins" and "cheaper hires" have been used as substitutes for employment reduction by Portuguese firms. In particular, from Table 4.5, we conclude that the probability of a firm reducing employment is around 20 percentage points lower for a firm that has frozen base wages, around 6.4 percentage points lower for a firm that has used the "flexible margins" and around 6.6 percentage points lower for a firm that has used the "cheaper hires".

The probability of a firm using "cheaper hires" is around 11.6 percentage points lower for a firm that has frozen base wages. This result suggests that "cheaper hires" and "base-wage freezes" were used as substitutes by firms, i.e., "cheaper hires" were mainly used in situations in which firms were unable to freeze base wages following a negative labour demand shock or to compensate abnormal or unexpected base-wage increases following a negative labour supply shock.

In contrast, the "flexible margins" do not emerge as substitutes to "base-wage freezes". That would be the case if they had been mainly used to compensate for abnormal or unexpected base-wage increases. Rather, the relationship between these two margins is positive (even though not significantly so) which means that the "flexible margins" have been predominantly used as a complement to "base-wage freezes" in reaction to negative labour demand shocks.

The probability for a firm of reducing employment if it has frozen base wages and used the "flexible margins" is around 27 percentage points lower than for an otherwise identical firm, and the probability for a firm of reducing employment if it has frozen base wages and used the "flexible margins" and the "cheaper hires" is around 35 percentage

points lower than for an otherwise identical firm.[63]

These results show that base-wage flexibility has a strong negative impact on the probability of a firm reducing employment, and that such effect has been significantly strengthened by the availability of alternative margins of labour cost adjustment, like the "flexible margins" and the "cheaper hires".

4.6 Concluding remarks

The studies aimed at assessing the extent and the effects of nominal wage rigidities have focused mainly on base wages or permanent wages (base wages plus the other components that are paid regularly on a monthly basis, such as meals allowances, tenure-related components, etc.), leaving aside potentially more flexible pay-components such as performance related bonuses and other monetary and non-monetary benefits which may strongly attenuate the negative impact on employment of base-wage rigidities.

Using survey data, this chapter investigates the implications for employment of base-wage rigidities together with other strategies that Portuguese firms have used to cut labour costs in the event of exogenous negative labour demand or supply shocks.

Our dataset shows that, among the firms that have reduced labour-costs, the reduction in the number of employees ("reduce employees") was by far the most commonly used strategy (around 72 percent of the firms) followed by the strategy "flexible margins", which includes the reduction or elimination of bonus payments and other monetary benefits, the reduction or elimination of non-monetary benefits and the slowdown or freezing of the rate at which promotions are filled (around 45 percent of the firms). The recruitment of new employees with a wage lower than the one of those who left the firm ("cheaper hires") was used by around 30 percent of the firms and around 26 percent of the firms have resorted to "base-wage freezes".

We find significant heterogeneity in the use of each of these strategies across firms.

[63] These correspond to the following probabilities (not shown in Table 4.5):
Prob($y_4 = 1|y_1 = 1, y_2 = 1, x_4$) - Prob($y_4 = 1|y_1 = 0, y_2 = 0, x_4$) and
Prob($y_4 = 1|y_1 = 1, y_2 = 1, y_3 = 1, x_4$) - Prob($y_4 = 1|y_1 = 0, y_2 = 0, y_3 = 0, x_4$) respectively, where y_4=reduce employees, y_3=cheaper hires, y_2=flexible margins, y_1=base-wage freezes and x_4=vector of exogenous regressors entering equation for y_4.

The use of each margin depends on several workers' and/or firms' attributes such as the tenure and skills distribution, measures of the unions' bargaining power, as well as some indicators of the economic environment in which firms operate. In particular, firms operating mainly in the foreign market, a more competitive environment, tend to use some of these strategies more heavily.

The econometric results suggest that the strategy "cheaper hires" is used as a substitute for "base-wage freezes" by Portuguese firms, i.e., it is predominantly used in situations in which firms do not freeze base wages after a negative labour demand shock or to compensate abnormal or unexpected base-wage increases after a negative labour supply shock. In contrast, the relationship between the strategies "flexible margins" and "base-wage freezes" is positive (even though not significantly so) which suggests that the "flexible margins" are predominantly used as a complement to "base-wage freezes" in reaction to negative labour demand shocks.

We also find a clear negative association between the margin "base-wage freezes", which we use as a measure of base-wage flexibility, and the strategy "reduce employees". In particular, we estimate that the probability of a firm reducing employment is around 21 percentage points lower for a firm that has frozen base wages than for an otherwise identical firm. The ability to use the "flexible margins" or "cheaper hires" also decreases the probability of a firm reducing employment (between 6 and 7 percentage points). Together, the probability for a firm of reducing employment if it uses the strategies "base-wage freezes", "flexible margins" and "cheaper hires" is around 35 percentage points lower than for an otherwise identical firm.

Overall, we conclude that base-wage flexibility has a strong positive impact on employment, and that such positive impact has been significantly strengthened by the possibility of firms resorting to alternative margins of labour cost adjustment, like more flexible compensation components (bonuses, benefits and promotions) and the recruitment of new employees at wages lower than those received by the employees that have left the firm.

Appendix - The covariates

In this Appendix, we describe the covariates used in the probit models whose results are presented in section 4.5, and provide the corresponding summary statistics. The details are as follows:

Tenure less than 5 years – Proportion of employees whose tenure is less than 5 years.

High-skilled blue-collar – Proportion of High-skilled blue-collar employees in total employment.

High-skilled white-collar – Proportion of High-skilled white-collar employees in total employment.

Permanent employees – Dummy variable that is equal to one if the proportion of permanent workers is higher than 98 percent of total workforce.

Coverage – Dummy variable that is equal to one if the proportion of employees covered by collective agreements is equal to 80 percent or higher.

Legislation – Dummy variable that equals one if the firm considers labour legislation or the collective agreement as an important or very important obstacle to freeze wages in a context where the firm needs to reduce costs.

Reputation of the firm – Dummy variable that equals one if the firm considers that the negative impact on firm's reputation is an important or very important obstacle to freeze wages in a context where the firm needs to reduce costs.

Workers attraction – Dummy variable that equals one if the firm considers that the difficulties in attracting new employees is an important or very important obstacle to freeze wages in a context where the firm needs to reduce costs.

Openness– Dummy variable that equals one if the proportion of sales in the foreign market is 50 percent of total sales or higher.

Size – Equal to one if the number of employees is larger than 100.

Price autonomy – Equal to one if the firm considers that it has autonomy to set the price (as opposed to cases in which the price is regulated by an external entity, or determined by the main competitors or main customers).

Domestic competition – Equal to one if the degrees of price competition experienced

by the firm vis-à-vis its main product is classified as "strong" or "severe" (as opposed to "weak" or "no competition").

Share of temporary employees – Proportion of temporary employees in total employment.

Cost price rigidity – Equal to one if the firm reacts to significant positive cost shocks with a long lag (changes the price more than a year after the shock).

Demand price rigidity – Equal to one if the firm reacts to significant negative demand shocks with a long lag (changes the price more than a year after the shock).

Energy – Equal to one if the firm operates in the energy sector.

Construction – Equal to one if the firm operates in the construction sector.

Trade – Equal to one if the firm operates in the trade sector.

Business services – Equal to one if the firm operates in the business services sector.

Chapter 5

Upward nominal wage rigidity

5.1 Introduction

The role played by labor market institutions in molding the dynamics of employment and the structure of wages is a matter of considerable debate both empirically and conceptually. Even though there is an ample discussion about the role of labor market institutions and its potential contribution to the sluggish adjustment of employment, there is still scant empirical evidence at the micro level about the way collective agreements influence firms' hiring and firing decisions.

Many institutional factors may hamper the efficient allocation of workers and jobs. Caballero and Hammour (2000) stress that a number of distortions in product, input, and credit markets can introduce inefficiencies in the reallocation process. Aside from the impact on flows stemming from quantitative restrictions on labor market adjustment, wage-setting policies, such as legal provisions restricting wage adjustment, wage schedules determined at the sector level, or the presence of national minimum wages also have an impact on the reallocation.

A factor that might affect the allocation of workers and jobs is the widespread practice of extending collective bargaining agreements to non-subscriber workers and employers. Since these agreements establish wage floors for most job titles, their frequent extension is equivalent to setting a wide range of compulsory minimum wages, which are regularly

adjusted upward, even if the scope in most cases is restricted to some sectors or industries. In some firms these extensions can result in a wage structure that may not be appropriate for some workers, causing fewer hirings and/or added dismissals. As pointed out by Cahuc and Zylberberg (2009) and Teulings and Hartog (2008), the potential job losses are the result of setting wage floors above the marginal productivity for some workers in firms that are bound by those extensions.

Legal provisions for mandatory extensions exist in several European countries such as Spain, France, Germany, Italy, the Netherlands, and Belgium, and they explain to a great extent the large gap observed between union density and union coverage.[64] The extension of contracts is also an important feature of the Portuguese wage setting system. Martins (2014) shows that between 2007 and 2011 around 90 percent of the sectoral collective wage agreements in Portugal were extended by the Ministry of Employment. The extension of collective agreements were issued almost uniformly throughout the twelve months of the year.

The scattered timing of these extensions introduces a type of wage rigidity that is very close to that emphasized in some macroeconomic models (Olivei and Tenreyro (2007, 2010) and Card (1990)). These models underscore the importance of the timing of collective wage agreements for the employment fluctuations observed in some advanced economies. Due to contract staggering, they show that wage rigidity is toned down in periods when collective agreements are under negotiation, i.e. the impact of a negative shock on employment depends on the timing of the wage negotiations. If the shock occurs at the time of wage negotiations, the wage bargaining process can reflect the impact of the shock and wages are set accordingly; if the shock occurs after wages have been settled by contracts, wages are unable to be adjusted and the risk of job losses is magnified. Catalán and Villanueva (2012) test this hypothesis for Spain in the period surrounding the late-2008 economic decline. They show that the probability of job separation increased significantly for workers covered by contracts negotiated before the drop in economic activity. Their results also suggest that the automatic extension of collective agreements in Spain during this period accounted for 36 percent of the increase in the

[64]See Visser (2013) for a comprehensive survey of wage bargaining institutions in a wide number of developed countries.

probability of job separation for low-skilled workers.

The impact of the (scattered) extension of collective agreements on employment is also examined by Martins (2014). Using data for Portugal covering the period between 2007 and 2011, this study analyzes the impact on employment over the four-month period after the extension of a collective agreement. The results show that over this time window the total number of workers in an industry fell by 1.7 percent. The detrimental effect of these extensions on employment is driven to a large extent by the fall in firms' hirings and not by an increase in separations, which remain largely unaffected. On the other hand, non-formal employment (the so-called service providers), which is not subject to the extension of wage floors, increased by 1.1 percent. In complement to this exercise the study also examines the impact of the extension of collective agreements on firm entry and exit. The evidence suggests that the entry of new firms is not affected by the extension of collective agreements, while the number of firms that leave an industry increases by 4 percent.

This work examines the microeconomic link between the increase in wage floors through automatic extension and the employment outcomes. As in Martins (2014),it is measured the impact on firms' hirings and separations, and the probability of closure resulting from firms' obligations to adjust their wages upward in order to comply with the new wage floors. This phenomenon will be called *upward nominal wage rigidity*. However, unlike the approach followed by Martins (2014), the focus in not on the timing of the extensions but on the magnitude of their impact on each particular firm. For this purpose for each firm (on the basis of each job title) it is computed the increase in the total wage bill necessary to comply with new collective wage agreement (*implied wage bill growth*).

The impact of the upward nominal wage rigidity on each particular firm is conditional on its workers' position in the wage distribution. In each firm we can distinguish two major groups of workers: those who are already collecting a base wage equal to or above the newly-agreed wage floor and whose contribution to the implied wage bill growth is zero; and those who are receiving a base wage that is below the new wage floor and whose contribution to the implied wage bill growth is the difference between their current base wage and the new wage floor. The impact of increasing the wage floors is potentially more

acute in firms with a greater fraction of the latter group of workers. Our approach differs from that of Martins (2014) also because Martins assumes that the impact of extensions is homogeneous for all workers in the same industry.

In the second part of the study a different but somewhat complementary exercise is performed. The analysis will be restricted to the newly-hired workers, i.e. workers with job tenure of less than one year. Most micro-level empirical research aimed at analyzing the degree of wage rigidity has been mostly concerned with wage changes of individual employees. This invariably restricts the focus of analysis to wages in ongoing employment relationships (see Haefke et al. (2007)). In contrast, the degree of rigidity of wages of newly-hired workers has received much less attention, despite the recognized importance of wages of this particular labor force group for job creation and for understanding the behavior of wages over the business cycle (see Pissarides (2009) and Galuscak et al. (2012)): newly-hired workers are the "marginal" workers that affect the decision of firms to create new jobs.[65]

The purpose of this exercise is to identify the extent to which firms' insider forces are important for the determination of wages of newly-hired workers. Bils et al. (2014) provide empirical evidence supporting the notion that the wages of new hires are partially determined by the prevailing wages of stayers. As Blanchard and Summers (1987) point out, if wage changes are essentially determined by insider factors (such as the internal wage schedule or the wages of workers with the same qualifications), this may generate hysteresis in the economy, so that the impact of shocks may last for long periods. We first analyze the relative importance of internal factors *vis-à-vis* the external factors (such as the wages of workers with similar qualifications and experience or the availability of workers with similar characteristics in the labor market) in the determination of entry wages. We then investigate the impact of the external wages on job flows (i.e. hirings and separations) of newly-hired workers as well as on the probability of firm closure.

[65]Most empirical research that distinguishes entry wages from wages of ongoing jobs focuses on their different behaviour over the business cycle. Such studies show that wages of newly-hired workers are considerably more volatile that the wages of incumbent workers. However, since the number of workers in ongoing jobs is higher than the number of new hires, the aggregate wage invariably becomes rigid. These studies have highlighted the idea that the wage response to aggregate labor conditions differs considerably between workers in ongoing jobs and newly-hired workers. Carneiro et al. (2012) use matched employer-employee data for Portugal 1986-2005 and find that after controlling for both firm and worker heterogeneity, entry wages are much more procyclical than wages of ongoing jobs.

The remainder of this work is structured as follows. A description of the main institutional characteristics of the wage setting process in Portugal is presented in Section 5.2. Section 5.3 describes the main features of the database used and explain how the key variables were obtained. Section 5.4 looks closely at the employment effects of increases in the wage floors for each specific job title and estimates the impact of externally driven wage increases on the probability of firm exit. Section 5.5 attempts to disentangle the internal and external drivers of the wages of newly-hired workers in order to reveal the link between external (internal) wages and job flows. Finally, Section 5.6 summarizes the main results of this research and suggests some of their implications.

5.2 Institutional Wage Setting in Portugal

This section succinctly describes some of the main institutional characteristics of the wage setting process in Portugal.

The Portuguese Constitution provides the legal principles of collective bargaining and grants unions the power to negotiate. The effects of the agreements are formally recognized and considered valid sources of labor law. Concerning the bargaining mechanisms, two regimes can be distinguished: the conventional regime and the mandatory regime. Conventional bargaining results from the direct negotiation between employers' and workers' representatives. A mandatory regime, on the other hand, does not result from direct bargaining between workers and employers, but is instead dictated by the Ministry of Employment. The systematic extension of industry-wide agreements by the Ministry of Employment is the most important mechanism shaping the formation of wages. Indeed, even though by law the collective agreement only binds the trade union members and the employer associations' affiliated firms that are parties to the agreement, there is no legal mechanism that obliges the trade unions and the employers association to reveal their constituency. This legal conundrum is almost always circumvented by extending the agreement to the whole sector through the use of the so-called "*portarias de extensão*".[66]

[66]Article 514 of the Portuguese labor code states that "a collective agreement [...] in force can be applied, entirely or partly, by an extension ordnance to employers and employees in the economic activity and profession considered in the collective agreement. The extension is possible after weighting the social and economic circumstances that may justify it, in particular the identity or economic social similarity

This means that wage agreements reached by trade unions and employers' associations with even very low representation have a strong impact in setting wage floors.[67] Indeed, in any given year collective bargaining sets around 30,000 minimum wages that correspond to 30,000 job-titles (see Carneiro et al. (2014), Torres et al. (2013), and Martins (2014)).

Since most collective agreements are industry-wide, covering companies with very different sizes and economic conditions, their contents tend to be general, setting minimum working conditions, especially the base monthly wage for each category of workers, overtime pay and the normal duration of work. Underlying the bargaining process there is a mandatory minimum monthly wage that sets the floor for wage negotiations.[68] National legal minimum wages and pervasive wage floors set by collective bargaining coupled with the legal prohibition of nominal wage cuts (that survives since the 1950s) creates a *de facto* situation of extreme nominal wage rigidity. In the context of the high inflation regime that characterized Portugal in the 1980s and 1990s, this restriction was not binding in real terms, as adjustments in real wages could be achieved by raising nominal wages at a rate below the inflation rate, or for firms paying wages above the corresponding new minimum, by reducing the wage drift. In such a setting, the higher the inflation rate the greater the leeway for manipulating the real wage.

However, in the current low-inflation regime nominal wage rigidity becomes an active restriction. Indeed, in this environment employers' response on the wage margin is limited to the possibility of reducing the wage drift or going for the lowest nominal wage increase possible, ultimately freezing wages. Hence, in a low-inflation regime negative shocks are expected to shift the employment distribution of nominal wage adjustment toward zero, the magnitude of real wage adjustment being conditional on the inflation rate. This is, in fact, what is observed during the current recession, in which the wage response is

of the cases in the extension and the underlying collective agreement."

[67] In 2012 a Government resolution stated that the extension would be possible only when the employers' subscribers to the agreements employ at least 50% of the workers of the relevant economic sector.

[68] Currently there is a unique legal minimum wage that applies to all workers. Workers formally classified as apprentices receive just 80% of the full rate. The minimum wage is updated annually by the parliament, under government proposal. Decisions on the level of the minimum wage are made on a discretionary basis, usually taking into account past and predicted inflation and after consulting the trade unions.

characterized as in the past by no (or limited) nominal negative variations (measured from base pay), but a much greater likelihood than in the past that wage variations are zero; there is also a salient move toward zero in the distribution of wage variations, corresponding approximately to the expected inflation rate and accentuating even more the low distribution spread.[69]

5.3 Dataset

5.3.1 Personnel Tables (*Quadros de Pessoal*)

The data used in this study come from a longitudinal matched employer-employee dataset known as the Tables of Personnel (*Quadros de Pessoal*). This unique dataset was created by the Portuguese Ministry of Employment and is constructed from a mandatory annual survey addressed to firms with wage earners. It has been conducted every year since 1986 with the exception of 1990 and 2001. The survey covers various firm and establishment characteristics, as well as a set of characteristics of the workforce. Being compulsory, it does not suffer from the non-response problems that often plague standard household and firm surveys. Furthermore, the survey covers almost all Portuguese employees, excluding only Public Administration.

The dataset includes information on the establishment (establishment identifier, location, industry, and employment), the firm (firm identifier, location, industry, legal form, ownership, year of start-up, employment, sales, and capital), and its worker (social security identifier, gender, age, education, skills, occupation, employment status, professional level, seniority, earnings, normal and overtime hours, time elapsed since the last promotion, and classification in the collective bargaining agreement).

[69] Dias et al. (2013) show that besides freezing the base wages, Portuguese firms make frequent use of a number of labor cost-cutting strategies, like freezing or cutting bonuses and other monetary or non-monetary benefits, slowing down or freezing the rate at which promotions are filled, or recruiting new employees at wages lower than those received by the employees that have left the firm. They provide evidence that the availability of these alternative labor-cost adjustment margins that firms can use in bad times makes dismissals a less likely outcome.

5.3.2 Bargained wage floor

The unique characteristics of our dataset with detailed information about the job title structure within each collective wage agreement provide the means to calculate with a great level of accuracy the bargained wage floor. The bargained wage floor for a given job title - a key variable in this study - is proxied by the modal base wage for each job title within each collective agreement. As shown in Cardoso and Portugal (2005), the mode of the distribution of the base wage corresponds with remarkable accuracy to the contractual wage set by collective bargaining.

5.3.3 Sample definition and general variables

The sample covers the period from 1986 to 2009, excluding the years in which the Personnel Tables have been discontinued (1990 and 2001). For the purposes of this study a subset of variables was selected, certain new variables created, and some observations removed. The final set of variables retained for analysis is given in Table 5.9 in Appendix A. A number of general restrictions were placed on the data used throughout the study. Given the specific purpose of this investigation (i.e. the impact of externally-set wage increases), the analysis excludes firms that apply firm-level agreements. In addition, the data exclude those individuals who were not working full time, who were aged less than 18 years and more than 60 years, who earned a nominal wage less than 80 percent of the legal minimum wage in each year or above the 99.9 percent quantile in each year, and who recorded errors in admission/birth dates, duplicate social security codes or other errors in their social security codes.[70]

The analysis performed herein examines the impact of extensions upon workers flows (hirings, separations and the net job creation), as well as upon the probability of firm exit (failure). Both hirings and separations were computed on the basis of social security identifiers: hirings correspond to the number of new social security identifiers reported by firms in each year (i.e. workers that are new in the database in a given year), whereas separations are the number of social security identifiers that were reported by firms in

[70]Individuals employed outside of mainland Portugal and those in agriculture, hunting, forestry, and fishing (as well as misclassified industries) were also excluded.

the previous year but not in the current year (i.e. workers that left the database in the current year). Both variables are divided by the number of workers in the previous year (hiring rate and separation rate). The net job creation rate is simply the difference between the hiring rate and the separation rate. The variable "failure" that is used to gauge the impact of extensions on the probability of firm closure is a binary variable that is equal to 1 in year t for firms whose individual identifier left the database in that year and 0 otherwise.

5.3.4 Specific sample restrictions and variables

In Section 5.4 is measured the employment effects of increases in the wage floors for each specific job title on the basis of a variable called *implied wage bill growth*. This variable is computed in the following way. For each firm based on each job title within the firm we calculate the increase between the actual base wage at time t and the new bargained wage floor set by the collective wage agreement for *t+1* (i.e. the increase in the wage bill necessary to comply with the new collective agreement). The implied wage bill growth corresponds to the aggregation of these changes for each firm assuming that the job title structure remains unchanged between year t and year *t+1*. In the imputation of the wage bill growth we exclude values above the 90th percentile to minimize measurement errors. Figure 5.1 shows the distribution of the implied wage bill growth weighted by the number of workers. The average implied wage bill growth in the sample period is 3.2 percent.

5.4 The impact of the upward nominal wage rigidity on job flows and firm closures

This section closely looks at the employment effects of increases in the wage floors for each specific job-title. For this purpose we compute for each firm, based on each job title within the firm, the increase in the wage bill necessary to comply with the new collective agreement. For this we took the job-title structure of the workforce of form i at year t, and assuming that the same exact job-title structure would prevail at year *t+1*, obtained

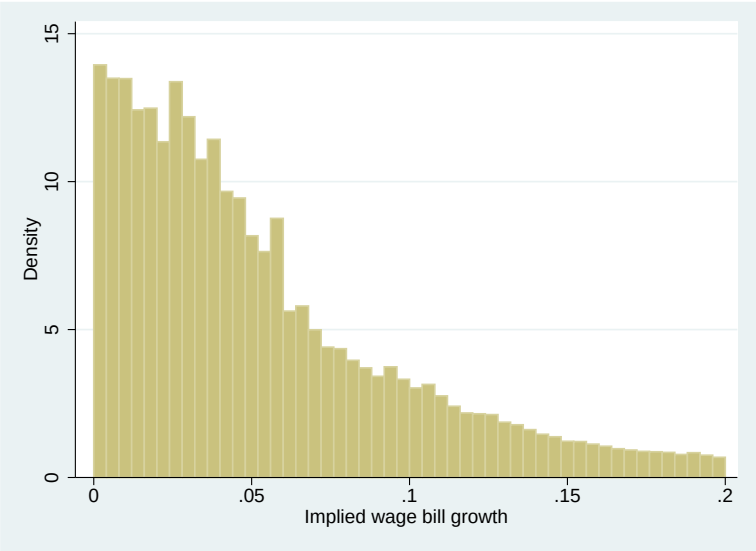

Figure 5.1: Distribution of the implied wage bill growth weighted by the number of workers

the increases in the base wage that would place those workers at the new wage floors, and aggregated all positive wage increases to define the *implied wage bill growth*. At this stage it is worth mentioning that there are potentially two types of workers: workers who are already collecting a wage equal to or above the newly-agreed wage. In this case the contribution to the implied wage bill growth will be zero; workers who are receiving a base wage that is below the new minimum. In this case, the contribution is, of course, the difference between the current base wage and the new wage floor.[71]

Within each firm both cases are possible. The larger the fraction of workers that are paid below the new job title wage floor, the larger will be the implied wage bill growth. Collective agreements that settle higher wage increases will also, of course, engender higher wage bill increases. The implied wage bill growth is our critical treatment variable. The identification of the employment effects of these externally imposed wage changes depends, of course, on the past wage policy of the firm, the job title structure of the workforce, and the size of the newly agreed wage floor increases. In this sense, this methodology is a straightforward generalization of the one suggested by Abowd et al.

[71] In our sample, on average 67 percent the workers receive wages below the new minimum wage: 25 percent are paid exactly at the current minimum, 22 percent receive a wage between the current and the new minimum, and 20 percent are even paid below the current wage floor.

(2000) to study the impact of minimum wage increases in France and the USA. Portugal and Cardoso (2006) exploit a similar strategy to analyze the impact of a subminimum wage hike on the workers' accession and separation rates.

To measure the effect of an increase in the wage bill implied by the updating of the wage floors settled by collective agreement on net job creation, we specified a simple labor demand equation in first differences:

$$\triangle y_{ft} = \xi \triangle wb_{ft} + \triangle x'_{ft}\beta + \lambda_t + \varepsilon_{ft} \tag{1}$$

where $\triangle y_{ft}$ stands for the net job creation rate, hiring rate, or separation rate in firm f at time t. $\triangle wb_{ft}$ represents the implied wage bill growth, x'_{ft} denotes a vector of explanatory variables (firm age, change in the market share and change in base wages), λ_t represents a set of time (yearly) effects, and ε_{ft} is a conventional error term.

The results provided in the firsts columns of Table 5.1 suggest a modest impact on the net job creation rate resulting from externally driven changes in the wage bill of the firms. According to our estimates, a 10 percent (real) increase in the wage bill leads to an employment decrease of 1.5 percentage points. The presence of firm's age, firm's average base wage, and firm's market share are not especially revealing but their inclusion (or exclusion) does not materially change the estimates of the implied wage bill growth regression coefficient. The estimates shown for the determinants of the hiring rate and the separation rate indicate that the impact of exogenous changes in wages produced via changes in collective agreements is largely driven by increases in separation rates (which increase by 1.56 percentage points in response to a 10 percent increase in the wage bill) rather than by decreases in hiring rates.

So far, we have taken the (job title specific) wage floors settled at the bargaining table as largely exogenous to the firm. But at least some firms are represented in the bargaining process. Since we cannot identify which firms are part of the bargaining and which are excluded, we still face endogeneity issues. One way to circumvent this problem is to account in the estimation for distinct time trend with each contract. A fully flexible way to proceed is simply to include a full set of contract/year dummies, removing (filtering) contract heterogeneity and contract time variation from the estimation. That is, the

Table 5.1: The impact of increases in bargained wage floors on firms' net job creation
OLS estimates

	Dependent variables					
	Net job creation		Hiring rate		Separation rate	
implied wage bill growth	−0.1514 (0.0451)	−0.1814 (0.0396)	0.0617 (0.0470)	0.0143 (0.0430)	0.1556 (0.0473)	0.1351 (0.0440)
firm age	−0.0133 (0.0013)	-	−0.0579 (0.0020)	-	−0.0391 (0.0019)	-
△market share	0.0296 (0.0296)	-	0.0466 (0.0290)	-	0.0182 (0.0315)	-
△base wages	−0.0145 (0.0044)	-	−0.0161 (0.0050)	-	0.0018 (0.0050)	-
number of firms	851,829	1,068,782	851,829	1,068,782	998,562	1,483,802
number of workers	8,382,456	9,372,755	8,382,456	9,372,755	9,035,794	10,253,881
yearly dummies	Yes					

Robust standard errors in parentheses. Results are weighted by firms' size based on the number of employees.

The sample excludes firms that apply firm-level collective agreements.

The original database covers the period from 1986 to 2009 (excepting 1990 and 2001). However, some years had to be excluded for estimation purposes (1986, 1989, 1999, 2000 and 2002) given the formulation of the dependent variables.

The "implied wage bill growth" for each firm results from the aggregation of the changes between the actual base wage at time t and the new wage floor set by the collective wage agreement for $t+1$ for all workers in the firm assuming that the job title structure remains unchanged. In the imputation of the wage bill growth we exclude values above the 90th percentile to minimize measurement errors.

Table 5.2: The impact of increases in bargained wage floors on firms' net job creation least square dummy variable estimates

	Dependent variables					
	Net job creation		Hiring rate		Separation rate	
implied wage bill growth	−0.2343 (0.0244)	−0.1562 (0.0215)	−0.1268 (0.0223)	0.0371 (0.0208)	0.0228 (0.0232)	0.0817 (0.0200)
firm age	−0.0211 (0.0005)	-	−0.0618 (0.0007)	-	−0.0334 (0.0007)	-
△market share	0.0288 (0.0247)	-	0.0395 (0.0258)	-	−0.0040 (0.0245)	-
△base wages	0.0172 (0.0033)	-	0.0119 (0.0033)	-	−0.0016 (0.0019)	-
number of firms	606,218	859,698	606,218	859,698	727,728	1,086,673
number of workers	2,293,543	2,951,842	2,293,543	2,951,482	2,568,741	3,406,289
collective wage agreements × year(s) dummies			YES			

Robust standard errors in parentheses.
Results are weighted by firms' size based on the number of employees.
See notes to Table 5.1 for additional details.

estimating equation is now:

$$\triangle y_{ft} = \xi \triangle wb_{ft} + \triangle x'_{ft}\beta + \lambda_{ct} + \varepsilon_{ft} \tag{2}$$

where λ_{ct} identifies the collective agreement ruling the bargained wages of firm f at time t.

Proceeding in this way we obtained the results shown in Table 5.2. The coefficients on the implied wage bill growth suggest a strong impact on the net job creation rate resulting from externally driven changes in the wage bill. However, differently from what we found before the estimates shown for the determinants of the hiring rate and the separation rate now indicate that the impact of exogenous changes in wages produced via changes in collective agreements is now largely driven by decreases in the hiring rate (which decrease by 1.27 percentage points in response to a 10 percent increase in the wage bill) rather than by increases in separation rates. These results are consistent with those provided by Martins (2014), despite the use of distinct identification strategies.

A frequently neglected dimension of the employment adjustment is its corresponding

extensive margin, that is, the entry and exit of firms (Addison et al. (2014)). In the current exercise any attempt to guess the effect of collective bargaining on the entry rates of firms would be a "*tour de force*", despite the potential importance of such an inquiry. Nonetheless, our sampling plan allows us to estimate how externally driven wage increases impact the probability of firm exit. To this end we specified a simple probit regression model taking the same covariates as before.

The regression results on the determinants of the failure of firms are given in Table 5.3. The main thrust of the estimation is the indication that the estimate of the quasi-elasticity of labor demand through firm closure is equal to 0.67, meaning that a 1 percent increase in the wage bill generated by the increase in the bargained wage floor increases the probability of firm closure by 0.67 percentage points. This appears to be a fairly sizeable effect, since the average failure rate in the current sample is around 11 percent (see Table 5.10 in Appendix A).

Table 5.3: The impact of increases in bargained wage floors on the probability of firm closure
probit estimates

	Dependent variable: failure			
	Probit estimates		Marginal effects	
implied wage bill growth	3.8199 (0.1081)	3.9319 (0.0848)	0.6659 (0.0188)	0.8053 (0.0173)
firm age	−0.1176 (0.0027)	-	−0.0205 (0.0005)	-
△market share	0.0683 (0.1499)	-	0.0119 (0.0261)	-
△base wages	0.0236 (0.0129)	-	0.0041 (0.0023)	-
△firm size	−0.2659 (0.0047)		−0.0463 (0.0008)	
number of firms	659,309	901,956	659,309	901,956
collective wage agreements × year(s) dummies			YES	

Robust standard errors in parentheses.
"Failure" is a binary variable that is equal to 1 for firms whose individual identifier left the database and 0 otherwise.
See notes to Table 5.1 for additional details.

5.5 The impact of external wages on hirings and separations of newly-hired workers

5.5.1 How important are external wages for the determination of wages of newly-hired workers

So far we have focused on the wage behavior of workers that were assumed to stay in the same firm, that is, of (potential) job stayers. Given the nature of the exercise we neglected by construction the wage behavior of new hires. But as discussed above, the determinants of entry wages are critical at both the theoretical and the empirical levels. In this section we shall attempt to disentangle the internal from external drivers of the wages of newly-hired workers. Once we succeed distinguishing between firms with different degrees of externally (internally) driven entry wages, we should be able to unveil the link between external (internal) wages and job flows.

The importance of internal wages driving entry wages has a number of implications. First, it may signify that firms more often than not choose to negotiate entry wages above the wage floors defined by the collective agreements. This may be due to fairness considerations or other strategic considerations (e.g., incentive contracting). In any case, such a finding would provide direct empirical evidence supporting the notion that the wages of new hires are partially determined by the prevailing wages of stayers, as hinted at in Bils et al. (2014). Second, by negotiating wages above the external option of the worker, those firms are more likely to avoid worker turnover and retain those workers, therefore decreasing worker separations. Third, because a significant fraction of firms offer wages above the minimum defined at the bargaining table (typically sectoral), they may benefit from the wage cushion (Cardoso and Portugal (2005)) engendered by the difference between the actual wage paid and the bargained wage. Confronted with a negative shock in the product demand or in the costs of inputs, those firms may better adjust through wages than firms that are remunerating their workers at the established minimum.

If this argument has some value, one should expect lower failure rates and less employment volatility among firms that are less constrained by external wages. On the other

hand, if the bargaining power of the workers, that is, the union power, is strong enough, wage floors agreed through collective negotiations may not leave space for firms to settle wages above the external wages. In this case, where external wages are binding (as in, for example, Dolado et al. (1997) for unskilled workers) the wage cushion will be small and the firms may lack room for maneuver to successfully adjust to negative product demand shocks. Fourth, there is convincing empirical evidence showing that that the wage policy of the firms is notoriously heterogeneous. The fact that firm fixed effects account for a large fraction of the wage variation (Torres et al. (2013)) is a clear sign that firms often cannot be taken as wage takers. Webber (2013) argues forcefully that the labor supply elasticities faced by the firms are relatively low, indicating that firms detain significant monopsony power (Manning (2003)). If, indeed, monopsony power plays an important role, it should influence the relative strength of internal and external factors in the determination of wages.

To better understand the nexus between entry wages and employment adjustments, we first provide a measure of the importance of inside and outside wages to next investigate, as before, the impact of externally driven wages on job flows. The exercise is restricted to the newly-hired workers, i.e. workers with a job tenure of less than 12 months. Furthermore, the analysis is also restricted to those cases where for each newly-hired worker there is at least one worker in the same firm and job title but with a job tenure of more than 12 months. A minimum of 10 hirings over the entire period is also imposed as a threshold for a firm to be included in the sample. In order to disentangle the internal from the external drivers of the wages of newly-hired workers, for each newly-hired worker in a particular firm we compute an *internal wage* and an *external wage*. The latter is simply the bargained wage floor that corresponds to the job title of the new hire in each year, whereas the *internal wage* is the modal base wage of all ongoing workers in the same job title, firm and year.

The way we measure the relative importance of internal and external wages driving the wages of new hires is simple but unconventional. In essence, what we do is run a regression of the entry wage on the internal and external wages as well as on a set of time dummies. Because we need to distinguish the wage policy of the firms, we allow the regression coefficients on the two wage regressors to change from one firm to another.

In other words, the model we wish to estimate relates the entry wages of workers to the "internal" and "external" wages in the same job title. Specifically, our model consists of:

$$w_{ifjt} = w^I_{fjt}\beta^I_f + w^o_{jt}\beta^o_f + \alpha_f + \lambda_t + \varepsilon_{ifjt} \tag{3}$$

where w_{ifjt} is the (log of) entry wage of worker i in firm f, in job j at time t, w^I_{fjt} is the corresponding "internal" wage (the modal wage of ongoing workers in the same job title, firm and year) and w^o_{fjt} is the "external" wage (the bargained wage floor for the same job title and year). The α_f is a standard firm fixed-effect that accounts for unique firm (or industry) characteristics that affect all entry wages alike (firm internal organization, higher productivity, etc) and λ_t is a time fixed effect. Note that the β coefficients in the above equation are specific to each firm, reflecting the fact that firms place different weights on "internal" and "external" wages when setting entry level wages. Direct estimation of the above model cannot be implemented using the standard procedure to deal with a model with one fixed effect. In Appendix B we detail the procedure to find the exact least squares solution for the parameters of the above model.

The regression coefficients of the (internal and external) wage variables can straightforwardly be interpreted as the weights attached to such drivers in the formation of starting wages.[72] Figures 5.2 and 5.3 show the distribution of both the internal wage and external wage fixed effects, whereas Table 5.4 illustrates how the mean of the distribution for the external wage fixed effect varies according to gender, sector, and worker age.

Results from Table 5.4 show that firm internal wage structure is relatively more important for the determination of wages of new workers: It accounts on average for 56 percent of the determination of base wages of newly-hired workers. However, the importance of externally-set wages is far from being negligible, as it accounts on average for 31 percent.

[72]To mitigate the unavoidable sampling error that result from firms with very low recruitments, we excluded weights below zero and above one.

Table 5.4: The determinants of wages of newly-hired workers internal vs. external factors

	Internal wage	External wage	Number of recruitments
Full sample	0.562	0.312	1,454,695
Men	0.571	0.309	894,157
Women	0.547	0.319	560,538
Manufacturing	0.554	0.334	444,129
Construction	0.585	0.341	280,846
Non-financial business services	0.548	0.277	417,259
Financial services	0.418	0.520	41,710
Trade	0.595	0.273	260,728
Workers older than 30	0.566	0.311	613,182
Workers under the age of 30	0.559	0.314	841,513

The "external wage" for a given newly-hired worker is the bargained wage floor for the corresponding job title and year, whereas the "internal wage" is the modal base wage of all ongoing workers in the same job title, firm and year. In both cases the values are expressed in logarithms.
The sample excludes firms that apply firm-level collective agreements.
Observations: 1,454,695 newly hired workers.

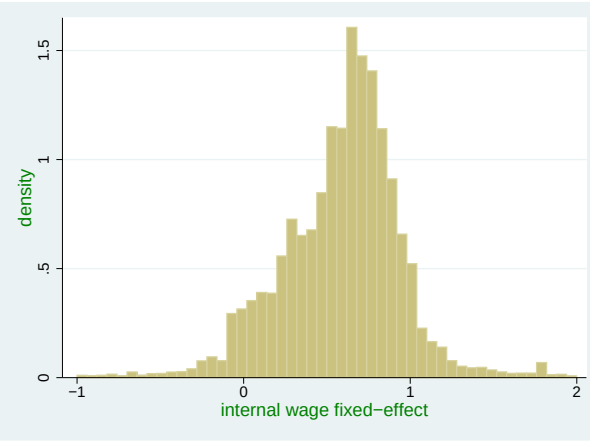

Figure 5.2: Distribution of the internal wage fixed-effect (weighted by the number of recruitments)

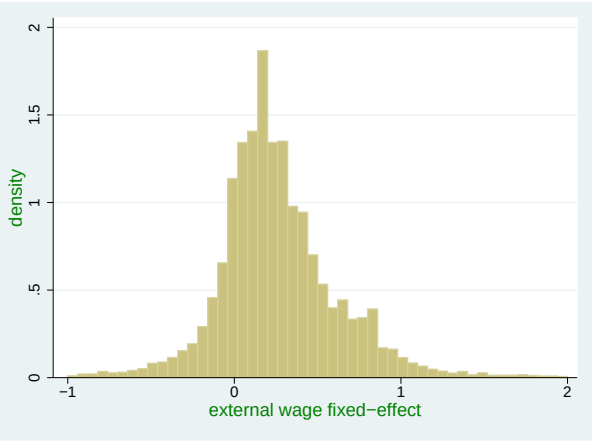

Figure 5.3: Distribution of the external wage fixed-effect (weighted by the number of recruitments)

5.5.2 How externally-set wages impact on firms' hirings and separations of newly-hired workers

The importance attached to the role of internal wages seems to vindicate the notion that entry wages are largely driven by the wages of job stayers, as forcefully argued by Bils et al. (2014). More generally, it is also consistent with the hysteresis story of Blanchard and Summers (1987). Galuscak et al. (2012) using survey data for 15 European countries provide evidence that suggests that the internal pay structure is more important for determining hiring wages than the external wage constraints. However, from the evidence that internal wages are good predictors of the wages of new hires it cannot be concluded that external wage constraints, such as those defined by wage floors, do not play a role. To shed some light on this issue we estimate a regression model on the determinants of job flows. In particular, we specified the following equation:

$$\triangle y_{ft} = \theta ew_f + \triangle x'_{ft}\beta + \lambda_t + \varepsilon_{ft} \tag{4}$$

where ew_f is the estimated external wage weight for firm f obtained from equation 3, that is $\hat{\beta}^o_f$. As before, $\triangle y_{ft}$ stands for the net job creation rate, hiring rate, or separation rate in firm f at time t, x'_{ft} denotes a vector of explanatory variables, λ_t represents a set

Table 5.5: The impact of externally set wages on firms' net job creation
OLS estimates

	Dependent variables					
	Hiring rate		Separation rate		Net job creation rate	
external wage weight	−0.0438	−0.0663	−0.0257	−0.0360	−0.0181	−0.0303
	(0.0068)	(0.0072)	(0.0062)	(0.0074)	(0.0057)	(0.0063)
firm age	-	−0.0879	-	−0.0436	-	−0.0443
		(0.0025)		(0.0023)		(0.0017)
△market share	-	0.0309	-	−0.0223	-	0.0532
		(0.0227)		(0.0221)		(0.0251)
△base wages	-	−0.1456	-	−0.0584	-	−0.0871
		(0.0259)		(0.0231)		(0.0152)
number of firms	271,625	182,879	271,625	182,879	271,625	182,879

Robust standard errors in parentheses. Results are weighted by the recruitments in each firm.
The sample excludes firms that apply firm-level collective agreements.
The "external wage weight" measures the contribution of external wages (see definitions above) to the formation of entry wages. To mitigate the unavoidable sampling error that result from firms with very low recruitments, we excluded weights below zero and above one.

of time (yearly) effects, and ε_{ft} is a conventional error term.

The estimation results are shown in Table 5.5. Here the critical parameter is the regression coefficient for the external wage variable: a 10 percent increase in the external wage weight generates a tiny 0.3 percentage point decrease in the net job creation rate. Interestingly this result is now largely driven by the sizeable hiring rate decrease (-0.7 percentage points), because the impact on separation rates is negative (-0.4 percentage points).

When we turn our attention to the effect of external wages on the failure rate, we find that firms whose wage policies are more driven by external wages face higher probabilities of failure, but this effect is small. A 10 percent increase in the external wage weight is associated with a 0.1 percentage point increase in the probability of firm closure (Table 5.6).

A thorny problem that emerges from our approach comes directly from the assumption that the wage policy of the firm is exogenous. The notion that the wage policy of the firm regarding the definition of entry wages is independent from the error term is clearly questionable, to say the least. Whereas the definition of the external wages is

Table 5.6: The impact of externally set wages on the probability of failure

	Dependent variable: failure			
	Probit estimates		Marginal effects	
external wage weight	0.3261	0.2582	0.0122	0.0099
	(0.0029)	(0.0025)	(0.0001)	(0.0001)
firm age	−0.0823	-	−0.0031	-
	(0.0008)		(0.0000)	
△market share	0.1078	-	0.0040	-
	(0.0102)		(0.0004)	
△base wages	−0.3273	-	−0.0123	-
	(0.0057)		(0.0021)	
△firm size	−0.3983	-	−0.0149	-
	(0.0015)		(0.0001)	
number of firms	182,879	271,625	182,879	271,625
yearly dummies		YES		

Robust standard errors in parentheses.
The sample excludes firms that apply firm-level collective agreements.
"Failure" is a binary variable that is equal to 1 for firms whose individual identifier left the database and 0 otherwise.
See notes to Table 5.5 for additional details.

largely exogenous to the firm, the decision to pay above the external wage floors can hardly be argued to be exogenous. Fortunately we can rely on the information regarding the identification of each collective agreement that binds each firm to construct a valid instrument. In other words, we shall replace the external weight variable by its estimated value from an auxiliary regression that simply regresses the external weight on a set of dummy variables identifying the ruling wage agreement. The estimating equation is now:

$$\triangle y_{ft} = \theta e\hat{w}_f + \triangle x'_{ft}\beta + \lambda_t + \varepsilon_{ft} \tag{5}$$

where $e\hat{w}_f$ is the predicted estimated external wage weight for firm f obtained from an auxiliary regression that regresses the external wage weight on a set of dummy variables identifying the ruling wage agreement.

Tables 5.7 and 5.8 exhibit the results from this two-stage approach. Now the regression coefficient for the external wage variable is -0.13, which means that a 10 percent increase in the external wage weight generates a 1.3 percentage point decrease in the net job creation rate. As before, this result is largely driven by the sizeable hiring rate decrease (-1.7 percentage points), because the impact on separation rates is small and negative (-0.4 percentage points). More generally, these results clearly indicate that the internal and external wage weights contain relevant information that can help us to predict employment outcomes. The impact of the external wage weight on firms' failure is greater than in the previous formulation: a 10 percent increase in the external wage weight is associated with a 1.1 percentage point increase in the probability of firm closure (Table 5.8).

Table 5.7: The impact of externally set wages on firms' net job creation
instrumental variable estimates

	Dependent variables					
	Hiring rate		Separation rate		Net job creation rate	
estimated external wage weight	−0.0696 (0.0081)	−0.1674 (0.0077)	−0.0199 (0.0082)	−0.0367 (0.0097)	−0.0895 (0.0093)	−0.1307 (0.0094)
firm age	-	−0.0866 (0.0005)	-	−0.0412 (0.0006)	-	−0.0454 (0.0007)
△market share	-	0.0155 (0.0105)	-	−0.0322 (0.0120)	-	0.0477 (0.0135)
△base wages	-	−0.0305 (0.0042)	-	−0.0200 (0.0045)	-	−0.0106 (0.0048)
number of firms	271,625	182,879	271,625	182,879	271,625	182,879

Bootstrapped standard errors in parentheses. Results are weighted by the number of recruitments in each firm.
The sample excludes firms that apply firm-level collective agreements.
The "external wage weight estimate" is the predicted estimated external wage weight for each firm obtained from an auxiliary regression that regresses the external wage weight on a set of dummy variables identifying the ruling wage agreement.

Table 5.8: The impact of externally set wages on the probability of
firm closure
probit estimates

	Dependent variable: failure			
	Probit estimates		Marginal effects	
estimated external wage weight	1.4910 (0.1187)	1.6607 (0.0935)	0.1028 (0.0082)	0.1097 (0.0063)
firm age	−0.0944 (0.0076)	-	−0.0065 (0.0005)	-
△market share	−0.1695 (0.1448)	-	−0.0117 (0.0100)	-
△base wages	−0.1930 (0.0475)	-	−0.0133 (0.0033)	-
△firm size	−0.2241 (0.0214)	-	−0.0154 (0.0015)	-
yearly dummies	YES			

Bootstrapped standard errors in parentheses.
Failure is a binary variable that is equal to 1 for firms whose individual identifier left the database and 0 otherwise.
See notes to Table 5.7 for additional details.

5.6 Conclusions

Every year in Portugal collective agreements update the wage floors of around 30,000 job titles (Carneiro et al. (2014), Torres et al. (2013), and Martins (2014)). Given the widespread use of extension mechanisms ("*portarias de extensão*"), the coverage of those "minimum wages" is close to 90 percent of all dependent workers in the private sector. This occurs despite the fact that the union density rates are very low (around 10 percent according to Portugal and Vilares (2013)).

This means that in the Portuguese labor market firms confront not only severe downward nominal wage rigidity because nominal wage cuts are forbidden (Dickens et al. (2007)), but also because what we tentatively call "upward nominal wage rigidity". This phenomenon is similar in nature to the frictions generated by nationwide mandatory minimum wages, in the sense that many firms are forced to increase their wages to comply with the updated wage agreements.

In this study we explore an unusually rich matched employer-employee data set, one that provides for each worker the identification of the collective agreement (and the corresponding job title) binding the formation of base wages. In this setup we estimate for each firm the wage bill growth that is implied by the signature of a new contract. We then present evidence showing that the firms that are more strongly affected by the change in the bargained wage floors increase their separation rates and, more importantly, significantly decrease their hiring rates, leading to fairly sizeable higher job destruction rates. Furthermore, higher wage impacts are also associated with greater failure rates of firms. These results are consistent with those provided by Martins (2014) and Catalán and Villanueva (2012), despite their use of distinct identification strategies.

When we focused on the stock of employed workers, we observe the impact of externally driven wage increases being largely concentrated on (lower) worker accessions. This is also true if we restrict the analysis to the newly-hired. Indeed, when we look at the determinants of the wages of new hires, what we see is that the role of external wages is more intense among (lower) worker accessions.

The set of empirical results collected in the current essay call into question the functionality of the architecture of the Portuguese wage setting system. In particular, it

raises very serious concerns with respect to the widespread use of extension mechanisms. Also, the limited role played by the workers councils in the Portuguese legal framework seriously dampens any moves toward a decentralized (firm based) system of wage negotiations. Furthermore, given the low representativeness of the unions and of the employer associations, it may well be possible that higher wage firms and higher wage workers engage in a strategic behavior, seeking to avoid the competition of lower wage firms and lower wage workers.

In this framework it seems to be justified to limit the extension of wage agreements to criteria based on the representativeness of the negotiation partners, as recently approved in Portugal. The praised German experience (Dustmann et al. (2014)) favoring opting out clauses and decentralized mechanisms where worker councils play an important role should also be given serious consideration, even though the governance structure of the Portuguese system of industrial relations is, unlike the German one, firmly rooted in legislation and overwhelmingly governed by the political process.

Appendix A - Description of variables

Table 5.9: Description of the variables used in the models

Variables	Description
Hiring rate	number of new social security identifiers reported by firms in each year divided by the number of workers in the previous year
Separation rate	number of social security identifiers that were reported by firms in the previous year but not in the current year divided by the number of workers in the previous year
Net job creation rate	difference between the hiring rate and the separation rate
Failure	binary variable that is equal to 1 in a given year t for firms whose individual identifier left the database in that year and 0 otherwise
Implied wage bill growth	sum for each firm of the changes between the new wage floor set by the collective wage agreement for t+1 and the current base wage at time t for all workers, assuming that the job title structure remains unchanged
External wage weight	contribution of external wages to the formation of entry wages; it is the coefficient of the external wage that results from a model that regresses entry wages on the internal and external wages in the same job title
External wage weight estimate	predicted estimated external wage weight for each firm obtained from an auxiliary regression that regresses the external wage weight on a set of dummy variables identifying the ruling wage agreement
Firm age	number of years since start-up expressed in logs
$\triangle$market share	difference between the log of the market share in time t and the log of the market share in t-1; market share calculated as the share of firms' sales in the 5-digit sector
$\triangle$firm size	difference between the number of workers in time t and the number of workers in time t-1 (number of workers in logs).
$\triangle$base wages	difference between the log of base wages in time t and the log of base wages in t-1

Table 5.10: Descriptive statistics

	Full sample		Newly-hired workers	
	Model of section 5.4		Model of section 5.5	
	mean	std. error	mean	std. error
net job creation	0.002	0.279	0.056	0.241
hiring rate	0.210	0.291	0.335	0.244
separation rate	0.206	0.305	0.279	0.217
failure rate	0.115	0.320	0.016	0.125
implied wage bill growth	0.024	0.023	-	-
external wage weight	-	-	0.313	0.227
$\triangle$ market share	0.000	0.019	0.002	0.073
$\triangle$ base wages	0.055	0.176	0.055	0.136
firm age	2.100	0.836	2.972	0.988
$\triangle$ firm size	0.021	0.461	0.098	0.456
firms$\times$years	1,311,160		271,625	

Firm age is expressed in logs; $\triangle$base wages, $\triangle$market share and $\triangle$firm size are expressed as difference in logs.

Appendix B - Least squares solution to the model presented in Section 5.5

The estimation of the model shown in section 5.5 cannot be implemented using the standard procedure to deal with a model with one fixed effect. This is because the number of β coefficients that would need to be estimated ($2 \times 15,787$) is too large to allow for the application of the within estimator. However, it is still possible to find the exact least squares solution to the model (equation 3).

The trick is to estimate the model in two steps making use of the Frisch-Waugh-Lovell (FWL) theorem and the fact that for a subset of variables the firm-level observations are independent. In the first step we expurgate from w_{ifjt} and x_t the effect of the other variables in the model. This amounts to calculating the residual of regressions on w^I_{fjt} and w^o_{jt} for each individual firm. Then we regress the residual of w_{ifjt} on the residual of the x_t and obtain $\widehat{\gamma}$, the OLS estimate of γ. To obtain the OLS estimates of β^I_f, β^o_f and α_f we need only to regress $w_{ifjt} - x_t\widehat{\gamma}$ on w^I_{fjt} and w^o_{jt} again for each individual firm. The constant term on firm level regressions are the OLS estimates of the α_f and the standard errors obtained by this procedure are correct as long as we adjust the degrees of freedom.[73]

[73]The Stata user-written program *regintfe* programmed by one of the authors implements this method. The code is available on the Statistical Software Components (SSC) Archive.

Chapter 6

Concluding remarks

This dissertation uncovered a number of new facts about the degree and sources of nominal price and wage rigidities in Portugal. It used two unique micro level datasets: a firm-level survey covering the most important sectors of the economy and a large longitudinal matched employer-employee dataset known as the Tables of Personnel.

In terms of price setting, the results presented in chapter 2 show that degree of price rigidity – measured by the time lags of price reaction to shocks – varies substantially across sectors and depends on market, product, and firm characteristics, such as the intensity of competition, the cost structure of the firm, the type of pricing policy, or the type of good. In particular, firms which discriminate prices, do quantity discounts or operate in more competitive environments tend to react faster to shocks than otherwise similar firms. I interpret these findings as support of the predictions of models of optimal price setting like the ones suggested in Barro (1972), Caballero (1989) or Alvarez et al. (2011).

The type of price reviewing strategy followed by firms (time-dependent or state-dependent) is also an indication about the degree of price rigidity. In the presence of frequent shocks, time-dependent price reviewing rules (e.g. annually, monthly,...) might lead to stickier prices than a state-dependent/contingent behaviour, provided that the time frame is quite large and the cost of changing prices low enough. Indeed, the results presented in chapter 3 show that the frequency of price changes and the speed of price reaction to shocks of time-dependent firms are significantly lower than that of state-

dependent firms. In line with the evidence found in other countries, Portuguese firms are strongly heterogeneous as regards their price-reviewing strategies: 32 percent of the firms follow time-dependent, 43 percent follow state-dependent and the remaining 25 percent follow time- and state-dependent price-reviewing strategies.

The fact that the frequency of price changes and the speed of price reaction to shocks depend on whether firms follow time-dependent, time- and state-dependent or state-dependent price-reviewing strategies is not irrelevant for monetary policy, as it implies that monetary policy effects will depend on the distribution of firms in terms of their price-reviewing strategies. In particular, changes in this distribution are likely to affect the speed of price reaction to monetary policy shocks. For instance, if, in line with what it was found for Portugal, the choice of a price-reviewing strategy varies with firm size, then it may be expected that the effects of monetary policy will be different in countries with different firm-size distributions as the masses of time- and state-dependent firms will also be different. Similarly, because firms in the services sector are more prone to follow time-dependent price-reviewing rules, changes in the structure of the economy that affect its composition (manufacturing versus services) will have the implication of changing the effects of monetary policy. This idea that firms rationally choose their price-reviewing strategy may help to understand the cross-sectional variation of monetary shocks (different countries/states are affected differently by the same type of monetary shock) and, at the same time, may also explain why the same monetary shock may affect the same country differently in different periods of its development path.

Another important result in terms of price setting is the existence of asymmetries in the speed with which firms adjust their prices in response to positive and negative demand or costs shocks. In line with similar empirical evidence found in literature, most firms seem to react faster to positive than to negative cost shocks, and more quickly to negative than to positive demand shocks. However, there is a significant degree of heterogeneity in the asymmetry of firm's responses to shocks which seems to have gone unnoticed so far. Moreover, the direction and magnitude of these asymmetries depend on the characteristics of the firms and of the market in which they operate. For example, firms operating in more competitive markets respond to different shocks more symmetrically.

Some results presented on asymmetric price responses are individually consistent with

some of the theoretical models suggested in the literature, but, overall, the results can only be explained by a combination of the models purporting to explain asymmetric behaviour in response to different shocks. This fact illustrates the complexity of the problem and suggests that further research will be needed to better understand the conditions under which different kinds of asymmetries will be observed.

This result is also important for monetary policy. Indeed, the existence of firm-level asymmetric price rigidity has the implication that the relationship between inflation and aggregate demand (Phillips curve) might be non-linear, calling for asymmetric monetary policy rules. However, in contrast to most of the theoretical literature which tends to favour the idea that prices are stickier downwards than upwards in response to demand shocks, the evidence obtained suggests that the type of asymmetry prevailing at the aggregate level depends on the relative importance of different types of firms in the economy and on the type of shock. Therefore, whether the relation between inflation and aggregate demand is linear, convex or concave is still an open issue and thus more empirical evidence is required before definite conclusions can be drawn on this matter.

Overall, in line with the results found elsewhere in other European countries (see Druant et al. (2012)) firms price setting behaviour varies substantially across sectors and depends strongly on economic features. In contrast, wage adjustment strategies are shaped to a great extent by the labour market institutional setting which is strongly country-specific. The role played by labour market institutions in shaping the dynamics of wages and employment is a matter of considerable debate both empirically and conceptually. Many institutional factors may obstruct the efficient allocation of workers and jobs. Aside from the impact on flows stemming from quantitative restrictions on labour market adjustment, wage-setting policies, such as legal provisions restricting wage adjustment, wage schedules determined at the sector level, or the presence of national minimum wages also have an impact on the reallocation.

A factor that might affect the allocation of workers and jobs is the widespread practice of extending collective bargaining agreements to non-subscriber workers and employers. Since these agreements establish wage floors for most job titles, their frequent extension is equivalent to setting a wide range of compulsory minimum wages, which are regularly adjusted upward, even if the scope in most cases is restricted to some sectors or industries.

This phenomenon - tentatively called "upward nominal wage rigidity" – is in fact similar in nature to the frictions generated by nationwide mandatory minimum wages, in the sense that many firms are forced to increase their wages to comply with the updated wage agreements. In some firms the upward nominal wage rigidity can result in a wage structure that may not be appropriate for some workers, causing fewer hirings and/or added dismissals.

Legal provisions for mandatory extensions exist in several European countries such as Spain, France, Germany, Italy, the Netherlands, and Belgium, and they are also an important feature of the Portuguese wage setting system (the so-called "*portarias de extensão*"). This means that every year collective agreements update the wage floors of around 30,000 job titles. Given the widespread use of extension mechanisms, the coverage of these "minimum wages" is close to 90 percent of all dependent workers in the private sector.

The evidence presented in Chapter 5 shows that firms that are more strongly affected by the change in the bargained wage floors increase their separation rates and, more importantly, significantly decrease their hiring rates, leading to fairly sizeable higher job destruction rates. Furthermore, higher wage impacts are also associated with greater failure rates of firms.

However besides the importance of the upward nominal wage rigidity, we should not lose sight what is still the most important source of nominal wage rigidity in Portugal: the fact that labour legislation strictly forbids cuts in base wages. Indeed, according to the Portuguese law, a firm cannot reduce contracted wages, including other regular and periodic monetary or non-monetary pay components, unless this is permitted by collective agreements. As a general rule, only bonuses, commissions and other monetary or non-monetary benefits associated to the worker's performance, not included in the collective agreement, may legally be reduced. Due to this legislation many studies place the Portuguese labour market among the most rigid countries in Europe.

Against this background, the research presented in Chapter 4 analysed how firms, in the presence of downward base wage rigidity, combine different channels of labour-cost adjustment in response to adverse shocks. Since firms are primarily concerned with total compensation per employee, the assessment of the importance of these alternative labour

cost adjustment strategies is crucial to evaluate the overall degree of labour cost flexibility and its implications. At this respect it is important to notice that under the assumption of a common negative shock, and in the absence of nominal wage cuts, those firms that are able to freeze their base wages are those where base wages exhibit the lowest degree of downward rigidity.

The evidence obtained shows that base-wage flexibility has a strong positive impact on employment in the face of negative shocks, and that such impact is significantly reinforced by the existence of alternative margins of labour cost adjustment. In particular, the availability of compensation components (bonuses, benefits and promotions) that firms can freeze or cut in bad times and the possibility of recruiting new employees at lower wages contribute to partly offset the negative impact of base-wage rigidities on employment.

In sum, the evidence collected should *inter alia* call into question the functionality of the architecture of the Portuguese wage setting system. In particular, it raises very serious concerns with respect to the widespread use of extension mechanisms and the existence of old-fashioned legislation that strictly forbids cuts. In the current low-inflation regime nominal wage rigidity has become an active restriction. Indeed, in this environment employers' response on the wage margin is limited to the possibility of reducing the wage drift or going for the lowest nominal wage increase possible, ultimately freezing wages.

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