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Explaining cross-industry heterogeneity in price stickiness.

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Abstract

This note explains cross industry heterogeneity in the frequency of price adjustment. We use the quasi-maximum approach of Papke and Wooldridge (1996) to avoid the shortcomings of OLS regressions to analyse frequencies. We pay particular attention to the role of costs and market competition in explaining cross-industry differences. We find that prices are stickier the higher the labour cost share and the lower are competition and the intermediate input share.

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1. Introduction

The last decade has seen an explosion of papers in which forward looking firms optimally set prices in a framework of nominal rigidities and imperfect competition. This literature has consistently found that the degree of price flexibility is a key element to assess the impact of nominal shocks on real variables. In this vein, Dynamic Stochastic General Equilibrium (DSGE) models, widely used for monetary policy analysis (*e.g.* Christiano et al. 2005, Smets and Wouters 2007), have relied on macroeconomic data evidence and have assumed that all firms in the economy adjust prices with the same frequency.

Recent years have also seen a burst of papers examining pricing behaviour at the micro level, where pricing decisions are actually made. Earlier micro-studies on price setting focussed on a very limited number of products (Stigler and Kindhal 1970, Carlton 1986, Cechetti 1986), but there is now ample evidence documenting individual price setting for consumer[1], and, to a lesser extent, producer[2] prices, using the large-scale data sets of individual prices underlying consumer and producer price indexes.

A common finding of these studies that study a wide spectrum of goods is that there is a substantial degree of heterogeneity in the frequency of price adjustment across products. Moreover, there is an incipient literature that analyses the macroeconomic implications of allowing for heterogeneity in price setting behaviour ((Carvalho 2006, Nakamura and Steinsson 2010, Álvarez and Burriel 2010). These papers take as given observed heterogeneity in price changes across products and find that analyses of the impact of shocks assuming homogeneous pricing behaviour give a heavily distorted picture.

However, the empirical evidence on the determinants of the frequency of price adjustment is rather scarce and mainly based in cross-industry ordinary least squares (OLS) regressions, which in this context have important econometric shortcomings. This is most unfortunate, as this research area may contribute to deepening our understanding of economic fluctuations and inflation dynamics. Along these lines, this note presents empirical[3] evidence on the role of the cost structure of a firm and the degree of competition in explaining differences in the degree of price flexibility across industries using Spanish producer price data. To do so we use the quasi-maximum likelihood (QML) approach of Papke and Woolridge (1996), which does not suffer from the problems associated with standard OLS analyses or log odds ratio models in the analysis of proportions.

2. Sectoral heterogeneity in the degree of price stickiness

Álvarez *et al.* (2010), using the individual price data underlying the construction of the Spanish PPI over the period 1991-1999, find that the average frequency of price changes, defined as the number of price changes as a share of the total number of observations, is 21%. Interestingly, there is a marked heterogeneity across products in the frequency of price

[1] Bils and Klenow (2004) analyse US data and Dhyne *et al* (2006) euro area countries. Álvarez (2008) surveys global evidence.

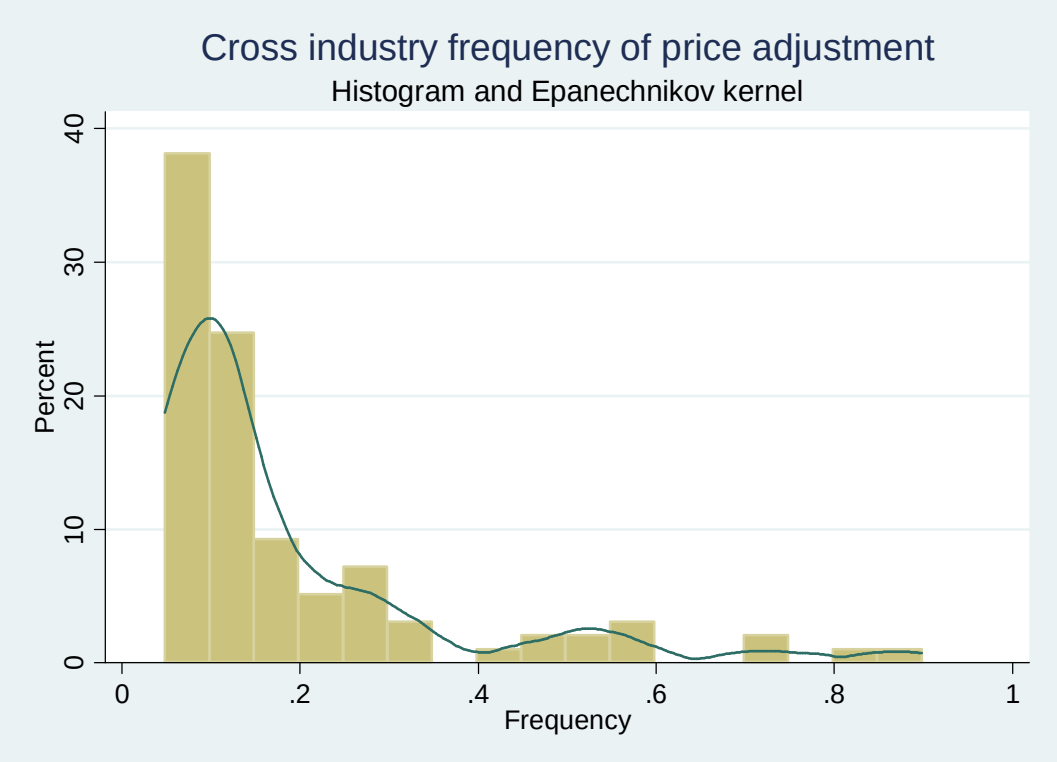
[2] Dias *et al.* (2004), Cornille and Dossche (2008), Gautier (2008), Fabiani *et al.* (2010), Stahl (2006) and Álvarez *et al.* (2010) study Portuguese, Belgian, French, Italian, German and Spanish data, respectively. Nakamura and Steinsson (2008) and Goldberg and Hellerstein (2009) study US data. Vermeulen *et al.* (2007) review evidence for euro area countries.

[3] Bonomo and Carvalho (2004) present a theoretical model in which the frequency of price adjustment is endogenised.

changes. Looking at the main product categories, this frequency is considerably larger for energy (38%), intermediate goods (28%) and food (24%) than for the rest, which can be explained by the relative importance of supply shocks for these categories. The frequency of price changes is much smaller for non-food consumption goods (10%) and for capital goods (8%). Vermeulen *et al.* (2007) report that this same ranking of broad product categories is also observed for other euro area countries.

The marked heterogeneity in the degree of price flexibility across products is even clearer when considering narrower product categories. Figure 1 presents the histogram and an Epanechnikov kernel estimate of the cross-industry (NACE 3) frequency of price adjustment and shows that dispersion is substantial (standard deviation: 0.18), as well as skewness (2.11) and kurtosis (7.11). A D'Agostino *et al.* (1990) normality test clearly rejects the null (Chi-squared: 53.56). The average frequency of price adjustment for NACE 3 groups ranges from 4.8% for "Manufacture of television and radio receivers, sound or video recording" to 89% for "Manufacture of refined petroleum products". There are several microeconomic factors that could explain such dispersion, including differences in the cost structure or the degree of market competition.

Figure 1



3. Determinants of the degree of price flexibility

In this section we explore the role of a number of factors in explaining the heterogeneity in the degree of price stickiness across products, using sectoral information.

3.1 Econometric methodology

Our measure of price flexibility is the frequency of price changes (*freq*), defined as the number of price changes as a share of total observations.[4] This measure is by nature bounded between 0 and 1, so that standard ordinary least squares regressions are inappropriate for two reasons. First, fitted values of these models may be outside the theoretical boundaries. Second, frequencies are not normally distributed, so that standard inference procedures are invalid. A common solution is to model the log-odds ratio $\log\left(\frac{freq}{1-freq}\right)$ as a linear function of explanatory variables. This implies that frequencies follow an additive logistic normal distribution (Aitchison 1986).

An alternative procedure is the quasi-maximum likelihood (QML) approach of Papke and Woolridge (1996). These authors suggest the direct estimation of a non-linear model. Specifically, their method involves expressing the observed frequency as a bounded non-linear function of the explanatory variables and maximizing a Bernoulli likelihood function. The corresponding estimator is consistent and asymptotically normal. Furthermore, it allows the recovery of the conditional expectation without further assumptions, in contrast with the log odds ratio model. We have followed the QML approach using a logistic cumulative distribution function and assuming the frequency (*freq*) to follow a Bernoulli distribution, *i.e* estimating

$$freq = \frac{e^{\alpha+\sum \beta_i x_i}}{1+e^{\alpha+\sum \beta_i x_i}} \qquad freq \sim \text{Bernoulli}$$

3.2 Potential factors explaining price flexibility

Table 1 reports the estimates for the cross-industry frequency of price adjustment of log odds ratio and Papke and Wooldrige (1996) models. The measure of price adjustment that we use is obtained by aggregating the individual price data underlying the Spanish Producer Price Index (PPI) into 84 NACE-3 sectors. The reason for employing sectoral data instead of firm level data is that data on explanatory variables is only available at the sectoral level.[5] Aitchison (1986) proposes testing that frequencies are distributed as additive logistic normal -as implicitly assumed under a log odds ratio approach-, by testing for normality of the logs odds ratio variable. We have carried out a D'Agostini et al. (1990) normality test, which clearly rejects the null hypothesis (Chi-squared: 31.70; skewness: 1.45; kurtosis: 5.02), suggesting that the log odds ratio model is not reliable in this context. In what follows, we discuss the main results.

[4] See Álvarez *et al.* (2010).

[5] The definition of the variables used in our analysis is reported in Table 1.

Table I Determinants of the frequency of price changes (a)

Variable	Papke and Wooldridge	Log odds ratio
Labour (b)	-2.98***	-2.55***
Energy (b)	10.37***	9.15***
Non-energy intermediate goods (b)	1.05***	0.88***
Outsourcing (b)	4.91***	4.81***
External competition (c)	1.12**	0.89*
Demand conditions (d)	0.22**	0.18*
Attractive prices (e)	-1.13***	-1.11***
Size (f)	-14.97***	-15.00***
Regulated (g)	-0.86*	-1.17***
Number of observations	84	84
Log likelihood	-23.9	-53.61
Akaike Information Criterion (AIC)	77.79	137.22
Bayesian Information Criterion (BIC)	114.26	173.68

Notes:

a) ***/**/* denote coefficient significant at the 1%/5%/10% level. Dummies for the six main product categories not reported.

b) Labour, Energy, Non-energy intermediate goods and Outsourcing are, respectively, the shares of labour costs, energy inputs, non-energy intermediate goods and works carried out by other firms, in terms of total costs. Source: Industrial survey.

c) Total imports over total resources. Source: Input-output tables

d) Importance attached by firm to demand conditions in explaining price changes. Source: Banco de España survey on pricing behaviour. See Álvarez and Hernando (2007a).

e) Fraction of prices set in attractive terms. Source: PPI database. See Álvarez *et al.* (2010).

f) Average size of price changes. Source: PPI database. See Álvarez *et al.* (2010).

g) Fraction of firms whose price is set by the government. Source: Banco de España survey on pricing behaviour. See Álvarez and Hernando (2007a).

Marginal cost variability is a highly significant element in explaining heterogeneity in price flexibility. Here, we characterize the sectoral cost structure by considering the shares of labor costs, intermediate inputs and outsourcing in terms of total costs. Given the low frequency of wage changes[6], we expect more (less) labor-intensive industries to carry out price revisions less (more) frequently. On the contrary, firms which are highly (lowly) intensive in the use of intermediate goods (*e.g.* energy) in their production processes are expected to adjust their prices more (less) often, because prices of intermediate goods, as shown above, change very frequently. In a similar vein, a higher (lower) degree of outsourcing is expected to result in a higher (lower) frequency of price change. In Table 1, all cost variables have the expected sign and are highly significant: the coefficient of the labor share is negative and those of the share of energy, non-energy intermediate inputs and outsourcing are positive. Related evidence refers to Hoffmann and Kurz-Kim (2005) who observe that differences in the frequency of consumer price adjustment are related to input price volatility. Similarly, Rumler (2007) estimates open-economy New Keynesian Phillips Curves and finds that firms facing more variable input costs tend to adjust their prices more frequently. Using survey data, Álvarez and Hernando (2007a, 2007b) also find a significant role of the cost structure in explaining cross industry differences in price adjustment.[7]

The degree of competition in the market in which a firm operates is also crucial in determining its price-setting behaviour.[8] In highly competitive markets, firms are more likely to adjust their prices in response to shocks, since the opportunity cost of setting non-optimal prices is higher. By contrast, this cost is smaller for firms enjoying significant market power. There is some empirical evidence on the link between price stickiness and the degree of competition. Geroski (1995) finds that price responses to both supply and demand shocks are faster in more competitive industries. Similarly, Hall *et al.* (2000) and Carlton (1986) find that companies in competitive markets tend to adjust their prices faster than companies facing less elastic demand[9].

We characterize the degree of market power by considering both direct measures, such as concentration indices or the number of competitors in a sector, and indirect measures, such as import penetration and the relevance attached by firms to demand conditions or to gaining market share. We expect a higher response to shocks by those firms operating in more competitive environments. As shown in Table 1, we find that a higher degree of competition results in more flexible price adjustment. Specifically, we find that the degree of import penetration, which proxies external competition, is significant. Furthermore, we find an additional effect from the relevance attached by firms to demand conditions, which proxies demand price elasticity. However, direct measures of price competition are never significant in explaining differences in the frequency of price changes. This probably reflects the fact that there are some competitive markets (*e.g.* telephone services) where a few firms have high market shares. Also, there are markets with a high number of firms with low market shares (*e.g.* bars and restaurants), which still enjoy some market power. This result confirms the relevant role of competition found in analysis explaining heterogeneity in survey data

[6] For euro area countries, Druant *et al.* (2009) report that only 11.4% of firms change wages more frequently than once a year.

[7] The studies reported in Vermeulen *et al.* (2007) also find a significant relationship between the frequency of price changes and the volatility of input costs

[8] See Martin (1993) for a theoretical model supporting this argument.

[9] Bils and Klenow (2004) do not find competition to be a significant driver of the frequency of price adjustment. This lack of significance may be related to their use of OLS regressions.

(Álvarez and Hernando 2007a, 2007b, Druant *et al.* 2009) and in conditional logit models estimated with micro producer price data (Gautier 2008).

Other variables which may help in explaining the frequency of price adjustment are attractive prices –prices ending in 0, 5 or 9-, government-set prices and the average size of price changes. The estimates for these variables display the expected signs. Sectors where prices are regulated are characterized by a lower frequency of change. The use of attractive prices is generally associated with more sluggish price adjustments. Finally, sectors with larger price changes generally present less frequent adjustments.

4. Conclusions

In this note, we study the determinants of the cross industry frequency of price adjustment. To avoid pitfalls of linear models in the analysis of proportions we use the quasi-maximum likelihood approach of Papke and Woolridge (1996). Our analysis indicates that both the cost structure of a firm and the degree of competition it faces affect the degree of price flexibility. More precisely, we find that prices are more flexible the lower the labour share, the higher the relevance of intermediate goods and the higher import penetration.

A natural extension of this note is to estimate this type of model for other countries. Another area of future research is to incorporate heterogeneity in macroeconomic models as a function of differences in technology and market structure. From a policy perspective, evaluating the response of the economy to changes in the degree of market competition seems particularly relevant.

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