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1330

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June 2007

This paper is part of the Kiel Working Paper Collection No. 2

"The Phillips Curve and the Natural Rate of Unemployment"
June 2007

http://www.ifw-kiel.de/pub/kap/kapcoll/kapcoll_02.htm

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Kiel Working Paper No. 1330

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by

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What do micro price data tell us on the validity of the New Keynesian Philips Curve?[1]

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Preliminary version: 22.4.2007

Abstract: The New Keynesian Phillips curve (NKPC) has become the dominant model on inflation dynamics. Moreover, a large body of empirical research has documented in recent years price-setting behaviour at the individual level, which allows the assessment of the micro-foundations of pricing models. It is found that a generalised version of the hybrid NKPC of Gali and Gertler (1999) accounts for a number of stylised facts, including rule of thumb price setters, and inflation persistence. Other frequently used versions of the NKPC, such as those that consider full or partial indexation or costs of adjustment, are clearly at odds with micro price evidence.

[1] This paper has been prepared for the Symposium "The Phillips Curve and the Natural Rate of Unemployment", organised by the Kiel Institute for the World Economy, 3-4 June 2007. I would like to thank Ignacio Hernando for helpful comments and suggestions on this draft and all members of the Eurosystem Inflation Persistence Network, particularly those involved in the analysis of micro data, for extensive discussions during the last years.

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1. Introduction

Recent years have seen considerable advances in the theoretical modelling of inflation. A new generation of models has emerged, characterised by pricing equations derived from the optimising behaviour of forward looking firms, in a framework of nominal rigidities and imperfect competition. Aggregation over individual behaviour leads to relations linking inflation to some measure of real activity, in the spirit of the traditional Phillips Curve, although with firm microfoundations. This new Keynesian Phillips Curve (NKPC) is now the dominant approach to price modelling and variants of it are used as the supply block of dynamic stochastic general equilibrium (DSGE) models, which have become increasingly popular in academic macroeconomics and policy making institutions[3].

There is also growing recognition that the understanding of price stickiness can be improved by examining pricing behaviour at the micro level, where pricing decisions are actually made. Individual information on price setting allows to determine to which extent the assumptions used in deriving theoretical models are actually realistic, which helps discriminate among competing models. Micro evidence is also an aid in solving problems of observational equivalence that are sometimes present in the analysis of aggregate time-series data. For instance, the popular Calvo (1983) pricing model can be distinguished from the quadratic adjustment model of Rotemberg (1982) on the basis of micro data.

Empirical evidence on pricing policies at the microeconomic level had remained quite limited until recent years. Indeed, most quantitative studies with individual price data were quite partial and focussed on very specific products[4]. Fortunately, a large and growing body of empirical research aimed at improving the understanding of the characteristics of the inflation process is now available. Following Bils and Klenow (2004), numerous authors have analysed datasets of the individual prices that are used to compute consumer price indices and producer price indices, mostly within the context of the Eurosystem Inflation Persistence Network (IPN). Following Blinder (1991), a significant number of central banks have conducted surveys on price setting behaviour, including those participating in the IPN.

The aim of this paper is to survey recent work on micro price data, focussing on those aspects related to the conformity of assumptions used in deriving the NKPC and its different variants and we refer the reader to a number of papers providing overviews of recent micro data work[5].

[3] See *e.g.* Erceg *et al.* (2006), Andrés *et al.* (2006) or Smets and Wouters (2003)

[4] Prominent examples include Cecchetti (1986) on newsstand prices of magazines, Carlton (1986) on producer prices of intermediate products used in manufacturing, and Lach and Tsiddon (1992) on retail food product prices.

[5] For an overview of IPN results on micro data, see Álvarez *et al.* (2006). More detailed IPN summaries on individual consumer prices are provided in Dhyne *et al.* (2006), and Sabbatini et al. (2007), which also consider producer price data. Vermeulen *et al.* (2007) summarises producer price data. Fabiani et al. (2006) and the book by Fabiani *et al*. (2007) give an overview of results on survey data in the euro area and Lünnemann and Mathä (2007) compares survey results in the euro area with other countries. Angeloni *et al.* (2006) and Gaspar *et al.* (2007) discuss the implications of micro IPN findings for

After this introduction, the remainder of this paper is organised as follows. Section 2 discusses the advantages and drawbacks of using micro CPI and PPI datasets, as well as survey data. Section 3 reviews the basics of the NKPC. Sections 4 and 5 refer to the implications derived from the analysis of frequencies and hazard rates of price adjustment and section 6 to observed heterogeneity. Sections 7 and 8 are devoted to assessing the relevance of time dependent and forward looking behaviour and section 9 presents available evidence on imperfect competition. The paper ends with a section of conclusions.

2. Data

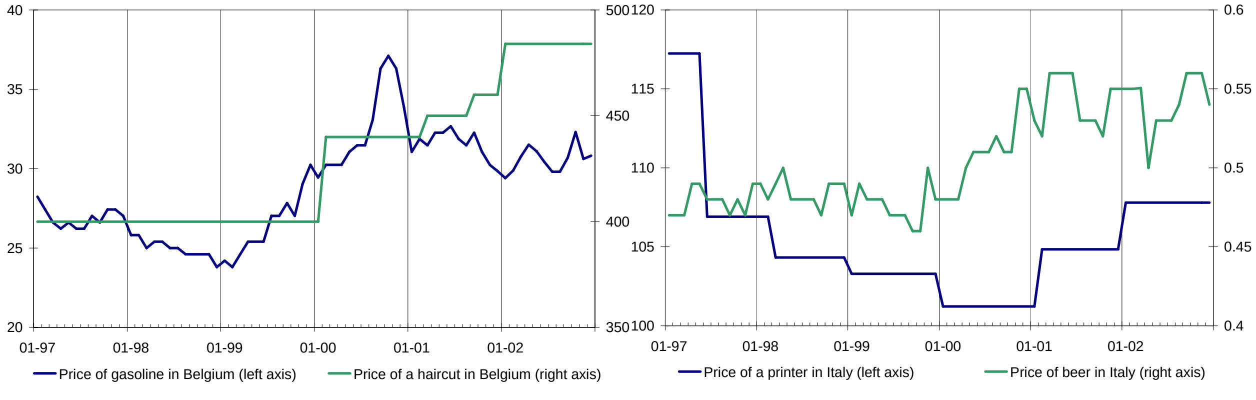
The types of evidence we consider refer to, on the one hand, quantitative datasets made up of the individual prices that are used to compute consumer price indices and producer price indices and, on the other, one-off surveys on pricing behaviour.

There are several reasons which make these quantitative datasets particularly useful. First, the number of considered goods and services is high and its choice is based on highly detailed household budget surveys, in the case of CPIs and on extensive industrial surveys, in the case of PPIs. This guarantees the representativeness of samples in terms of products. Importantly, services prices are included in CPI datasets. Second, prices are collected in different types of outlets, which may follow different pricing strategies. Third, prices are collected in a large number of cities, thus ensuring high geographical representativity. Fourth, databases contain monthly observations extending for several years. All in all, these data sets of individual prices typically contain a huge number of price quotes, that may add up to several millions.

Figure 1

Examples of individual price trajectories

Consumer prices | **Producer prices**



Source: Aucremanne and Dhyne (2004) for Belgian data and Sabbatini *et al.* (2006) for Italian data. Consumer prices are in Belgian Francs and producer prices are in euro.

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macroeconomic modelling and the design of monetary policy. Altissimo *et al.* (2006) present a summary of the complete results of the IPN.

Figure 1 displays some paths of actual price series corresponding to consumer prices in Belgium and producer prices in Italy that are typical of the patterns found in other datasets. [See *e.g.* Baumgartner *et al.* (2005)]. There are four features that are worth highlighting. First, individual prices tend to remain unchanged for several months. Second, the timing of price adjustments does not seem to obey a regular pattern. Third, very small price changes coexist with sizable price adjustments and fourth, there is marked heterogeneity across products in the frequency of price change.

The analysis of consumer and producer price micro datasets allows for a rich characterisation of the frequency and size of price changes. However, these quantitative sources do not allow for a full understanding of the rationale of the behaviour of price setters. A complementary approach to shed light on these issues is to survey firms directly on how they set prices. Surveys offer unique information on certain aspects of firms' pricing polices such as the information set used in price setting or the reasons justifying delays in price adjustments. Moreover, survey results are also useful in cross checking and extending the evidence obtained from quantitative databases.

Pioneers in the modern use of surveys to analyze firm price-setting behaviour (Blinder (1991) and Blinder et al. (1998)) already discussed reasons for which the approach could be considered controversial. First, it may be argued that companies may have no incentive to respond truthfully or thoughtfully and that they may give misleading answers. However, in the case of price stickiness questionnaires, it is not easy to find reasons that would justify firms concealing the truth or giving wrong answers. Second, low response rates of the surveys could raise fears of selectivity bias, but in practice response rates are not generally low. Third, responses could be be sensitive to, for instance, the wording of questions, the order in which they appear, and the setting in which the questions were answered. Nonetheless, the fact that questionnaires using the same approach but with different wording, different samples, and under different circumstances produce similar results suggests that the quantitative importance of these concerns is probably minor.

3. The New Keynesian Phillips Curve

As shown by Roberts (1995), the NKPC can be derived from a number of different models of price rigidity, although the literature has tended to focus on Calvo (1983) pricing. In this model, the timing of price adjustment by individual firms has a constant probability $1-\theta$, which is independent of calendar time and also of the length of time elapsed since the last adjustment. The Calvo model seems to capture key aspects of price dynamics at the level of individual firms that were observed in figure 1, namely that there are discrete adjustments which occur at irregularly spaced intervals of time. Moreover, it leads to tractable and parsimonious price level and price-setting expressions.

In the Calvo model, there are two key equations governing the behaviour of prices. The first key equation captures forward looking price setting. Optimal prices are set by firms by maximizing the discounted expected stream of profits. Firms re-setting their prices today recognize that the prices they choose are likely to remain effective for more than one period, so they rationally take into account expected future market conditions. Specifically, the log-linear approximation to the log optimal price (p_t^*) is given by

$$p_t^* = \mu + (1-\beta\theta)\sum_{j=0}^{\infty}(\beta\theta)^j \ E_t(nmc_{t+j})$$

where μ is the steady state mark-up, nmc_t is the logarithm of nominal marginal cost and E_t is the conditional expectations operator, where expectations are conditioned on all current and past information. The expression shows that the optimal price chosen by firms is a distributed lead of nominal marginal costs. There are two parameters that imply discounting the future: *β,* which represents a conventional discount factor and *θ,* which reflects the fact that firms know that there is a lower probability of keeping unchanged today's price as they look further ahead.

The second key equation is a backward-looking price level equation which is simply a weighted average of the nominal prices set by firms in prior periods. With a large number of firms in the economy, the fraction of firms adjusting prices in a period is equal to the probability of price adjustment and the fraction of firms that keep a price that is *j* periods old is $(1-\theta)\,\theta^j$. The log-linear approximation to the log price level (p_t) takes then the particularly simple form,

$$p_t = (1-\theta)\sum_{j=0}^{\infty}\theta^j \ p_{t-j}^* = \theta \ p_{t-1} + (1-\theta) \ p_t^*$$

Combining the equations of the optimal price and the price level yields the marginal cost formulation of the New Keynesian Phillips Curve (NKPC)

$$\pi_t = \beta \ E_t\pi_{t+1} + \lambda \ \hat{s}_t$$

where the inflation rate is $\pi_t = p_t - p_{t-1}$, $\hat{s}_t$ is the deviation of log real marginal cost from its steady-state value and $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$. The NKPC relates inflation, anticipated future inflation and real marginal cost. The slope of the curve depends on the parameter that governs the degree of price rigidity[6]. In particular, the stickier are prices, the less sensitive is inflation to movements in marginal cost.

Alternatively, under some assumptions on technology and labour market structure, the real marginal cost is positively related to the output gap, so that

$$\pi_t = \beta \ E_t\pi_{t+1} + \delta \ (y_t - \bar{y})$$

[6] In more complex formulations, the slope is also affected by the degree of real rigidities.

where y_t is output and $\bar{y}$ is the natural level of output, defined as the level of output which would obtain under flexible prices.

Some authors (*e.g.* Fuhrer and Moore (1995)) have emphasised that the NKPC fails to account for the empirical importance of lagged inflation in inflation equations, even after having conditioned on driving variables. Indeed, in the NKPC price setters are forward looking and inflation can jump immediately to its new level in response to a shock, so that the only inertia is inherited from inertia in its driving variables. This had led to the development of variants of the NKPC that account for this feature. Proposals include some form of price indexation (Christiano *et al.* (2005), Smets and Wouters (2003)), frictions on price adjustment (Kozicki and Tinsley (2002), general hazard functions (Sheedy (2005) or rule of thumb price behaviour (Galí and Gerlter (1999)). In general, these proposals give rise to NKPC of the form:

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f \; E_t \pi_{t+1} + \psi \; \hat{s}_t$$

so that inflation depends on lagged and expected inflation and on real marginal costs.

4. Frequency of price adjustment

Table 1 presents available estimates of the frequency of price change obtained in studies that employ the individual data that are used to compute consumer and producer price indices. The data clearly confirm the impression from figure 1 that price adjustment is infrequent[7]. Indeed, the median (unweighted) estimate for consumer prices is 18.1% and the corresponding figure for producer prices is 22.5%. Unsurprisingly, the frequencies of price adjustment are higher in countries like Sierra Leone and Slovakia, where aggregate inflation has been higher than in the rest of countries.

Table 2 presents the distribution of price changes reported by firms in surveys. In most countries, the majority of companies state that they adjust prices once a year and a non negligible fraction of firms report that they change prices less than once a year. On average, prices remain unchanged around 12 months. Thus, survey data confirm that there is substantial price stickiness.

The low frequency of price adjustment that is observed in every country, regardless of the data source used, is clear evidence against some models proposed in the literature. For instance, the quadratic cost of adjustment model of Rotemberg (1982), which is observationally equivalent at the aggregate level to the Calvo model, implies that firms must adjust prices continuously, clearly at odds with the facts. In related research, Kozicki and Tinsley (2002) have generalised the Rotemberg (1982) model, by assuming that firms set prices so as to minimise deviations from the optimal price subject to polynomial frictions of price adjustment. This is interesting,

[7] Gopinath and Rigobon (2006) also find that price adjustment is infrequent with import and export micro price data.

since it provides a rationalisation of the appearance of lagged inflation terms in the Phillips Curve. Specifically, the implied equation is

$$\pi_t = \sum_{i=1}^{m} (\sum_{j=1}^{m} \beta^j \ \delta_j) \ E_t \ \pi_{t+i} - \sum_{i=2}^{m} \sum_{j=1}^{m} \delta_j \ \pi_{t-i+1} + \gamma \ (y_t - \bar{y})$$

where coefficients are functions of the friction polynomial of order m+1. Again, the model is clearly at odds with the evidence on low frequency of price adjustment.

Table 1

Monthly frequency of price changes (%). Quantitative micro data

Consumer prices				Producer prices			
Country	Paper	Sample period	Frequency	Country	Paper	Sample period	Frequency
Austria	Baumgartner et al. (2005)	1996:1- 2003:12	15.1				
Belgium	Aucremanne and Dhyne (2004)	1989:1- 2001:1	16.9	Belgium	Cornille and Dossche (2006)	2001:1- 2005:1	24
Denmark	Hansen and Hansen (2006)	1997:1- 2005:12	17.3				
Euro area	Dhyne et al (2006)	1996:1- 2001:1	15.1	Euro area	Vermuelen et al (2007)		21
Finland	Vilmunen and Laakkonen (2005)	1997:1- 2003:12	16.5				
France	Baudry et al. (2006)	1994:7 - 2003:2	18.9	France	Gautier (2006)	1994:1-2005:6	25
Germany	Hoffmann and Kurz-Kim (2006)	1998:2 - 2004:1	11.3	Germany	Stahl (2006)	1997:1-2003:9	22
Hungary	Gábriel and Reiff (2007)	2002:1-2006:5	19.9				
Italy	Veronese et al. (2006)	1996:1 - 2003:12	10.0	Italy	Sabbatini et al. (2006)	1997:1- 2002:12	15
Japan	Saita et al. (2006)	1999:1-2003:12	23.1				
Luxembourg	Lünnemann and Mathä (2005)	1999:1 - 2004:12	17.0				
Mexico	Gagnon (2006)	1994.1-2004:12	22.6				
Netherlands	Jonker et al. (2004)	1998:11 - 2003:4	16.5				
Portugal	Dias et al. (2004)	1992:1 - 2001:1	22.2	Portugal	Dias et al. (2004)	1995:1- 2001:1	23
Sierra Leone	Kovanen (2006)	1999:11-2003:4	51.5				
Slovakia	Coricelli and Horváth (2006)	1997:1-2001:12	34.0				
Spain	Álvarez and Hernando (2006)	1993:1 - 2001:12	15.0	Spain	Álvarez et al. (2005a)	1991:11-1999:2	21
United States	Bils and Klenow (2004)	1995:1-1997:12	26.1				
United States	Klenow and Kryvtsov (2005)	1988:2-2003:12	23.3				
United States	Nakamura and Steinsson (2007)	1988:1-2005:12	21.1	United States	Nakamura and Steinsson (2007)	1988:1-2005:12	24.7

For German CPI, frequencies refer to the sample considering item replacements and non quality adjusted data
For Mexican CPI, figures refer to the low inflation 2002-2003 period, whereas those in brackets refer to the high inflation 1995-1997 period
For Spanish CPI, the sample excludes energy products, which biases downwards aggregate frequency
For Italian PPI, figures exclude energy products, which biases downwards aggregate frequency
For French PPI, the reported figure does not include business services
Figures from Klenow and Kryvtsov (2005) correpond to regular prices, whereas those in brackets refer to all prices
Figures from Nakamura and Steinsson (2006) correspond to the 1998-2005 period. CPI frequencies refer to regular prices, wheras figures in brackets correspond to all prices. PPI figures correspond to finished goods

Another explanation for inflation inertia, which is particularly used in DGSE models, is some sort of automatic indexation mechanism. For instance, in the Christiano *et al.* (2005) model, lagged inflation enters the NKPC because firms are assumed to index their prices using lagged inflation rates in the periods where prices are not adjusted optimally. In Smets and Wouters (2003) firms partially index to the aggregate price index. These models lead to a generalisation of the NKPC of the form

$$\pi_t - \rho \ \pi_{t-1} = \beta \ E_t \left[\pi_{t+1} - \rho \ \pi_t \right] + \xi \ \hat{s}_t$$

where ρ is the indexation parameter, which is equal to one in the Christiano *et al.* (2005) model and is left unrestricted in Smets and Wouters (2003). Again, as stressed by Woodford (2007) and Angeloni *et al.* (2006), the indexation models contradict the empirical regularity that prices remain unchanged for long periods of time, that is observed in every study of tables 1 and 2. In addition, survey evidence points out that indexation is extremely rare. For instance, Stahl (2006b) reports that only 2% of firms link their prices to another price. Moreover, the evidence on the size of price adjustments reported by Dhyne *et al.* (2006) and Vermeulen *et al.* (2007) shows that the typical size of price change considerably exceeds aggregate inflation, casting additional doubt on the indexation hypothesis.

Table 2

Number of price changes per year (%). Survey data

Country	Paper	<1	1	2– 3	$\geq$ 4	Median	Mean (in months)
Austria	Kwapil et al. (2005)	24	51	15	11	1	12.7
Belgium	Aucremanne and Collin (2005)	18	55	18	8	1	11.9
Canada	Amirault et al. (2006)	8	27	23	44	2-3	6.8
Estonia	Dabušinskas and Randveer (2006)	14	43	25	18	1	10.0
Euro area	Fabiani et al (2006)	27	39	20	14	1	12.3
France	Loupias and Ricart (2004)	21	46	24	9	1	11.8
Germany	Stahl (2005)	44	14	21	21	1	13.5
Italy	Fabiani et al. (2004)	20	50	19	11	1	11.9
Japan	Nakagawa et al. (2000)	23	52	11	14	1	12.5
Luxembourg	Lünnemann and Mathä (2006)	15	31	27	27	2-3	9.0
Netherlands	Hoeberichts and Stokman (2006)	10	60	19	11	1	10.7
Portugal	Martins (2005)	24	51	14	12	1	12.7
Spain	Álvarez and Hernando (2005)	14	57	15	14	1	11.1
Sweden	Apel et al. (2005)	29	43	6	20	1	12.7
United Kingdom	Hall et al. (2000)	6	37	44	14	2-3	8.2
United States	Blinder et al. (1998)	10	39	29	22	1	8.8

Figures for United Kingdom and Sweden taken from Mash (2004)
Figures for Germany taken from Fabiani et al. (2006)
Figures for Japan correspond to less than 1, 1-2, 3-4 and over 5, changes per year, respectively.
Mean implicit durations obtained from the interval-grouped data. The following assumptions have been made: for firms declaring "at least four price changes per year" 8 price changes are considered (i.e. mean duration of 1.33 months); for those declaring "two or three changes per year" 2.5 price changes (i.e. mean duration: 4.8 months); for those declaring "one change per year" a duration of 12 months; and for those declaring "less than one price change per year", a change every two years is considered (mean duration of 24 months)

The relationship between the slope of the NKPC (λ) and the frequency of price adjustment (θ) $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$ provides a way to check the plausibility of the model. Empirical estimates of the slope of the NKPC tend to be positive but small in absolute value (*e.g.* Galí and Gertler (1999) or Sbordone (2002)), implying that prices are adjusted less than once a year, which is high according to estimates in the micro literature reported in tables 1 and 2. Partly in response to this criticism, a number of authors (*e.g.* Woodford (2005) and Eichenbaum and Fisher (2004)) have suggested alternative supply-side refinements to the standard model that modify this relationship between the slope of the NKPC and the implied frequency of price adjustment. One possibility is the consideration of firm-specific capital, instead of the usual but unrealistic assumption that firms rent capital in perfectly competitive markets. In this setting, Woodford (2005) shows that the slope of the Phillips Curve not only depends on the extent of price stickiness, but also on the magnitude of capital adjustment costs: the coefficient is smaller the less frequently prices are adjusted and the more costly it is to adjust capital. Thus, low estimated values of λ do not necessarily imply a high degree of price stickiness[8].

Additional sources of real rigidities that have a similar effect on the relationship between the slope of the NKPC and the frequency of price adjustment are considered in Woodford (2003, 2005). For instance, it may be assumed that each good is produced using not only labour and capital, but also, more realistically, intermediate inputs produced by other industries. This assumption is clearly supported by input-output tables and also by recent survey data. Indeed, many surveys have included questions about factors that are important for pricing decisions. The general result that emerges (see *e.g.* Fabiani *et al.* (2004) for Italy, Loupias and Ricart (2005) for France or Stahl (2005) for Germany) is that costs of raw materials are considered to be even more important than labour costs when explaining both price increases and decreases.

5. The hazard function of price changes

The literature on NKPC models has mainly concentrated on matching the average frequency of price adjustment. This focus on the average implied price duration entails discarding useful information that allows to discriminate among competing models. In contrast, the hazard function of price changes (*i.e.* the probability that a price will change after k periods, provided that it has remained constant during the previous k-1 periods) does not involve any information loss, since it contains the same information as the cumulative distribution function of price durations, with the added advantage that it is readily interpreted in the light of many pricing models.

The most common time dependent pricing specifications in the literature are those described by Taylor (1980) and Calvo (1983). In Taylor's model, prices are set by multiperiod contracts, thus remaining constant for the duration of the contract. In this case, the hazard rate is zero, except in the period in which the end of the Taylor contract occurs, when the hazard is one. In the Calvo model, there is a constant probability that a given price setter will change its price at any instant. Similarly, Dotsey (2002) and Bakhshi *et al.* (2003) consider a truncated Calvo model, which allows for a constant hazard up to a given horizon J, in which all firms must adjust, so that the

[8] In the parameterisation chosen by Woodford (2005), a slope of the NKPC of 0.02 implies an average duration of 7.3 quarters in the case of homogeneous factor markets but only 3.5 quarters in the case of industry specific labour markets and firm-specific capital.

hazard rate is one. The model rules out the possibility of price durations of arbitrarily long length by assuming a zero hazard rate for horizons greater than J. In turn, Wolman (1999) considers the case of an increasing hazard when there is a maximum period that a firm's price can be set. More generally, Goodfriend and King (1997) propose an arbitrary distribution of price durations, so that the hazard function can take any shape. In the state dependent literature, Dotsey *et al.* (1999) present a menu cost model in which the existence of inflation causes older prices to be more likely to be adjusted, so that the hazard rate is increasing. More recent menu cost models, like those of Golosov and Lucas (2006) and Nakamura and Steinsson (2007) introduce idiosyncratic productivity shocks. It is shown that as the variance of idiosyncratic shocks rises relative to the rate of inflation, the hazard function flattens out at longer durations but remains steeply upward sloping in the first few periods.

A number of authors have derived the implications in terms of Phillips Curves of the different assumption on hazard rates. Roberts (1995) provides the expressions for Taylor, Calvo and the quadratic adjustment cost model of Rotemberg (1982). Dotsey (2002) and Bakhshi *et al.* (2003) analyse the truncated Calvo model and find that this model is able to account for inflation inertia, in the sense that lagged inflation appears in the New Keynesian Phillips Curve. Specifically,

$$\pi_t = \sum_{i=1}^{\infty} \varphi_i \pi_{t-i} + \sum_{j=1}^{J} \mu_j \ E_t \ \pi_{t+j} + \sum_{j=0}^{J} \kappa_j \ \hat{s}_{t+j}$$

so that current inflation depends of lagged inflation, future expected inflation and real marginal costs. More recently, Mash (2004), Sheedy (2005) and Whelan (2007) have provided expressions for NK Phillips Curves for a general distribution of price durations. The paper by Sheedy is particularly clear in showing that microfounded models of price stickiness are able to generate structural persistence if the hazard rate is increasing. This is theoretically attractive since it provides an explanation of structural persistence by relaxing the assumption of a constant probability of price adjustment made in the Calvo model. Specifically, Sheedy (2005) obtains a recursive representation of the Phillips Curve of order n for the general case

$$\pi_t = \sum_{i=1}^{n-1} \varphi_i \pi_{t-i} + \sum_{j=1}^{n} \mu_j \ E_t \pi_{t+j} + \kappa \ \hat{s}_t$$

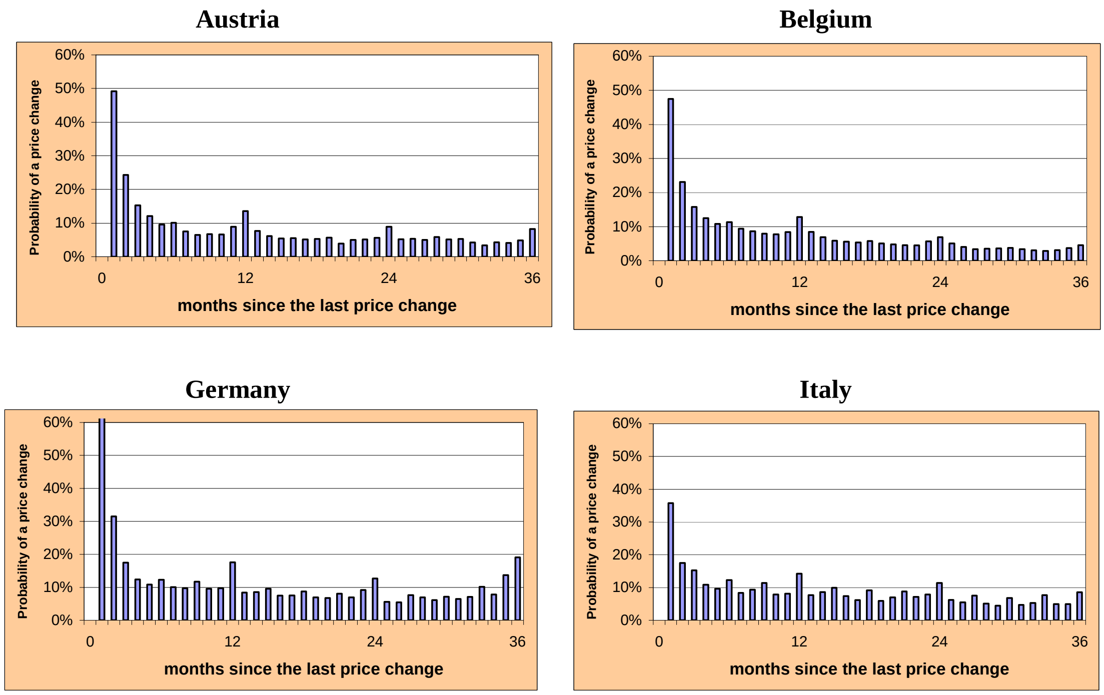
Thus, current inflation depends on n-1 lags of past inflation, n expected future inflation rates, and current real marginal cost. Further, if the hazard function has a positive slope then all lags of inflation have positive coefficients.

The validity of the different theoretical models can be assessed on the basis of estimates of hazard functions using consumer price micro data (See *e.g.* Fougère *et al.* (2007) for France, Hansen and Hansen (2006) for Denmark or Saita *et al.* (2006) for Japan). Figure 2 presents estimates of this function for Austria, Belgium, Germany and Italy. There are three common findings that are observed in every country. First, hazard functions of price changes are downward sloping. Second, a large fraction of firms change their prices monthly. Third, an important number of firms adjust prices every 12, 24, 36 ... months, in line with survey evidence. This type of result is also found with producer price data as shown by Álvarez, Burriel and Hernando (2005b) for Spain or Nakamura and Steinssson (2007) for the US.

The downward slope of the hazard function, taken at face value, means that a firm will have a lower probability of changing its price the longer it has kept it unchanged, which is at odds with theoretical time and state dependent models of price setting. A more reasonable explanation is that it simply reflects the aggregation of heterogeneous price setters. Indeed, it is well known in the failure literature that a mixture of distributions with non-increasing failure rates has a decreasing failure rate (see Proschan (1963)). The intuition is as follows. By definition, firms with sticky pricing strategies have a lower probability of adjusting prices than firms with flexible pricing rules. The aggregate hazard function considers price changes for all firms and the share of price changes by firms with flexible pricing strategies decreases with the age of the price, that is, with the amount of time since the price was last changed. For high ages only price changes of sticky firms are observed.

Figure 2

Hazard functions for consumer price changes



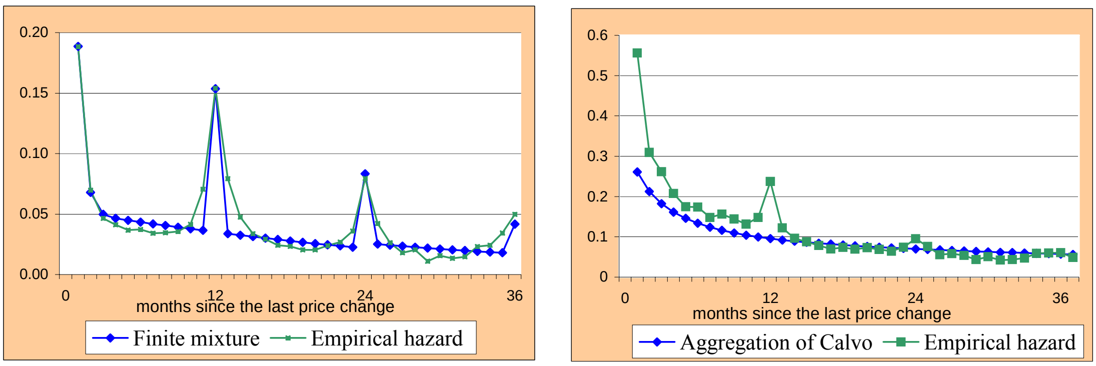
These stylised facts cannot be accounted for on the basis of any of the theoretical models mentioned above. To account for them, Álvarez, Burriel and Hernando (2005b) propose a parsimonious model made up of several Calvo agents with different average price durations. Specifically, they estimate finite mixtures of Calvo models to characterise Spanish producer and consumer micro price data. As can be seen in the left panel of figure 3, they find that a very accurate representation of individual data is obtained by considering just 4 groups of agents: one group of flexible Calvo agents, one group of intermediate Calvo agents and one group of sticky Calvo agents plus an annual Calvo process. This annual Calvo process entails a hazard rate which is non-zero and constant for ages that are multiples of a year.

Another possibility would be to consider that economies are made up of numerous sectors and that each of them follows a Calvo pricing rule with a different parameter (Some authors such as *e.g.* Carvalho (2006) calibrate multisector models under this assumption). This could be seen as producing a more accurate representation of the data. However, the results in the right panel of figure 3 point to some problems of this alternative hypothesis. The aggregation of Calvo price setters misses some features of the hazard function of price changes. First, for the aggregate of Calvo price setters, the hazard rate for prices of age 1 equals the average frequency of price adjustment, which is typically considerably lower than the empirical hazard rate. Second, by construction, the hazard of the aggregate does not show annual spikes that are present in the data. Finally, the hazard of the aggregate converges asymptotically to the hazard rate of the group with highest average duration. In general, there will be some price setters who show stickier than the average of the stickiest group.

Figure 3

Hazard functions for price changes

Spanish producer prices | **United States consumer prices**



6. Heterogeneity

As seen in the previous section, one possible explanation for the downward slope of hazard functions is that there is heterogeneity in pricing behaviour. However, the standard NKPC assumes that all firms are identical. If differences in pricing behaviour exist but are not taken into account this will lead to misspecificied models. Indeed, Imbs *et al.* (2007) show that ignoring heterogeneity leads to biases in the coefficients of the NKPC that correspond to expected inflation and real marginal costs. The analytical expressions they provide show that the direction and size of the bias depend on the coefficients and on whether Generalized Method of Moments (GMM) or Maximum Likelihood (ML) techniques are used.

Interestingly, Carvalho (2006) has extended the NKPC to allow for heterogeneity, continuing previous work by Aoki (2001) and Benigno (2004). Specifically, he models heterogeneity following Calvo (1983): in every period, each firm changes its price with a constant, sector-specific probability. He obtains a generalized NKPC that accounts explicitly for heterogeneity in price stickiness.

$$\pi_t = \beta \, E_t \pi_{t+1} + \varphi \; (y_t - \bar{y}) + \psi \; g_t$$

The expression differs from the standard one in a fundamental way: heterogeneity produces a new, endogenous shift term (g_t) that can be written as a weighted average of sectoral output gaps, with weights related to sectoral frequencies of price adjustment. Moreover, the coefficient on the aggregate output gap in the Phillips curve also depends on the sectoral distribution of price stickiness. The standard NKPC obtains as a special case when the frequency of price changes is the same across all sectors. In this model, monetary shocks have considerably larger and more persistent real effects than in identical-firms economies with similar degrees of nominal and real rigidities.

Table 3

Heterogeneity in pricing behaviour

Monthly frequency of price changes (%).

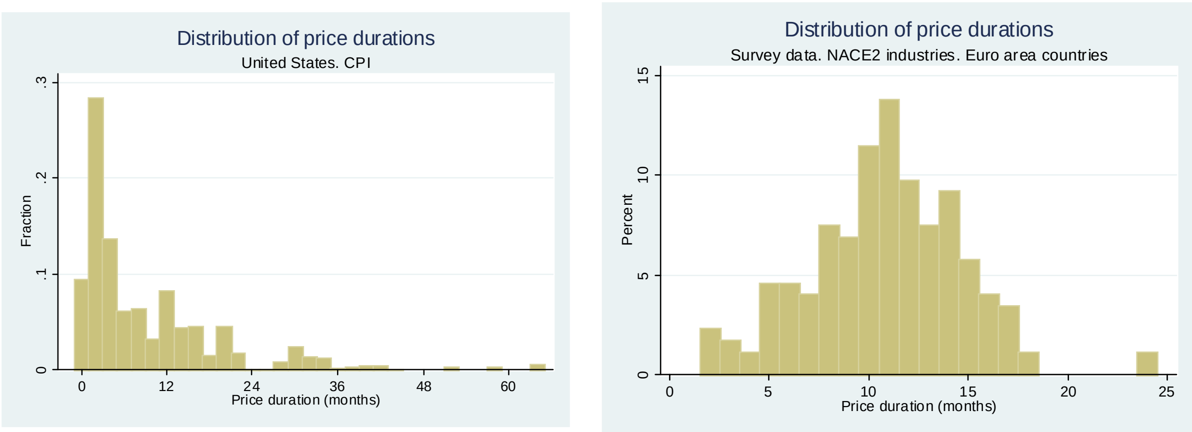
1. Consumer prices	Unprocessed food	Processed food	Energy	Non energy industrial goods	Services
Austria	37.5	15.5	72.3	8.4	7.1
Belgium	31.5	19.1	81.6	5.9	3
Denmark	57.5	17.6	94.6	8.3	7.3
Euro area	28.3	13.7	78	9.2	5.6
Finland	52.7	12.8	89.3	18.1	11.6
France	24.7	20.3	76.9	18	7.4
Germany	25.2	8.9	91.4	5.4	4.3
Italy	19.3	9.4	61.6	5.8	4.6
Japan	71.8	30.8	50.9	22.7	3.9
Luxembourg	54.6	10.5	73.9	14.5	4.8
Mexico	26.4	12.5	54.9	18.7	6.1
Netherlands	30.8	17.3	72.6	14.2	7.9
Portugal	55.3	24.5	15.9	14.3	13.6
Spain	50.9	17.7	n.a.	6.1	4.6
United States	47.7	27.1	74.1	22.4	15

2. Producer prices	Food	Durable products	Energy	Non-durable non-food	Intermediate products	Capital goods
Belgium	20	14	50	11	28	13
Euro area	27	10	72	11	22	9
France	32	13	66	10	23	12
Germany	26	10	94	14	23	10
Italy	27	7	n.a	10	18	5
Portugal	21	18	66	5	12	n.a
Spain	24	10	38	10	28	8

Source: Consumer prices: For euro area countries and United States, Dhyne et al (2006); for Denmark, Hansen and Hansen (2006); for Japan, Saita et al. (2006) and for Mexico, Gagnon (2006). Figures for Mexico refer to the period 2003-2004. For producer prices, Vermeulen et al (2007)

The recent micro evidence consistently finds that price adjustment is heterogeneous across firms. Indeed, as can be seen in table 3, companies that change prices frequently coexist with firms that keep prices unchanged for relatively long periods. Some interesting findings arise. Specifically, CPI price adjustments are particularly frequent for energy and unprocessed food products, whereas services prices tend to remain constant for long periods. In turn, processed food products and non-energy industrial goods tend to occupy an intermediate ranking. Survey data also show that prices of food and energy are changed more frequently than for other goods or services (see Álvarez and Hernando (2005) for Spain). Within sector heterogeneity is still highly relevant as can be seen in figure 4. The left panel presents the histogram of price durations in the Nakamura and Steinsson (2007) dataset of United States consumer price data. The right panel presents the histogram of price durations based on survey data of NACE 2 euro area industries used in Álvarez and Hernando (2007). Available evidence (*e.g.* Jonker *et al.* (2004) for the Netherlands or Veronese *et al.* (2005) for Italy) also points out the impact of the type of outlet on the frequency of price adjustment. Indeed, the frequency of price changes is significantly higher in supermarkets and hypermarkets than in traditional shops, suggesting that the structure of the retail sector plays a role in explaining differences in the degree of price adjustment. Analysis of producer prices also finds that energy and food products are also characterised by more frequent price adjustment, whereas capital goods and durables are the stickier components.

Figure 4



Interestingly, heterogeneity is found to be related to differences in industry characteristics such as costs and market competition. For instance, the frequency of consumer price change depends on the variability of input prices (Hoffmann and Kurz-Kim (2006)) and differences in the cost structure help explain differences in the degree of producer price flexibility (Álvarez, Burriel, and Hernando (2005a) and Cornille and Dossche (2006)), a result also found with survey data (Álvarez and Hernando (2005, 2007)). Specifically, the share of labour costs in variable costs negatively affects the frequency of price change -given that wages do not change often-, whereas the share of costs of intermediate goods in variable costs has a positive impact. Regarding market competition, survey evidence shows that higher competition leads to more frequent price changes (Álvarez and Hernando (2005, 2007)), a result also found with consumer prices (Lünnemann and Mathä (2005)).

7. Time dependent behaviour

Some measures have been suggested in the literature to measure the relative importance of time-dependent price setters. The one most commonly used was introduced by Klenow and Kryvtsov (2005). Their method is based on a decomposition of the variance of inflation into two components. The first depends on the variance of the average size of non-zero price changes. The second depends on the variance of the share of items that change prices and on the covariance between the size of non-zero price changes and the fraction of items changing price. Given this decomposition of the variance of inflation, Klenow and Kryvtsov (2005) use the ratio between the time-dependent component of the inflation variance and the total variance of inflation as a measure of the importance of time-dependent price setting schemes. Strictly speaking, the measure reflects the relevance of uniform staggering, as *e.g.* in the Calvo model As an alternative measure of time dependent behaviour, Dias *et al.* (2005) suggest that the complement of the Fisher and Konieczny (2000) index can be seen as an estimator for the share of firms with uniformly staggered pricing behaviour.

Table 4

Importance of time dependent behaviour. Quantitative micro data

	Consumer prices			Producer prices	
Country	Dias et al measure	Paper	Klenow Kryvstov measure	Paper	Klenow Kryvstov measure
Austria	79				
Belgium	82			Cornille and Dossche (2006)	86 (36)
Finland	64	Kurri (2007)	98		
France	81	Baudry et al. (2006)	83	Gautier (2006)	92.2 (97.9)
Germany	87				
Italy	76				
Luxembourg	52				
Netherlands	73				
Portugal	83	Dias et al. (2006)	74 (69)	Dias et al. (2006)	92
Spain	85				
Euro area	82				
United States		Klenov and Kryvtsov (2005)	97(91)		
Mexico		Gagnon (2006)	34.6 (82.7)		
Sierra Leone		Kovanen (2006)	3.1		

Notes: Dias et al. (2005) measures computed as the complement of the median synchronisation ratio presented in Dhyne et al. (2005). Klenow-Kryvstov measures: For Portuguese CPI, figures refer to 1993-1997 and those in brackets to 1998-2000. For French PPI, figures in brackets control for seasonality, VAT rate changes and euro cash-changeover. For Belgian PPI, figures exclude the months of January and December, whereas those in brackets do not. For Mexican CPI figures refer to the high inflation 1995-1999 period, whereas those in brackets refer to the low inflation 1999-2002 period. For US CPI, figures in brackets refer to regular prices including substitutions

Table 4 presents the results of these measures. In general, both measures point to the relevance of time dependent behaviour for countries with low and moderate inflation and are in line with the stability over time of the frequency of price change reported in the different micro studies. Interestingly, the Klenow and Kryvstov measure points to a very low share of time dependent price setters for Sierra Leone and Mexico, which is to be expected given the high inflation rates in those countries in the period under analysis.

Quantitative studies also find some specific elements of state dependence. For instance, inflation is associated with higher frequencies of price increases and lower frequencies of price decreases (see *e.g.* Veronese *et al.* (2005) for Italian CPI or Stahl (2006a) for German PPI evidence), although the magnitude of the effects is moderate. Indirect tax changes are also found to have an impact on the frequency of price adjustment (see *e.g.* Aucremanne and Dhyne (2004) for Belgian CPI or Álvarez et al. (2005a) for Spanish PPI), although the share of firms that adjust prices following an indirect tax rate change is relatively small.

An alternative way of determining the relevance of time dependent price is obtained from survey data (table 5). Firms have been asked for the strategy they follow when reviewing their prices. In the typical survey, they were offered the following options: "At specific time intervals", which can be interpreted as evidence of time dependence, "In response to specific events", which is in line with state dependent models, and "Mainly at specific time intervals, but also in response to specific events", which reflects a mixed strategy. In general, results show the coexistence of time and state dependent elements in pricing behaviour at the individual level.

Table 5

Importance of time dependent behaviour. Survey data

Share of firms (%)

Country	Paper	Time-dependent	Time and state dependent
Austria	Kwapil et al. (2005)	41	32
Belgium	Aucremanne and Collin (2005)	26	40
Canada	Amirault et al. (2006)	66	-
Estonia	Dabušinskas and Randveer (2006)	27	50
Euro area	Fabiani et al. (2006)	34	46
France	Loupias and Ricart (2004)	39	55
Germany	Stahl (2005)	26	55
Italy	Fabiani et al. (2004)	40	46
Luxembourg	Lünnemann and Mathä (2006)	18	32
Netherlands	Hoeberichts and Stokman (2006)	36	18
Portugal	Martins (2005)	35	19
Spain	Álvarez and Hernando (2005)	33	28
United Kingdom	Hall et al. (2000)	79	10
United States	Blinder et al. (1998)	60	10

For US: time and state dependent considers periodic price reviews for some products but not for others. For France, the figure corresponds to the one reported in Fabiani et al. (2006)

The evidence on country studies summarised in Fabiani *et al.* (2006) generally shows that the share of firms following mainly time-dependent rules is generally higher for other services than in trade, which, in turn, is higher than in manufacturing. Larger companies also tend to use time dependent rules slightly more often. To shed more light on the relationship between use of time dependent pricing strategies and industry characteristics table 6 presents the results of a multinomial logit model with Spanish survey data. The following results are worth highlighting: First: time dependent rules tend to be used more the higher is the labour intensity of production processes, reflecting a higher stability of marginal costs in those industries. Second: the higher is the degree of perceived competition the lower is the fraction of firms using purely time-dependent rules. This result is consistent with the idea that prices of firms operating in more competitive markets are more likely to react to changes in their environment. Third, small sized firms tend to rely less on time dependent pricing strategies.

Table 6

Multinomial logit regression. Price review

	Time dependent			Time and state dependent		
Vatiable	Coefficient	Standard error	z	Coefficient	Standard error	z
Labour	3.15	0.55	5.7	2.16	0.58	3.7
Competition	-0.12	0.06	-2.1	0.06	0.06	1.1
Demand conditions	0.04	0.03	1.3	0.07	0.03	2.1
Small sized firm	-0.48	0.12	-3.9	-0.68	0.13	-5.4
Food	-0.61	0.41	-1.5	0.41	0.47	0.9
Consumer non food	-0.29	0.38	-0.8	0.54	0.45	1.2
Intermediate	-1.52	0.37	-4.1	-0.37	0.44	-0.8
Capital goods	-1.34	0.38	-3.5	-0.11	0.45	-0.3
Food trade	-0.18	0.41	-0.4	0.23	0.48	0.5
Energy trade	0.05	0.75	0.1	0.23	0.91	0.3
Other trade	0.02	0.37	0.1	0.63	0.44	1.4
Hotels and travel agents	0.27	0.44	0.6	1.09	0.52	2.1
Bars and restaurants	-0.56	0.39	-1.4	0.59	0.46	1.3
Transport	-0.07	0.37	-0.2	0.66	0.46	1.5
Communications	-0.67	0.47	-1.4	-0.21	0.58	-0.4
Constant	-0.24	0.38	-0.6	-1.40	0.45	-3.1

Number of observations	1847
Wald chi2 (30)	213.08
Log likelihood	-1881.63
AIC	3768.71
BIC	3945.39
Pseudo R2	0.07

Reference group: State dependent. Reference sector: Energy
Robust standard errors

Overall, there seems to be a need to develop more realistic theoretical state dependent models, though, since implications of the most widespread models are at odds with micro data. For instance, most state dependent models, like those based on menu costs, assume that firms evaluate their pricing policy every period and set a new price if they find it convenient. However, in practice, firms do not continuously evaluate their pricing plans. Fabiani *et al.* (2006) and Lünnemann and Mathä (2007) show that firms review prices infrequently. Indeed, for the euro area as a whole, Fabiani *et al.* (2006) find that 57% of firms review prices not more than three times a year and only 12% review more than once a month. The modal firm reviews prices once a year, a result also found for non euro area countries (Lünnemann and Mathä (2007)). These kind of results are in line with the predictions of Reis (2006) inattentiveness model, which rationalises infrequent price reviewing. Unfortunately, this model also predicts that firms must change prices continuously, which is clearly at odds with micro evidence.

An additional problem for menu costs models is that they are typically among the least recognised theories by firms, despite their prevalence in theoretical research. Fabiani *et al.* (2006) report that menu costs rank eight out of ten theories for the euro area and similar results are reported by Lünnemann and Mathä (2007) for other countries.

8. Forward looking behaviour

Survey evidence allows to determine to which extent pricing policies of firms are forward looking. This is relevant since the Calvo model relies on forward looking price setters. Further, some proposals of hybrid NKPC allow for departures of this assumption. Galí and Gertler (1999) propose a model, where they assume that a fraction of firms set prices according to a backward looking rule of thumb. Specifically, they index on last period's optimal price, rather than simply last period's aggregate price index. This leads to a NKPC of the form

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f \; E_t \pi_{t+1} + \psi \; \hat{s}_t$$

where all the coefficients are explicit functions of structural parameters: the degree of price stickiness, the share of rule of thumb price setters and the discount factor. Kiley (2007) proposes a generalisation of this rule of thumb, whereby prices are indexed to a 4 quarter moving average of inflation.

A related approach has been proposed by Roberts (1997). This author assumes that a fraction of price setters are backward looking and use a simple autoregressive model to forecast inflation, whereas the remaining fraction are purely forward looking. Aggregating across agents, a hybrid model of inflation with forward-looking and backward looking agents is obtained.

Table 7 presents evidence on forward looking pricing behaviour in the surveys of the United States and Canada. The evidence shows substantial departures from the hypothesis of forward looking price setters. In particular, a significant fraction of firms is not affected by changes in the outlook for the national economy, suggesting an important role for firm specific factors. The impact of future inflation is generally more important, although less so than anticipated firm specific costs. Only 45% of US firms and 40% of Canadian firm state that they will raise prices in the face of anticipated costs increases. When asked about the reasons for not changing prices in this context, firms give especial attention to coordination failure and implicit and explicit contract explanations. These are also the theories that tend to receive the broadest support in surveys carried out in other countries.

Table 7

Forward looking price behaviour. American surveys

Share of firms (%)

United States

1. Do forecasts about the future outlook for the national economy ever directly affect the prices you set?

Never	70.5
Ocassionally	15.0
Often	14.5

2.Do forecasts of future economy-wide inflation rates ever directly affect the prices you set?

Never	51.8
Ocassionally	19.9
Often	28.3

3. When you see cost or wage increase coming, do you raise your prices in anticipation?

Yes or often	44.4
No or rarely	55.6

4. Why do not firms raise their prices in the face of anticipated cost increases?

We worry compting firms won't raise their prices	26.4
It would antagonize or cause difficulty for our customers	25.6
Once costs rise, we can raise our prices promptly	14.9
We lack confidence in our cost forecasts	8.3
Contracts or regulation prohibit anticipatory price hikes	6.6
Other	18.2

Canada

If you foresee an increase in your future costs (such as raw materials), do you raise your own prices in anticipation?

Yes	40
Other	60

Source: Author calculations on the basis of individual data in Blinder et al (1998). Question 3 only asked to firms that do not consider cost totally unimportant. Question 4 only asked to firms that do not rise prices in anticipation of cost increases. For Canada, Amirault et al. (2006)

Table 8 presents the evidence of European surveys. Again, the existence of a significant share of firms deviating from full forward looking behaviour is generally found. Interestingly, some surveys have asked firms whether when setting prices they follow some simple rule of thumb (for instance, changing prices by a fixed percentage, or following a CPI indexation rule) or whether they consider a wide set of indicators that relate to the current environment (backward looking firms) or include expectations on the future economic environment (forward looking firms). It is found that around one third of firms employ some simple rule of thumb when setting prices, supporting the hybrid model of Galí and Gertler (1999). However, Álvarez and Hernando (2005) find that the fact that a firm applies a rule of thumb has a significative negative impact on the frequency of price change. It seems that firms which use simple rule of thumbs change prices less frequently than the rest. In contrast, in Galí and Gertler model (1999) rule of thumb price setters change prices continuously. Probably, a rule of thumb whereby firms change prices once a year, in line with aggregate past inflation, would capture inflation dynamics more realistically.

Table 8

Forward looking price behaviour. European surveys

Share of firms (%)

Country	Rule of thumb	Backward looking	Forward looking
Belgium	37	29	34
Estonia	n.a.	59	41
Luxembourg	32	34	34
Portugal	25	33	42
Spain	33	39	28
	Past information	Past information and forecasts	Forecasts
Austria	37	51	12
	Past information	Current and future information	
Italy	32	68	
	Past information	Contemporary information	Expectations
Germany	23	55	15

Note: For Germany, rescaled figures from Stahl (2006b) on firms stating that the corresponding information vintage is very important.

To analyse the relationship between the information set that a firm uses and industry characteristics, Table 9 presents the results of a multinomial logit model with Spanish survey data. Some interesting results are obtained: First, a higher industry labour share is associated with a greater reliance on rule of thumb behaviour, reflecting lower uncertainty in total costs developments. Second, the higher is the degree of market competition, the higher is forward looking behaviour. Third, the more relevant are demand conditions the higher is the use of forward looking strategies. Fourth, small sized firms are more likely to adopt some simple rule of thumb.

9. Imperfect competition

One defining characteristic of New Keynesian price setting models is some element of imperfect competition, which provides a price formation story: prices arise from the profit-maximizing decisions of individual firms. Imperfect competition also makes it feasible for some firms not to adjust their price in a given period, in contrast with a perfect competition environment.

The standard form of imperfect competition in NKPC is the model of monopolistic competition of Dixit and Stiglitz (1977). Firms produce differentiated products and so are able to influence the market price of their products by altering production. Firms maximize profits by setting prices at a mark-up over marginal costs taking into consideration their demand curve. The assumption of constant elasticity of demand implies that the profit-maximizing mark-up is constant regardless of changes in demand or in production costs. Mark-ups nevertheless vary in this class of sticky-price models as firms do not constantly change prices. More recently, Eichenbaum and Fisher (2004) have considered the implication for the NKPC of the demand curve proposed by Kimball (1995). This implies that as prices rise, the elasticity of demand increases. Demand functions of this kind can imply that a 1 percent increase in marginal costs results in a less than 1 percent increase in prices. It is shown that the form of the NKPC remains the same but the relationship between the slope of the Phillips curve and the implied frequency of price change is modified.

Table 9

Multinomial logit regression. Information set

	Backward looking			**Forward looking**		
	Coefficient	Standard error	z	Coefficient	Standard error	z
Labour	-2.16	0.54	-4.0	-1.92	0.61	-3.1
Competition	0.21	0.05	4.0	0.21	0.06	3.4
Demand conditions	0.09	0.03	3.0	0.13	0.04	3.6
Small sized firm	-0.22	0.12	-1.9	-1.13	0.14	-8.0
Food	0.44	0.40	1.1	0.32	0.43	0.7
Consumer non food	0.35	0.38	0.9	0.30	0.39	0.8
Intermediate	0.65	0.37	1.8	0.51	0.37	1.4
Capital goods	0.26	0.38	0.7	0.04	0.38	0.1
Food trade	0.07	0.41	0.2	-1.05	0.46	-2.3
Energy trade	1.25	0.93	1.3	0.95	1.08	0.9
Other trade	0.14	0.37	0.4	-0.32	0.39	-0.8
Hotels and travel agents	0.70	0.41	1.7	0.99	0.42	2.4
Bars and restaurants	0.29	0.38	0.8	-0.47	0.43	-1.1
Transport	-0.13	0.37	-0.4	-0.35	0.39	-0.9
Communications	-0.50	0.54	-0.9	0.39	0.45	0.9
Constant	-0.35	0.38	-0.9	-0.49	0.40	-1.2
Number of observations	1847					
Wald chi2 (30)	253.33					
Log likelihood	-1852.35					
AIC	3768.71					
BIC	3945.39					
Pseudo R2	0.07					

Reference group: Rule of thumb. Reference sector: Energy
Robust standard errors

The various surveys address the issue of how firms set prices using slightly different formulations. Nevertheless, the results of the national surveys can be compared by grouping the answers into three alternatives: “markup over costs”, “price set according to competitors’ prices” and “other”. For the euro area as a whole, a significant share of firms (54%) set their prices as a markup over marginal costs, suggesting that they enjoy a non negligible degree of market power. The fraction of companies setting prices according to those of their competitors is 27%. Finally, around 19% of the companies state that they do not have autonomous price setting policies. For these firms, the final decision on the price charged is taken by a different economic agent, and this may be the public sector, the parent company, the main customers or the suppliers. Country results, as reported in table 10, provide a similar picture. Overall, survey evidence provides strong support for the view that imperfect competition characterizes most product markets. Imperfect competition, though, seems to be of a more complex kind than implied by the monopolistic competition model, since there is evidence of *e.g.* price discrimination.

Table 10

Price setting rules

	Markup	Variable mark-up	Competitors' price	Other
Belgium	46	33	36	18
Estonia	53		46	2
Euro area	54		27	18
France	40		38	22
Germany	73	69	17	10
Italy	42		32	26
Netherlands	56	30	22	21
Portugal	65		13	23
Spain	52		27	21

Notes: 1.Rescaled figures excluding non-responses. 2. For Belgium, variable markup corresponds to firms adopting a markup rule and responding "important" or "very important" to at least one of the theories concerning countercyclical markups. 3. For Portugal, the question was not addressed directly. The information reported in the table has been estimated on the basis of the answers to other questions. 4. For Estonia, firms were asked to assess the relevance of different price setting rules – the results in the table refer to the most relevant rule chosen.
Source: For euro area countries, Fabiani et al. (2006). For Estonia, Dabušinskas and Randveer (2006)

10. Conclusions

A generalised version of the hybrid NKPC model of Galí and Gertler (1999) seems able to account for a number of micro data facts on nominal price rigidity and the existence of intrinsic inflation persistence. In this model, a fraction of firms set prices optimally à la Calvo. These firms change prices infrequently, as observed in micro data studies and in contrast with models that rely on some indexation mechanism (*e.g*. Christiano *et al.* (2005)) or on polynomial costs on price adjustment (*e.g.* Rotemberg (1982) or Kozicki and Tinsley (2002)). Moreover, micro data studies usually find that the length of time between price changes varies considerably within individual price trajectories, which is consistent with Calvo pricing but contradicts the predictions of Taylor-type contracting models. The Calvo model is also able to account for the downward hazard function of price changes if the standard model is extended to allow for heterogeneity in pricing behaviour. The downward slope of the hazard cannot be explained by several theoretically attractive models, like those of Sheedy (2005) or Dotsey, King and Wolman (1999). It is also found that a significant fraction of firms employ some simple rule of thumb when setting prices, supporting the hybrid model of Galí and Gertler (1999). However, available evidence suggests that firms which use simple rule of thumbs change prices less frequently than the rest, instead of continuously, as in Galí and Gertler (1999). A variation of the model whereby rule of thumb firms change prices once a year, in line with annual inflation, is likely to capture inflation dynamics more realistically.

The micro evidence also suggests that elements of state dependence should play a role. However, there seems to be a need to develop more realistic theoretical state dependent models, since implications of the most widespread models are at odds with micro data. For instance, most state dependent models, like those based on menu costs, assume that firms evaluate their pricing policy every period and set a new price if they find it convenient. However, in practice, firms do not continuously evaluate their pricing plans. Models that rationalise infrequent price reviewing, like Reis (2006) inattentiveness model, unfortunately also predict that firms must change prices continuously, which is clearly at odds with micro evidence. An additional problem for menu costs models is that they are typically among the least recognised theories by firms.

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Appendix

Data definitions for variables used in multinomial logit models

Variable	Source	Comment
Labour	Industrial, Trade and Services surveys. Instituto Nacional de Estadíitica	Labor costs as a percentage of labour and intermediate inputs costs. NACE 3 digit level
Competition	Álvarez and Hernando (2005)	Importance of competitors' prices to explain price decreases
Demand conditions	Álvarez and Hernando (2005)	Importance attached by firms to demand conditions in explaining price changes.
Small sized firm	Álvarez and Hernando (2005)	Employment of firms with less than 50 employees