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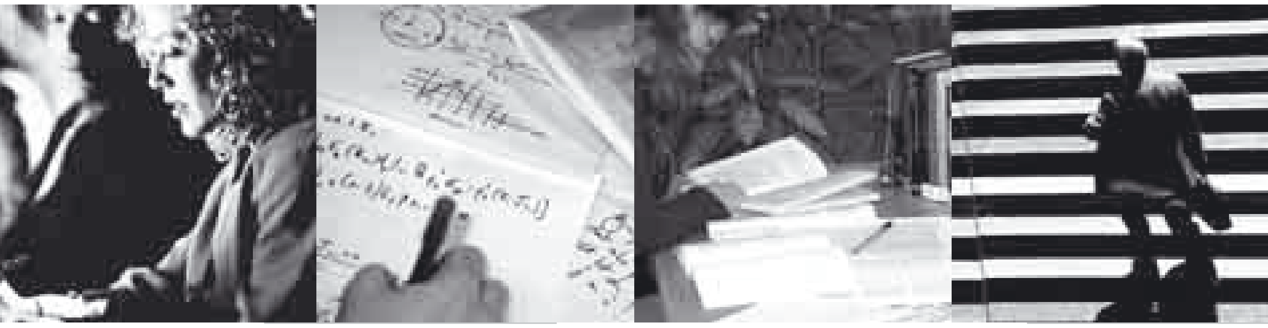

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LUMPY PRICE ADJUSTMENTS: A MICROECONOMETRIC ANALYSIS

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Editorial

On October 12-13, 2006 the National Bank of Belgium hosted a Conference on *"Price and Wage Rigidities in an Open Economy"*. Papers presented at this conference are made available to a broader audience in the NBB Working Paper Series (www.nbb.be).

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Abstract

This paper presents a simple model of state-dependent pricing that allows identifying the relative importance of both nominal and real factors in price rigidity. Using two rich datasets consisting of a large fraction of the price quotes used to compute the Belgian and French Consumer Price Indices, we are able to evaluate, the importance of the menu costs and to discriminate between idiosyncratic and common shocks that affect the marginal cost and/or the desired mark-up at the outlet level. We find that infrequent price changes are not necessarily associated with large menu costs. Indeed, real rigidities appear to play a significant role. We also find that asymmetry in the price adjustment may result from a trend in marginal costs and/or desired mark-ups rather than from asymmetric menu costs.

JEL-code : C51, C81, D21.

Keywords: Sticky prices, menu costs, nominal and real rigidities, micro panels.

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1 Introduction

Following the seminal contributions of Cecchetti (1986) on newspaper prices, Kashyap (1995) on catalog prices (both using US data), and Lach and Tsiddon (1992) on meat and wine prices in Israel, a recent wave of empirical research has provided new evidence on consumer and producer price stickiness at the micro level using large data sets. For studies of consumer prices see, for example, Bils and Klenow (2004) and Klenow and Kryvstov (2005) who focus on the US, and Dhyne *et al.* (2006) who provide synthesis of the recent studies carried out for the euro area countries. Studies of producer prices include those by Cornille and Dossche (2006), Alvarez *et al.* (2006), Stahl (2005), Dias, Dias and Neves (2004), and Sabbatini *et al.* (2005).

One of the main conclusions of these studies is the existence of a significant heterogeneity across different product categories in the degree of price flexibility. Some products are characterized by a high frequency of price changes where firms reset their prices almost on a continuous basis (for instance, oil products and perishable goods), whilst other product categories are characterized by a very low frequency of price changes (for instance, in some services). Moreover, several studies (Baudry *et al.*, 2004, Jonker, Blijenberg and Folkertsma, 2004, Veronese *et al.*, 2005) have shown that the frequency of consumer price changes not only differs across product categories, but also across categories of retailers. Hyper and super-markets change their prices more frequently than local corner shops. Aucremanne and Dhyne (2004) also document a high degree of heterogeneity in the duration of price spells (and hence in the frequency of price changes) even within relatively homogeneous product categories.

However, these studies are silent as to the reasons for such infrequent price changes. A low frequency of price change has sometimes been taken as evidence of nominal rigidity. This ignores the role of real rigidity in price stickiness. Although large menu costs lead firms to adjust their price infrequently, infrequent price changes are not necessarily due to high menu costs (i.e. nominal rigidities). Indeed, when marginal costs and other market conditions do not vary, firms have little incentive to change their prices. In this paper, we aim at identifying the respective contributions of nominal and real rigidities to the observed price stickiness. For that purpose, we develop a state dependent price-setting model that relates price changes to the variations in an unobserved optimal price reflecting common and idiosyncratic movements in marginal costs and/or in the *desired* mark-up, but where price changes are subject to menu costs.[1] Considering very homogenous product categories, this microeconomic (s, S) pricing model, which closely relates in spirit to Cecchetti (1986), allows us to discriminate between real and nominal rigidity.

Compared to the existing literature, we argue and show that the frequency of price changes may be a poor indicator of nominal rigidities. For example, for some services which are characterized by a low frequency of price changes, our estimates reveal that the scarcity of price changes originates essentially from real rigidities rather than from high menu costs. Price stickiness may thus be explained by low volatility of common or idiosyncratic shocks affecting marginal costs and/or *desired* mark-ups.

The structure of the paper is as follows. We first present the theoretical model in Section 2. We then discuss the estimation procedure in Section 3. Section 4 describes the micro price data sets used and presents the estimation results. Section 5 concludes.

2 A Canonical Model of Sticky Prices

It is now a well-established stylized fact that most consumer prices remain unchanged for periods that can last several months (e.g. see Bils and Klenow (2004), Dhyne *et al.* (2006) among many others). Indeed, for a number of reasons (physical menu costs, fear of consumers anger, etc.), retailers may be reluctant to immediately adjust their prices to changes in their environment (costs increases/decreases, demand variations, changes in local competition, etc.). Such a behavior can be modelled assuming fixed menu costs,[2] leading to an optimal price strategy of the (s, S) variety (see, for example, Sheshinski and Weiss, 1977, 1983, Cecchetti, 1986, or Gertler and Leahy, 2006).

[1] The use of state dependent price-setting models by firms seem to be supported by surveys. Indeed, Fabiani *et al.* (2005) report for the euro area that 66% of firms consider pure or mixed state dependent pricing rules in order to decide when to change their prices.

[2] Several papers have find evidence of fixed physical menu costs of price adjustment (Levy *et al.*, 1997, Zbaracki *et al.*, 2004). However, Zbaracki *et al.* (2004) argue that, in addition to these fixed physical menu costs, managerial and customers costs are convex in the price change, while Blinder *et al.* (1998) survey's responses suggest that price adjustment costs are fixed.

A simple representation of this behavior can be written as:

$$p_{it} = \begin{cases} p_{i,t-1} & \text{if } |p^*_{it} - p_{i,t-1}| \leq c_{it}, \\ p^*_{it} & \text{if } |p^*_{it} - p_{i,t-1}| > c_{it}, \end{cases} \tag{1}$$

where p_{it} is the (log) observed price, p^*_{it} is the (log) optimal price that would be set in the absence of any adjustment costs, and c_{it} measures the extent to which price changes are costly.

This model is very close in spirit to that proposed by Rosett (1959). However, we depart from Rosett's model in that, in our model, the adjustment costs c_{it} only affect the decision to change prices but not the level of the newly set prices p^*_{it}. Indeed, we consider that when firms decide to adjust their prices, they fully adjust to the optimal price while in Rosett's model, agents are assumed to reduce the magnitude of their effective adjustment by the amount of the adjustment cost they incur.[3] Denoting by $I(A)$ an indicator function that takes the value of unity if $A > 0$ and zero otherwise, the model (1), can be written as:

$$\begin{aligned} p_{it} &= p_{i,t-1} + (p^*_{it} - p_{i,t-1}) I(p^*_{it} - p_{i,t-1} - c_{it}) \\ &\quad + (p^*_{it} - p_{i,t-1}) I(p_{i,t-1} - p^*_{it} - c_{it}). \end{aligned} \tag{2}$$

This formulation is reasonably general and allows the menu costs to vary both over time and across outlets. Assuming a constant and common menu cost might be considered as a strong assumption since, as documented in Aucremanne and Dhyne (2004), price setting can be strongly heterogeneous, even in relatively homogeneous product categories. Some price trajectories, measured at the level of individual outlets, may be characterized by very frequent price changes, while others may be characterized by infrequent price changes. Moreover, for some products, the frequency of price changes has clearly a seasonal component (e.g. because of sales), a phenomenon that could be captured by assuming a particular profile of c_{it} over time. In this respect, our state-dependent pricing model could also account for some time dependent price-setting behavior.

We refer to the condition

$$|p^*_{it} - p_{i,t-1}| \geq c_{it}, \tag{3}$$

[3] We shall propose in the next section an extension of our model allowing for a partial adjustment of prices.

as the 'price change trigger' condition. The magnitude of c_{it} critically governs the extent of nominal price rigidity. The larger it is, the lower the likelihood of a price change in response to a given shock. Under our log-linear formulation c_{it} measures the cost in time t for outlet i corresponding to a price change as a percentage of the price level.

As mentioned above, c_{it} partly reflects the narrow traditional menu costs (the cost of changing posted prices) but it is also intended to reflect a broader definition of menu costs. For instance, these menu costs may reflect the specific marketing policy of outlets, regarding sales or promotions. They may also incorporate the degree of customers anger against price changes, as in Rotemberg (2003). If a firm fears to lose a significant fraction of its customers when it changes its prices, it will keep its prices constant so long as the loss induced by a non optimal price is smaller than the loss associated with customers anger. Interpreting the fixed menu cost parameter as a degree of the importance of customer relationship instead of traditional menu cost is supported by surveys on price setting behavior. Indeed, Fabiani *et al.* (2005) for the euro area, Aucremanne and Druant (2005) for Belgium or Loupias and Ricart (2005) for France, on the basis of surveys about firms' price setting behavior, indicate that a major source of price stickiness lies in customer relationships (existence of implicit or explicit contracts), while physical menu costs are not considered as a major source of nominal rigidity.

It is however important to stress that the impact of stable customer relationships on the frequency of price changes is questionable. Ball and Romer (2003) argue that a firm can benefit from stable customer relationships in order to change more frequently its prices by small amounts, as the firms know that the customers will not change their consumption habits in reaction to small price changes. Such a theory would imply smaller menu costs and smaller price changes for products that are bought on a regular basis.

The existence of consumers' anger against price changes is another possible reason for a seasonal profile in the menu costs. Indeed, Aucremanne and Dhyne (2004) and Baudry et al. (2004) document that service prices are commonly changed in January, so that customers may anticipate such price changes to occur during that month while they would react more strongly if such changes had occurred in December. The same remark applies to the expected price increases corresponding to the end of a sales period, that consumers clearly anticipate and which are then less likely to be considered as unfair.[4]

Now, the question arises as whether we can also identify real rigidities that arise when frequency and magnitude of price changes are compared with changes in the fundamentals that underlie changes to the marginal costs and market structure. Unfortunately, despite their size and coverage, the data sets available on consumer prices do not provide any information about costs and demand conditions faced by outlets. Assessing real rigidities then requires making further assumptions. We consider that the (log) optimal price of retailer i at time t can be decomposed into

$$p_{it}^{*} = f_t + \gamma_{it}, \tag{4}$$

where f_t represents the unobserved common component of the (log) optimal price, and γ_{it} represents the idiosyncratic component, possibly including outlet specific components that are fixed over time, such as location and outlet type, and other outlet specific components that vary over time, such the quality of customer relations, seasonal patterns arising form outlet specific sales and other forms of market promotions.

More specifically, consider that, for a given product line, retailer i that operates on a market characterized by imperfect competition sets optimally its price by its marginal cost, MC_{it}, augmented by its *desired* mark-up rate (MU_{it}):

$$P_{it}^{*} = MC_{it} \times (1 + MU_{it}).$$

Using logarithms, the (log) optimal price may be written as:

$$p_{it}^{*} = mc_{it} + \mu_{it}.$$

Then, both the (log) marginal cost, mc_{it}, and the (log) *desired* mark-up μ_{it}, can be decomposed into a component that is common to all firms and other factors that are firm specific. Consequently, for a given product, the common component, f_t, can be viewed as the out of factory (log) producer price, faced by all outlets, augmented by the average level of the *desired* mark-up. Then, changes in the marginal costs as well as other changes in the market conditions (competition, demand variations) faced by all outlets should be reflected in f_t.

[4] In Belgium and France, sales are regulated and occur during periods that are legally determined.

Consequently, the degree of stickiness of f_t can be seen as an indicator of real rigidity.

Accordingly, the firm specific component, γ_{it}, in (4) could represent idiosyncratic shocks to marginal costs and/or to the *desired* mark-up, and can depend on some particular factors such as specific (local) competition conditions, rebates on the wholesale price obtained by large retailers chains, management quality, etc.. Adopting a linear specification, γ_{it} can be decomposed as :

$$\gamma_{it} = \mathbf{x}_{it}'\boldsymbol{\beta} + v_i + \varepsilon_{it}, \tag{5}$$

where $\mathbf{x}_{it}$ is a vector of observable retail-specific variables (hyper or supermarket versus corner shop, geographical location, etc.), v_i are retail-specific unobservable fixed effects, while ε_{it} accounts for firm-specific idiosyncratic shocks that vary over time.

The retail-specific unobservable effects, v_i, account for the heterogeneity in observed prices at the product category level that can not be traced to observables. It could be due to product differentiation and/or the ability of retailer i to consistently price above or below the common component f_t, e.g. because of local competitive conditions.

The magnitude of idiosyncratic shocks, as measured by the standard deviation of ε_{it}, say σ_ε, is also informative about the extent of real rigidities. For example, we would expect firms with low estimates of σ_ε also to have relatively low frequency of price changes. This factor may also be an important source of infrequent price changes if we consider the results reported in Fabiani *et al.* (2005), Aucremanne and Druant (2005) or Loupias and Ricart (2005). Indeed, these papers show that, in addition to customer relationship, what is considered as a major source of price rigidity by firms is the fact that their marginal costs are relatively stable. Finally, following Golosov and Lucas (2003), this idiosyncratic component might be a crucial factor in capturing the very diverse price dynamics that are observed for relatively homogenous product categories. This point is illustrated in the price trajectories for oranges in Belgium and men's socks in France displayed in figures Figures 1.A and 1.B, respectively.

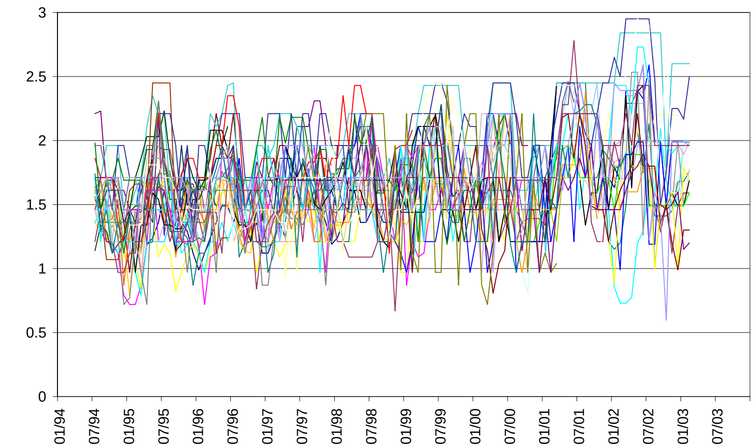

FIGURE 1.A. - 50 PRICE TRAJECTORIES - ORANGES (IN EUR/KG) - BELGIAN CPI

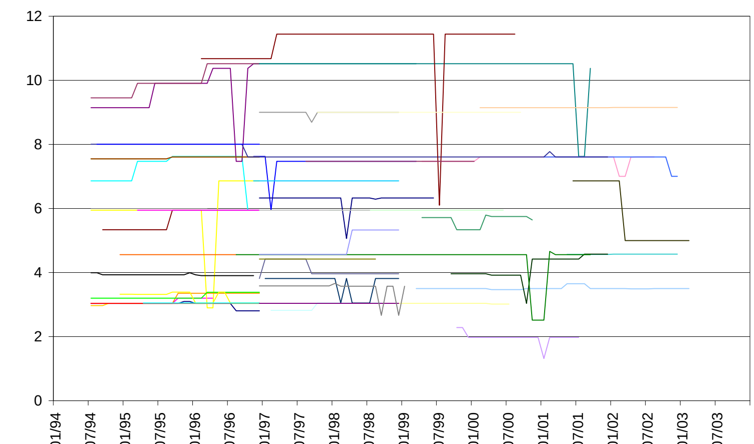

FIGURE 1.B - 50 PRICE TRAJECTORIES - MEN SOCKS (IN EUR) - FRENCH CPI

2.1 Extensions to the Basic Model

The above sticky price model can be generalized in a number of ways. In this paper, we focus only on two of them.

2.1.1 Gradual adjustment

One important extension of the basic model is to allow for only a partial adjustment of prices to their optimal values. While the basic model assumes that, once the retailers decide to adjust their prices, they fully adjust to the optimal price p_{it}^*, retailers may possibly decide to proceed only to a partial adjustment of their prices, setting their new price p_{it} as $(1-\lambda)\, p_{it}^* + \lambda p_{i,t-1}$, where λ is the partial adjustment coefficient $(0 \leq \lambda < 1)$. Such a partial adjustment process may be motivated on several grounds. First, uncertainty surrounding the evaluation of the size and source (common or idiosyncratic) of the shocks to the marginal costs and/or *desired* mark-ups may lead firms to adopt a conservative attitude towards change. Indeed, competition on the product market may induce firms to proceed only to partial price adjustments in response to shocks, in order to keep their market shares when they do not know about their competitors' reaction. Second, under consumers' inattention (Levy *et al.*, 2005), it may be more profitable for outlets to perform gradual adjustments to the optimal price level rather than a single large price change.

In that case, the price change trigger condition becomes:

$$\left|(1-\lambda)\, p_{it}^* + \lambda p_{i,t-1} - p_{i,t-1}\right| > c_{it},$$

or

$$(1-\lambda)\left|p_{it}^* - p_{i,t-1}\right| > c_{it}.$$

A non zero λ parameter will introduce an additional source of rigidity due to price level persistence and introduce a backward-looking component in the model.

2.1.2 Asymmetric menu costs

Another natural extension of the basic model is to allow for asymmetric menu costs. Indeed, Aucremanne and Dhyne (2004) and Baudry *et al.* (2004), among others, have highlighted that price decreases are less frequently observed than price increases, especially in the service sector. This could result from asymmetric menu costs and, more specifically, from stronger downward nominal rigidities (as discussed in Hall and Yates, 1998, and Yates, 1998). In order to test this assumption, one can extend our basic specification and write:

$$
\begin{aligned}
p_{it} &= p_{i,t-1} + (p^*_{it} - p_{i,t-1}) I(p^*_{it} - p_{i,t-1} - c_{Uit}) \\
&\quad + (p^*_{it} - p_{i,t-1}) I(p_{i,t-1} - p^*_{it} - c_{Lit}).
\end{aligned}
$$

If $c_{Lit} > c_{Uit}$, this model will produce more price increases than price decreases, for any given values of f_t. However, it is important to stress that asymmetry in the menu costs is not a necessary condition to generate more price increases than price decreases. As long as f_t is characterized by an upward sloping trend, our baseline model, where $c_{Lit} = c_{Uit} = c_{it}$, will naturally generate more price rises than price falls, as in Ball and Mankiw (1994).

Our model with asymmetric menu costs is very close to the one used in Ratfai (2006). However, we depart from Ratfai's model by allowing menu costs to vary across outlets and over time.[5]

3 Estimation of the model

One can synthesize equations (2), (4) and (5) representing our baseline price-setting model into the following econometric representation:

$$
\begin{aligned}
p_{it} &= p_{i,t-1} \\
&\quad + (f_t + \mathbf{x}'_{it}\boldsymbol{\beta} + v_i + \varepsilon_{it} - p_{i,t-1}) I(f_t + \mathbf{x}'_{it}\boldsymbol{\beta} + v_i + \varepsilon_{it} - p_{i,t-1} - c_{it}) \\
&\quad + (f_t + \mathbf{x}'_{it}\boldsymbol{\beta} + v_i + \varepsilon_{it} - p_{i,t-1}) I(p_{i,t-1} - f_t - \mathbf{x}'_{it}\boldsymbol{\beta} - v_i - \varepsilon_{it} - c_{it})
\end{aligned} \tag{6}
$$

There are essentially two groups of parameters to estimate in this model. First, the unobserved common components f_t which can be viewed as unobserved time effects. Second, the other structural parameters: c and σ_c which respectively denote the mean and standard deviation of c_{it}, σ_ε, the standard deviation of the idiosyncratic shocks ε_{it}, σ_v, the standard deviation of the firm specific random effect v_i and $\boldsymbol{\beta}$, the parameters associated with the observed explanatory variables, $\mathbf{x}_{it}$.

The estimation of the baseline model can be carried out in two ways. First, one can use an iterative procedure that combines the estimation of the f_t's using

[5] We also depart from Ratfai (2006) in the way we model the common component of the optimal prices p^*_{it}. In his work, Ratfai approximates the unobserved common component of p^*_{it} by the relevant producer price index.

the cross-sectional dimension of the data and the maximum likelihood estimation of the remaining structural parameters, conditional on f_t. Alternatively, one can use a standard maximum likelihood procedure, where the f_t's are estimated simultaneously with the other parameters. The two procedures lead to consistent estimates, provided N and T are sufficiently large. It is worthwhile noting that if N is small, one would face the well-known incidental parameters problem: the bias in estimating f_t, due to the limited size of the cross-sectional dimension, would contaminate the other parameter estimates. In the alternative situation where T happens to be small, the problem of the initial observation would then become an important issue. Therefore, our estimation procedure is essentially valid for large N and T. Fortunately, in our context, prices of most of the products we consider have been observed monthly over the period 1994:7 - 2003:2 (i.e. more than 100 months) and the number of outlets selling the various products we consider is always important, averaging to 285 in Belgium and to more than 400 in France in each period. Indeed, the data sets we use to estimate our model are very large (about 10 millions observations in total for the Belgian sample and about 13 millions for the French one).

3.1 Estimation of f_t from Cross-Sectional Averages

As mentioned above, f_t is in practice an unobserved time effect that needs to be estimated along with the other unknown parameters. It reflects the common component in the marginal cost and *desired* mark-up for each particular product for which we estimate the model. Thanks to the very large size and high degree of disaggregation of our data, we can split our data sets according to a very detailed definition of the products while keeping, at the same time, a large size of the resulting sub-samples in their cross-sectional dimension.

Moreover, because we are able to consider very precisely defined types of products, such as a kilogram of powder sugar, of lamb chops, or a bunch of roses, it is reasonable to assume that any remaining cross-sectional heterogeneity in the price level can be modelled through the observable outlet-specific characteristics, $\mathbf{x}_{it}$, and through random specific effects (accounting for outlets unobserved characteristics). Accordingly, we assume that, conditional on $\mathbf{h}_{it} = (f_t, \mathbf{x}'_{it}, p_{i,t-1})'$, c_{it}, v_i, and ε_{it} are distributed independently across i, and that c_{it} and ε_{it} are serially uncorrelated. Due to the non-linear nature of the pricing process and to make the analysis tractable, we shall also assume that

$$\begin{pmatrix} c_{it} \\ v_i \\ \varepsilon_{it} \end{pmatrix} |\mathbf{h}_{it} \backsim i.i.d.N \left(\begin{pmatrix} c \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_c^2 & 0 & 0 \\ 0 & \sigma_v^2 & 0 \\ 0 & 0 & \sigma_\varepsilon^2 \end{pmatrix} \right).$$

The assumption of zero covariances across the errors is made for convenience and can be relaxed.

Before discussing the derivation of f_t we state the following lemma, established in the Appendix, which provides a few results needed below.

Lemma 1 *Suppose that* $y \backsim N(\mu, \sigma^2)$ *then*

$$E\left[yI(y+a)\right] = \sigma\phi\left(\frac{a+\mu}{\sigma}\right) + \mu\Phi\left(\frac{a+\mu}{\sigma}\right),$$

$$E\left[\phi\left(\frac{y+a}{b}\right)\right] = \frac{b}{\sqrt{b^2+\sigma^2}}\phi\left(\frac{a+\mu}{\sqrt{b^2+\sigma^2}}\right),$$

$$E_y\left[\Phi\left(\frac{y+a}{b}\right)\right] = \Phi\left(\frac{a+\mu}{\sqrt{b^2+\sigma^2}}\right),$$

where $\phi(\cdot)$ *and* $\Phi(\cdot)$ *are, respectively, the density and the cumulative distribution function of the standard normal variate, and* $I(A)$ *is the indicator function defined above.*

Let

$$d_{it} = f_t + \mathbf{x}_{it}'\boldsymbol{\beta} - p_{i,t-1}, \quad \xi_{it} = v_i + \varepsilon_{it} \backsim N(0, \sigma_\xi^2),$$

and note that $\sigma_\xi^2 = \sigma_v^2 + \sigma_\varepsilon^2$. Consider now the baseline model, (6), and using the above write it as

$$\Delta p_{it} = (d_{it} + \xi_{it})I(d_{it} + \xi_{it} - c_{it}) + (d_{it} + \xi_{it})I(-d_{it} - \xi_{it} - c_{it}),$$

or

$$\Delta p_{it} = (d_{it} + \xi_{it}) + (d_{it} + \xi_{it})\left[I(d_{it} + \xi_{it} - c_{it}) - I(d_{it} + \xi_{it} + c_{it})\right].$$

Denote the unknown parameters of the model by $\boldsymbol{\theta} = (c, \boldsymbol{\beta}', \sigma_c^2, \sigma_v^2, \sigma_\varepsilon^2)'$ and note that

$$E\left(\Delta p_{it} \left| \mathbf{h}_{it}, \boldsymbol{\theta}\right.\right) = d_{it} + g_{it},$$

where

$$g_{it} = g_{1,it} + g_{2,it},$$

with

$$g_{1,it} = d_{it}E\left[I(d_{it}+\xi_{it}-c_{it}) - I(d_{it}+\xi_{it}+c_{it})\,|\mathbf{h}_{it},\boldsymbol{\theta}\right],$$

and

$$g_{2,it} = E\left[\xi_{it}I(d_{it}+\xi_{it}-c_{it}) - \xi_{it}I(d_{it}+\xi_{it}+c_{it})\,|\mathbf{h}_{it},\boldsymbol{\theta}\right].$$

Also, under our assumptions

$$\begin{pmatrix} c_{it} \\ \xi_{it} \end{pmatrix} |\mathbf{h}_{it} \backsim i.i.d.N\left(\begin{pmatrix} c \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_c^2 & 0 \\ 0 & \sigma_v^2+\sigma_\varepsilon^2 \end{pmatrix}\right).$$

and it is easily seen that

$$\begin{aligned} & E\left[I(d_{it}+\xi_{it}-c_{it}) - I(d_{it}+\xi_{it}+c_{it})\,|\mathbf{h}_{it},\boldsymbol{\theta}\right] \\ = \; & \Phi\left(\frac{d_{it}-c}{\sqrt{\sigma_c^2+\sigma_\xi^2}}\right) - \Phi\left(\frac{d_{it}+c}{\sqrt{\sigma_c^2+\sigma_\xi^2}}\right). \end{aligned}$$

Using the results in Lemma 1 and noting that $\xi_{it}\,|\mathbf{h}_{it},\boldsymbol{\theta} \backsim N(0,\sigma_\xi^2)$, then

$$E\left[\xi_{it}I(d_{it}+\xi_{it}-c_{it})\,|\mathbf{h}_{it},\boldsymbol{\theta},c_{it}\right] = \sigma_\xi\phi\left(\frac{d_{it}-c_{it}}{\sigma_\xi}\right).$$

Hence, taking expectations with respect to c_{it}, we have

$$E\left[\xi_{it}I(d_{it}+\xi_{it}-c_{it})\,|\mathbf{h}_{it},\boldsymbol{\theta}\right] = \sigma_\xi E\left[\phi\left(\frac{d_{it}-c_{it}}{\sigma_\xi}\right)|\mathbf{h}_{it},\boldsymbol{\theta}\right].$$

Again using the results in Lemma 1 we have

$$E\left[\phi\left(\frac{d_{it}-c_{it}}{\sigma_\xi}\right)|\mathbf{h}_{it},\boldsymbol{\theta}\right] = \frac{\sigma_\xi}{\sqrt{\sigma_c^2+\sigma_\xi^2}}\phi\left(\frac{d_{it}-c}{\sqrt{\sigma_c^2+\sigma_\xi^2}}\right),$$

and therefore,

$$E\left[\xi_{it}I(d_{it}+\xi_{it}-c_{it})\,|\mathbf{h}_{it},\boldsymbol{\theta}\right] = \frac{\sigma_\xi^2}{\sqrt{\sigma_c^2+\sigma_\xi^2}}\phi\left(\frac{d_{it}-c}{\sqrt{\sigma_c^2+\sigma_\xi^2}}\right).$$

Similarly,

$$E\left[\xi_{it}I(d_{it}+\xi_{it}+c_{it})\,|\mathbf{h}_{it},\boldsymbol{\theta}\right] = \frac{\sigma_\xi^2}{\sqrt{\sigma_c^2+\sigma_\xi^2}}\phi\left(\frac{d_{it}+c}{\sqrt{\sigma_c^2+\sigma_\xi^2}}\right).$$

Collecting the various results we obtain

$$g_{1,it} = d_{it}\left[\Phi\left(\frac{d_{it}-c}{\sqrt{\sigma_c^2+\sigma_\xi^2}}\right)-\Phi\left(\frac{d_{it}+c}{\sqrt{\sigma_c^2+\sigma_\xi^2}}\right)\right],$$

and

$$g_{2,it} = \frac{\sigma_\xi^2}{\sqrt{\sigma_c^2+\sigma_\xi^2}}\left[\phi\left(\frac{d_{it}-c}{\sqrt{\sigma_c^2+\sigma_\xi^2}}\right)-\phi\left(\frac{d_{it}+c}{\sqrt{\sigma_c^2+\sigma_\xi^2}}\right)\right].$$

Note that $g_{1,it}$ and $g_{2,it}$ are non-linear functions of f_t and depend on i only through the observable, $p_{i,t-1}$ and $\mathbf{x}_{it}$. It is therefore possible to compute f_t for each t in terms of $p_{i,t-1}$, $\mathbf{x}_{it}$ and $\boldsymbol{\theta}$.

Then, following Pesaran (2006), the cross-sectional average estimator of f_t, denoted by $\tilde{f}_t$, can be obtained as the solution to the following non-linear equation

$$\bar{p}_t = \tilde{f}_t + \bar{\mathbf{x}}_t'\boldsymbol{\beta} + \bar{g}_t(\tilde{f}_t), \tag{7}$$

where

$$\bar{p}_t = \sum_{i=1}^{N} w_{it}\ p_{it},\ \bar{\mathbf{x}}_t = \sum_{i=1}^{N} w_{it}\ \mathbf{x}_{it},\ \text{and}\ \bar{g}_t(f_t) = \sum_{i=1}^{N} w_{it}\ g_{it},$$

and $\{w_{it}, i = 1, 2, .., N\}$ represent a predetermined set of weights such that

$$w_{it} = O(N^{-1}),\ \text{and} \sum_{i=1}^{N} w_{it}^2 = O(N^{-1}).$$

For a given value of $\boldsymbol{\theta}$ and each t, (7) provides a non-linear function in $\tilde{f}_t$. This equation clearly shows that unlike the linear models considered in Pesaran (2006), here the solution to the common component f_t does not reduce to a simple (weighted) average of (log) prices. In particular, it also accounts for the dynamic feature of the price-setting behavior through the $\bar{g}_t$ component, which depends on $p_{i,t-1}$. Equation (7) has a unique solution as long as $c > 0$. A proof is provided in the Appendix. It is also easily seen that under the cross-sectional independence of v_i and ε_{it}, $\bar{g}_t(f_t) \to E(g_{it})$ and $\tilde{f}_t \to f_t$ as $N \to \infty$.[6]

[6] For the sake of simplicity, we assume here that the sample is balanced: all outlets are observed over the full time period. This is not the case in practice. However, the result can be easily generalized to unbalanced panels assuming that $N_t \to \infty$ for each t (see the appendix).

3.2 Conditional Likelihood Estimation with no Individual Effect

In this section, we derive the maximum likelihood estimation of the structural parameters, $\boldsymbol{\theta}$, conditional on f_t and assuming there are no firm-specific effects, so that $\sigma_v^2 = 0$, and hence in this case $\boldsymbol{\theta} = (c, \boldsymbol{\beta}', \sigma_c^2, \sigma_\varepsilon^2)'$. Given the distributional assumptions stated in Section 3.1, and defining ζ_{it} as $c_{it} - c$, our baseline model can be rewritten as

$$\Delta p_{it} = d_{it} + \varepsilon_{it} + (d_{it} + \varepsilon_{it}) \left\{ I\left[d_{it} + \varepsilon_{it} - \zeta_{it} - c\right] - I\left[d_{it} + \varepsilon_{it} + \zeta_{it} + c\right] \right\},$$

where

$$\begin{pmatrix} \zeta_{it} \\ \varepsilon_{it} \end{pmatrix} \backsim iid\ N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_c^2 & 0 \\ 0 & \sigma_\varepsilon^2 \end{pmatrix} \right), \text{ for } i = 1, 2, ..., N;\ t = 1, 2, ..., T.$$

Equivalently

$$\Delta p_{it} = d_{it} + \varepsilon_{it} + (d_{it} + \varepsilon_{it}) \left\{ I\left[d_{it} - c + \varepsilon_{1it}\right] - I\left[d_{it} + c + \varepsilon_{2it}\right] \right\},$$

where

$$\varepsilon_{1it} = \varepsilon_{it} - \zeta_{it},\ \varepsilon_{2it} = \varepsilon_{it} + \zeta_{it},$$

with

$$\begin{pmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \\ \varepsilon_{it} \end{pmatrix} \sim iidN\left(\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_\varepsilon^2 + \sigma_c^2 & \sigma_\varepsilon^2 - \sigma_c^2 & \sigma_\varepsilon^2 \\ . & \sigma_\varepsilon^2 + \sigma_c^2 & \sigma_\varepsilon^2 \\ . & . & \sigma_\varepsilon^2 \end{pmatrix} \right), \text{for } i = 1, 2, ..., N;\ t = 1, 2, ..., T.$$

Let

$$\begin{aligned}
\tau_{1it} &= \begin{cases} 1 \text{ if } \Delta p_{it} = 0 \text{ for } i = 1, 2, ..., N \text{ and } t = 1, 2, ..., T, \\ 0 \text{ otherwise} \end{cases} \\
\tau_{2it} &= \begin{cases} 1 \text{ if } \Delta p_{it} > 0 \text{ for } i = 1, 2, ..., N \text{ and } t = 1, 2, ..., T, \\ 0 \text{ otherwise} \end{cases} \\
\tau_{3it} &= \begin{cases} 1 \text{ if } \Delta p_{it} < 0 \text{ for } i = 1, 2, ..., N \text{ and } t = 1, 2, ..., T, \\ 0 \text{ otherwise} \end{cases}
\end{aligned}$$

Then conditional on t and the initial value p_{i0}, the log-likelihood function of the model for each i can be written as

$$\begin{aligned}
L_i(\theta\,|\mathbf{f}\,) &= \Pr\left(\Delta p_{i1}\,|p_{i0}\right)\Pr\left(\Delta p_{i2}\,|p_{i0}, p_{i1}\right) \\
&\quad \times \Pr\left(\Delta p_{i,T}\,|p_{i0}, p_{i1}, ..., p_{i,T-1}\right) \times \Pr\left(p_{i0}\right)
\end{aligned}$$

where $\mathbf{f} = (f_1, f_2, ..., f_T)'$, and in view of the first-order Markovian property of the model we have

$$\begin{aligned} L_i(\theta\,|\mathbf{f}\,) &= \Pr\left(\Delta p_{i1}\,|p_{i0}\,\right)\Pr\left(\Delta p_{i2}\,|p_{i1}\,\right) \\ &\quad \times \Pr\left(\Delta p_{i,T}\,|p_{i,T-1}\,\right) \times \Pr\left(p_{i0}\right). \end{aligned}$$

When T is small, the contribution of $\Pr(p_{i0})$ could be important. In what follows we assume that p_{i0} is given and T reasonably large so that the contribution of the initial observations to the log-likelihood function is relatively unimportant.

To derive $\Pr\left(\Delta p_{it}\,|p_{i,t-1}, f_t\,\right)$ we distinguish between cases where $\Delta p_{it} = 0$, $\Delta p_{it} > 0$ and $\Delta p_{it} < 0$, noting that

$$\begin{aligned} & \Pr\left(\Delta p_{it}\,|\Delta p_{it} = 0, p_{i,t-1}, f_t\,\right) \\ = \; & \Pr\left(\varepsilon_{1it} \leq c - d_{it}\ ;\ \varepsilon_{2it} \geq -c - d_{it}\right) \\ = \; & \Pr\left(\varepsilon_{1it} \leq c - d_{it}\right) - \Pr\left(\varepsilon_{1it} \leq c - d_{it}\ ;\ \varepsilon_{2it} \leq -c - d_{it}\right) \\ = \; & \Phi\left(\frac{c - d_{it}}{\sqrt{\sigma_\varepsilon^2 + \sigma_c^2}}\right) - \Phi_2\left(\frac{c - d_{it}}{\sqrt{\sigma_\varepsilon^2 + \sigma_c^2}}; \frac{-c - d_{it}}{\sqrt{\sigma_\varepsilon^2 + \sigma_c^2}}; \frac{\sigma_\varepsilon^2 - \sigma_c^2}{\sigma_\varepsilon^2 + \sigma_c^2}\right) \\ = \; & \pi_{1it} \end{aligned}$$

where $\Phi_2\left(x; y; \rho\right)$ is the cumulated distribution of the standard bivariate normal. Similarly

$$\begin{aligned} & \Pr\left(\Delta p_{it}\,|\Delta p_{it} > 0, p_{i,t-1}, f_t\,\right) \\ = \; & \Pr\left(\varepsilon_{it} = \Delta p_{it} - d_{it}\right)\Pr\left(\varepsilon_{1it} \geq c - d_{it}\ ;\ \varepsilon_{2it} > -c - d_{it}\,|\varepsilon_{it}\,\right) \\ = \; & \frac{1}{\sigma_\varepsilon}\phi\left(\frac{\Delta p_{it} - d_{it}}{\sigma_\varepsilon}\right)\left[\Phi\left(\frac{-c + \Delta p_{it}}{\sigma_c}\right) - \Phi\left(\frac{-c - \Delta p_{it}}{\sigma_c}\right)\right] \\ = \; & \pi_{2it} \end{aligned}$$

and

$$\begin{aligned} & \Pr\left(\Delta p_{it}\,|\Delta p_{it} < 0, p_{i,t-1}, f_t\,\right) \\ = \; & \Pr\left(\varepsilon_{it} = \Delta p_{it} - d_{it}\right)\Pr\left(\varepsilon_{1it} < c - d_{it}\ ;\ \varepsilon_{2it} \leq -c - d_{it}\,|\varepsilon_{it}\,\right) \\ = \; & \frac{1}{\sigma_\varepsilon}\phi\left(\frac{\Delta p_{it} - d_{it}}{\sigma_\varepsilon}\right)\left[\Phi\left(\frac{-c - \Delta p_{it}}{\sigma_c}\right) - \Phi\left(\frac{-c + \Delta p_{it}}{\sigma_c}\right)\right] \\ = \; & \pi_{3it}. \end{aligned}$$

Hence

$$\ell\left(\boldsymbol{\theta}, \mathbf{f}\right) = \sum_{i=1}^{N} \ln L_i(\boldsymbol{\theta}, \mathbf{f}) = \sum_{i=1}^{N}\sum_{t=1}^{T}\left[\tau_{1it}\ln(\pi_{1it}) + \tau_{2it}\ln(\pi_{2it}) + \tau_{3it}\ln(\pi_{3it})\right]. \tag{8}$$

The ML estimator of $\boldsymbol{\theta}$ is given by

$$\hat{\boldsymbol{\theta}}_{ML}(\mathbf{f}) = \arg\max_{\boldsymbol{\theta}} \ell\left(\boldsymbol{\theta}, \mathbf{f}\right)$$

and N and T sufficiently large yield.

$$\sqrt{NT}\left(\hat{\boldsymbol{\theta}}_{ML}(\mathbf{f}) - \boldsymbol{\theta}\right) \overset{a}{\backsim} N(0, \mathbf{V}_{\boldsymbol{\theta}}),$$

where $\mathbf{V}_{\boldsymbol{\theta}}$ is the asymptotic variance of the ML estimator and can be estimated consistently using the second derivatives of the log likelihood function.

Remark 2 In the case where f_t, $t = 1, 2, ..., T$ are estimated, the ML estimators will continue to be consistent as both N and T tend to infinity. However, the asymptotic distribution of the ML estimator is likely to be subject to the generated regressor problem. The importance of the generated regressor problem in the present application could be investigated using a bootstrap procedure.

3.3 Conditional Likelihood Estimation with Random Effects

Consider now the random effects specification where $\gamma_{it} = \mathbf{x}'_{it}\boldsymbol{\beta} + v_i + \varepsilon_{it}$, and note that

$$Cov(\gamma_{it}, \gamma_{it'} \left| \mathbf{x}_{it}, \mathbf{x}_{it'} \right.) = \sigma_v^2 \text{ for all } t \text{ and } t',\ t \neq t'.$$

Under this model, the probability of no price change in a given period, conditional on the previous price $p_{i,t-1}$, will not be independent of previous absences of price changes. So we need to consider the joint probability distribution of successive unchanged prices. For example, suppose that prices for outlet i have remained unchanged over the period t and $t+1$, then the relevant joint events of interest are

$$\mathcal{A}_{it} : \left\{-c - \zeta_{it} - d_{it} \leq \varepsilon_{it} + v_i \leq c + \zeta_{it} - d_{it}\right\},$$

and

$$\mathcal{A}_{i,t+1} : \left\{-c - \zeta_{i,t+1} - d_{i,t+1} \leq \varepsilon_{i,t+1} + v_i \leq c + \zeta_{it} - d_{i,t+1}\right\}.$$

An explicit derivation would seem rather difficult. An alternative strategy is to use the conditional independence property of successive price changes, and note that for each i and conditional on $\mathbf{v} = (v_1, v_2, ..., v_N)'$ and $\mathbf{f}$ the likelihood function will be given by

$$L(\boldsymbol{\theta}, \mathbf{v}, \mathbf{f}) = \prod_{i=1}^{N} \prod_{t=1}^{T} [\pi_{1it}(v_i)]^{\tau_{1it}} [\pi_{2it}(v_i)]^{\tau_{2it}} [\pi_{3it}(v_i)]^{\tau_{2it}} ,$$

where

$$\begin{aligned}
\pi_{1it}(v_i, f_t) &= \Phi\left(\frac{c - \nu_i - d_{it}}{\sqrt{\sigma_\varepsilon^2 + \sigma_c^2}}\right) - \Phi_2\left(\frac{c - \nu_i - d_{it}}{\sqrt{\sigma_\varepsilon^2 + \sigma_c^2}}; \frac{-c - \nu_i - d_{it}}{\sqrt{\sigma_\varepsilon^2 + \sigma_c^2}}; \frac{\sigma_\varepsilon^2 - \sigma_c^2}{\sigma_\varepsilon^2 + \sigma_c^2}\right), \\
\pi_{2it}(v_i, f_t) &= \frac{1}{\sigma_\varepsilon}\phi\left(\frac{\Delta p_{it} - \nu_i - d_{it}}{\sigma_\varepsilon}\right)\left[\Phi\left(\frac{-c + \Delta p_{it}}{\sigma_c}\right) - \Phi\left(\frac{-c - \Delta p_{it}}{\sigma_c}\right)\right]
\end{aligned}$$

and

$$\pi_{3it}(v_i, f_t) = \frac{1}{\sigma_\varepsilon}\phi\left(\frac{\Delta p_{it} - \nu_i - d_{it}}{\sigma_\varepsilon}\right)\left[\Phi\left(\frac{-c - \Delta p_{it}}{\sigma_c}\right) - \Phi\left(\frac{-c + \Delta p_{it}}{\sigma_c}\right)\right].$$

The random effects can now be integrated out with respect to the distribution of v_i $\left[\text{assuming } v_i \sim N\left(0, \sigma_v^2\right), \text{ for example}\right]$ and then the integrated log-likelihood function, $E_{\mathbf{v}}\left[\ell(\boldsymbol{\theta}, \mathbf{v}, \mathbf{f})\right]$, maximized with respect to $\boldsymbol{\theta}$.[7]

3.4 Full Maximum Likelihood Estimation

In the case where N and T are sufficiently large, the incidental parameters problem does not arise and the effects of the initial distributions, $\Pr(p_{i0})$, on the likelihood function can be ignored. Then, the maximum likelihood estimators of θ and f_t, for $t = 1, 2, ...T$ can be obtained as the solution to the following maximization problem:

$$\left(\hat{\mathbf{f}}_{ML}, \widehat{\boldsymbol{\theta}}_{ML}\right) = \arg\max_{\mathbf{f}, \boldsymbol{\theta}} \sum_{t=1}^{T} \sum_{i=1}^{N} \left[\tau_{1it} \ln(\pi_{1it}) + \tau_{2it} \ln(\pi_{2it}) + \tau_{3it} \ln(\pi_{3it})\right], \quad (9)$$

where $f = (f_1, f_2, ..., f_T)'$. Note that for a given value of θ the ML estimate of f_t can be obtained as

$$\hat{f}_t(\boldsymbol{\theta}) = \arg\max_{f_t} \sum_{i=1}^{N} \left[\tau_{1it} \ln(\pi_{1it}) + \tau_{2it} \ln(\pi_{2it}) + \tau_{3it} \ln(\pi_{3it})\right],$$

[7] A further extension of the model would consist of including also a firm specific effect into the menu cost. However, the estimation of this model would then requires a double integration with respect to the distribution of the two individual effects.

and will be consistent as $N \to \infty$, since conditional on θ and f_t the elements in the above sum are independently distributed. Also for a given estimate of f, the optimization problem defined by (9) will yield a consistent estimate of θ as N and $T \to \infty$. Iterating between the solutions of the two optimization problems will deliver consistent estimates of θ and $f_1, f_2, ..., f_T$, even though the number of incidental parameters, $f_t, t = 1, 2, ..., T$, is rising without bounds as $T \to \infty$. This is analogous to the problem of estimating time and fixed effects in standard linear panel data models. Fixed effects can be consistently estimated from the time dimension and time effects from the cross section dimension. Therefore, to allow for both effects in panels and estimate them consistently we need N and T large.

3.5 Some Monte Carlo simulations

In order to evaluate the performance of the two alternative estimation procedures (that is, the iterative procedure based on the cross-sectional estimates of f_t and the Full Maximum Likelihood estimation of the model), we carried out a limited number of Monte Carlo simulations. We generated the log price series according to the baseline model, (6), by setting $c = 0.15$, $\sigma_\varepsilon = 0.05$, $\sigma_c = 0.01$ and simulating the common factors as the first order autoregressive process

$$f_t = \rho_0 + \rho_1 \ f_{t-1} + \omega_t, \ \omega_t \backsim N(0, \sigma_\omega^2),$$

with $\rho_0 = 0.05$, $\rho_1 = 0.90$, and $\sigma_\omega = 0.10$. These parameter values lead to an average frequency of price changes of around one sixth. In Table 1, we report the average (across R replications) of the point estimates of c, σ_ε, σ_c and σ_v and their average standard errors in different setups. Concerning the estimation of f_t, we compute the RMSE with respect to the true f_t and compare the standard deviation of the true f_t with that of the estimated f_t. In our reference case, the sample size is set at $N = 50$, $T = 50$.

Under both estimation procedures, initial values for the estimation of f_t are set to $\overline{p}_t$. In the iterative procedure, a first set of estimates for the remaining parameters of the model, $\boldsymbol{\theta}$, are then obtained by maximum likelihood, which is in turn used to compute another estimate of the unobserved common components, and the procedure is iterated until convergence. The standard errors of the parameter estimates are computed from the second derivatives of the full log-likelihood function given by (9).

The estimation of the models with and without random effects by the Full Maximum Likelihood roughly leads to similar results.[8] The point estimates and precision of the estimators are of the same order of magnitude, although the estimation of σ_c appears to improve in a model with random effects.

	c	σ_ε	σ_c	σ_v	RMSE(f_t)	relative std(f_t)	R
with random effects							
true value	0.15	0.05	0.01	0.025			
N=50, T=50, full ML							500
ML(.)	0.150	0.049	0.011	0.027	0.0002	1.001	
std(.)	0.0014	0.0011	0.0013	0.0030			
no random effects							
true value	0.15	0.05	0.01	0			
N=50, T=50, full ML							1000
ML(.)	0.150	0.049	0.007		0.0001	1.0018	
std(.)	0.0013	0.0011	0.0013				
N=25, T=50, full ML							500
ML(.)	0.150	0.048	0.006		0.0003	1.005	
std(.)	0.0019	0.0015	0.0018				
N=50, T=25, full ML							250
ML(.)	0.150	0.049	0.003		0.0001	1.003	
std(.)	0.0019	0.0015	0.0018				
N=50, T=25, iterative procedure							250
ML(.)	0.148	0.051	0.005		0.0002	0.990	
std(.)	0.0018	0.0016	0.0017				

R is the number of replications, ML(.) is the average of the point estimates, std(.) is the average of the standard deviation of the coefficient, relative std(f_t) stands for the ratio of the standard deviation of the estimated f_t over the standard deviation of the true f_t.

Table 1 - Monte Carlo Simulations

Considering the model without random effects, the estimates of the parame-

[8] At this stage, because the estimation procedure with random effects takes much more time, we ran most simulations without random effects, and the number of replications is limited for some experiments.

ters c and σ_ε obtained by full ML are essentially unbiased. However, σ_c appears slightly underestimated. The unobserved component, f_t, is also very precisely estimated, and its volatility is only 0.2% higher than that of the true f_t.

Unsurprisingly, the precision of the estimates increases with the total size of the sample $N \times T$, as suggested by a comparison of the standard errors of the coefficients c, σ_ε and σ_c, in three alternative set of simulations without random effects. However, N and T do not play a symmetrical role for the point estimates. For small values of N there may be a downward bias in σ_ε. Furthermore, the RMSE of $\widehat{f_t}$ is higher and its volatility relative to that of the true f_t increases. So, when the number of trajectories is small, the unobserved component f_t is poorly estimated, because the cross-sectional dimension is too small for the idiosyncratic shocks, ε_{it}, to cancel out by aggregation. This results in excessive volatility in the estimated f_t. Consequently, in order for the model to be in line with the observed frequency of price changes, the volatility of the idiosyncratic shock has to diminish. Decreasing T from 50 to 25 does not seem to have any significant impact on the estimates. It might be for only quite low values of T that the impact of ignoring the initial observations in the likelihood function could be non negligible.

We also report a comparison of the full ML and iterative estimation procedures. The results suggest that the point estimates of the coefficients are very close, and that the iterative procedure delivers a smoother f_t than the full ML.[9] The full ML may produce slightly better results in the sense that, as compared to the iterative procedure, the difference between the point estimate of c and its true value is smaller, the RMSE of f_t as compared to the true f_t is lower, and the volatility of f_t is closer to the true one.

Finally, in practice, the iterative procedure is much more time consuming than the "full maximum likelihood" method. Therefore, we chose to estimate our baseline pricing model using the full maximum likelihood method. Indeed, given the above Monte-Carlo results and the large size (in both N and T) of our samples, we know that the two methods will not differ in any significant way and that the estimates obtained with the full ML will be consistent and have a good precision.

[9] Iterative estimations made on real data for a limited number of products also produce less or equally volative f_t as compared to the full ML estimate of f_t. The estimates of the other parameters are similar.

4 Estimation Results

The data we use for estimating our baseline model, given by (6), consist of the individual consumer price quotes compiled by the Belgian and French statistical institutes for the computation of their consumer price indices.[10] These data refer to monthly price series of individual products sold in a particular outlet. The period covered has been restricted to the intersection of the two databases, that is July 1994 - February 2003.

Since we want to estimate our model for narrowly defined products, price series have been grouped into 368 product categories for Belgium and 305 for France. However, as the estimation procedure is particularly time consuming, the estimation has only been conducted on a subset of randomly selected product categories, using price trajectories of at least 20 months.[11] For Belgium, our baseline model has thus been estimated for 98 product categories, [12] while for France, the estimation has currently been conducted for 30 product categories. Extended versions of the model (introduction of gradual adjustment or asymmetric menu costs) have also been estimated with Belgian data for some selected products.

As stated above, we have opted, for practical reasons, for the "full maximum likelihood" estimator so that we have simultaneously estimated, for each product category, the unobserved common component f_t as well as the other parameters of our model: the average level of menu cost, c, and its variability, σ_c, the magnitude of the idiosyncratic shocks, σ_ε, and the variability of firms specific desired mark-up, σ_v. Finally, as we lack information on local competition or other factors that might affect the (log) optimal price, the $\mathbf{x}$ variables appearing in the model only contains a dummy variable corresponding to the nature of the outlet: the dummy takes the value 1 whenever the price has been observed in a "super or hypermarket", 0 otherwise.

[10] Each of these two datasets contains more than 10 millions observations. They are described in detail in Aucremanne and Dhyne (2004) for Belgium and in Baudry *et al.* (2004) for France.

[11] We define a price trajectory as a continuous sequence of price reports referring to one particular product sold in store i. The prices we refer to are (logs of) prices per unit of products so that promotions in quantities are also captured in our analysis.

[12] Although, we have estimated our model for 98 product categories, the summary statistics presented in the following sections are based on a subset of 88 product categories for which our goodness of fit criteria are met. Also see the sub-section 4.3.

The response of actual prices to changes in the common component of the "optimal" price clearly depends on the profile of this common component. Variations in this common component are likely to induce price changes, even though they are partly predictable. Minimum wage changes are a good example of such predictable changes that induce variations in the optimal prices which in turn, are likely to lead to changes in actual prices. For instance, in France, changes in the minimum wage are decided by the government and are put into effect annually in July.[13] Part of these changes are legally set up by a formula linking them with the observed CPI inflation over the preceding year; part of them are discretionary. Such wage increases are then largely predictable and have a clear impact on prices (e.g. see Loupias and Sevestre (2006) for a study of French industrial price movements and Stahl (2005) for a study on German industrial prices).

Obviously, unpredictable common shocks (such as the impact of the "mad cow disease" on the demand for beef and other kinds of meat, the variations in the price of raw materials, or bad weather conditions affecting the harvest of vegetal products) may also have an impact on the likelihood of a price change.

Then, in order to help interpreting the impact on price changes of the variations in this common component of optimal prices, we propose a decomposition of these variations into several components: a trend, an autoregressive component and a random component. More specifically, we have estimated for each of our estimated series of f_t the following time series representation

$$f_t = \beta_0 + \beta_1 t + \sum_{k=1}^{K} \rho_k f_{t-k} + \omega_t$$

with $\omega_t \backsim N\left(0, \sigma_\omega^2\right)$, and where K, the number of lags.

In our tables, we present estimates of σ_ω, and the sum of the autoregressive coefficients, $\overline{\rho} = \sum_{k=1}^{K} \rho_k$. For each product category, K is selected to eliminate any serial correlation in ω_t, using AIC applied to autoregressions with a maximum value of K set to 12. Therefore, the optimal number of lags may differ across product categories. The tables also provide some basic statistics such as the unconditional standard-deviation of the f_t's and their autocorrelation coefficients of orders 1, 2, 3, 4, 6 and 12.

[13] The government may decide minimum wage changes at any time but changes at other dates are rather uncommon.

To characterize the magnitude of common variations in the optimal prices p^*_{it} in the following subsections, we use two different measures : the unconditional standard deviation of f_t, $std(f_t)$ and the magnitude of the shocks to the common factors, σ_ω.

Table 2 below presents a summary of the estimates by broad product category.[14]

4.1 Assessing nominal rigidities

Overall, the average level of the fixed menu costs is estimated to represent one third of the price level (36% in Belgium and 30% in France). These are of comparable magnitude to the estimates reported in Levy *et al.* (1997) for the US. Indeed, Levy *et al.* (1997), using a data set of prices, sales and costs in 5 large multi-store chains, report estimates of menu costs in the US retail grocery trade, in money terms. To obtain measures of menu costs comparable to our estimated c, we divide their evaluation of menu cost per price change by the average price of the product. This yields menu costs ranging from 27.1% to 40.0%, with an average of 30.7%.

However, these average estimates hide an extensive degree of heterogeneity across product categories. Since numerous studies point to a remarkable ranking of the frequency of price changes according to the product category (e.g. see Bils and Klenow (2004) for the US and Dhyne et al. (2006) for the euro area), it is worth looking at the average menu costs by type of products. These are given in the first column of Table 2.

[14] Tables A and B in the appendix first present detailed results for the estimated structural parameters and the time-series representation of the estimated common component. These tables also include some basic statistics that characterize the price setting behavior of each product category (frequency of price changes, average absolute size of price changes, share of price increases) and, in the case of Belgium, the correlations between f_t and $\overline{p_t}$ and between f_t and the log of the product category price index, $lnIP_t$, and indicators of the ability of the model to replicate on simulated data the observed frequency of price changes, size of absolute price changes and share of price increases). Tables C and D in the appendix provide further statistics associated with the estimated common component.

Product type	$\widehat{c}$	$\widehat{\sigma_{\varepsilon}}$	$\widehat{\sigma_{c}}$	$\widehat{\sigma_{u}}$	$std(\widehat{f_t})$	$\widehat{\sigma_{\omega}}$	$\widehat{\rho}$	$Freq$	$\overline{\lvert\Delta p\rvert}$	$\%up$
Energy (BE - 3 product categories ; FR - 1 product category)										
Average - Belgium	0.014	0.030	0.006	0.091	0.176	0.038	0.866	0.731	0.043	0.535
Average - France	0.004	0.018	0.003	0.026	0.090	0.018	0.912	0.799	0.023	0.560
Average - Belgium + France	0.012	0.027	0.005	0.075	0.155	0.033	0.878	0.748	0.038	0.541
Perishable food (BE - 24 product categories ; FR - 3 product categories)										
Average - Belgium	0.274	0.097	0.143	0.154	0.073	0.030	0.674	0.230	0.128	0.648
Average - France	0.202	0.109	0.140	0.200	0.078	0.016	0.837	0.303	0.148	0.553
Average - Belgium + France	0.266	0.098	0.143	0.159	0.074	0.028	0.692	0.238	0.130	0.637
Non perishable food (BE - 12 product categories ; FR - 5 product categories)										
Average - Belgium	0.309	0.080	0.173	0.202	0.055	0.018	0.802	0.127	0.104	0.627
Average - France	0.180	0.068	0.118	0.213	0.048	0.010	0.800	0.217	0.107	0.565
Average - Belgium + France	0.271	0.076	0.157	0.205	0.053	0.016	0.801	0.153	0.105	0.609
Non durable goods (BE - 15 product categories ; FR - 9 product categories)										
Average - Belgium	0.375	0.079	0.178	0.233	0.064	0.013	0.852	0.147	0.089	0.686
Average - France	0.330	0.098	0.178	0.373	0.061	0.029	0.560	0.188	0.306	0.525
Average - Belgium + France	0.358	0.086	0.178	0.286	0.063	0.019	0.743	0.162	0.170	0.626
Durable goods (BE - 16 product categories ; FR - 5 product categories)										
Average - Belgium	0.551	0.077	0.262	0.229	0.057	0.013	0.736	0.049	0.075	0.623
Average - France	0.306	0.078	0.167	0.367	0.033	0.023	0.787	0.164	0.239	0.506
Average - Belgium + France	0.493	0.077	0.239	0.262	0.051	0.015	0.748	0.076	0.114	0.595
Services (BE - 18 product categories ; FR - 7 product categories)										
Average - Belgium	0.380	0.046	0.169	0.156	0.112	0.010	0.731	0.040	0.061	0.689
Average - France	0.396	0.123	0.185	0.257	0.075	0.020	0.631	0.115	0.161	0.664
Average - Belgium + France	0.384	0.068	0.173	0.184	0.102	0.013	0.703	0.061	0.089	0.682
Full basket (BE - 88 product category - FR - 30 product categories)										
Average - Belgium	0.359	0.075	0.175	0.186	0.077	0.018	0.751	0.161	0.136	0.583
Average - France	0.293	0.094	0.158	0.289	0.060	0.021	0.694	0.204	0.203	0.565
Average - Belgium + France	0.342	0.080	0.171	0.212	0.073	0.019	0.737	0.172	0.153	0.578

Table 2 - Estimation results by product type

The most striking conclusion from the simple comparison of the price change frequencies with the estimated menu costs is that indeed, the incidences of less frequent price changes are associated with higher menu costs. Overall, the estimates obtained for Belgium and France lead to similar conclusions. Even though there exist some differences between the two countries in the estimated menu costs for non-perishable food and durable goods, those differences are mainly due to the products sampled rather than to "national" differences.

Our estimates of the menu cost parameter for perishable food are also very close to the numbers reported in Ratfai (2006) for meat products in Hungary.[15]

The relatively high frequency of price changes observed for energy and especially oil products can be (partly) explained by uncostly price changes: the menu cost estimate, $\hat{c}$, for oil energy products is on average in the range 1.2 - 1.4 % compared to a sample average of about 34% for the product categories as a whole. Similarly, numerous price changes of perishable food products are associated with lower menu costs. At the opposite, manufactured goods and services exhibit higher menu costs that explain, at least partly, the often underlined stronger stickiness of their prices.

However, the observed differences in the frequency of price changes cannot be fully explained by those in the estimated menu costs. This is illustrated by the following two examples. First, the monthly frequency of price changes associated with beef sirloin (14.9%) in the Belgian data set represents only a fourth of the frequency of price changes of kiwis (54,2%). However, menu costs of these two products are of the same order of magnitude (c equal to 0.166 for sirloin compared to 0.141 for kiwis). Therefore, differences in the frequency of price changes must originate in differences in the size of the common and/or idiosyncratic shocks. A second interesting example relates to men coats and sugar in France. While the observed frequencies of price changes of these two products are quite similar (18.7% and 18.9%, respectively), their estimated menu costs differ markedly as their respective values are 0.32 for the former product and only 0.13 for the latter.

Therefore, nominal rigidities as measured by the menu costs cannot fully explain the frequency of price changes. Real rigidities must play an important role too.

4.2 Assessing real rigidities

From our estimates, one can indeed conclude that the relative magnitude of shocks, common or idiosyncratic, also plays an important role in the explanation of the frequency of price changes. This result can be readily illustrated using the two examples discussed above. First, in the case of men coats and sugar

[15] Using a Probit model describing an (S,s) pricing strategy, Ratfai (2006) estimates suggest a menu cost for meat products that ranges between 0.13 and 0.18.

in France, we observe that, despite significantly differing menu cost estimates, the frequencies of price changes of these two products are quite similar. This clearly seems to be due to differences in the profile and magnitude of the shocks affecting the optimal prices of these two product categories. First, while the overall variability of the common component f_t (as measured by $std(f_t)$) appears to be quite similar for the two products, their profile over time differs strikingly. Indeed, the autocorrelation profile of the estimated f_t's for men coats exhibit a strong autocorrelation of order 6 and even more so at order 12, suggesting strong seasonal effects in prices of men coats. A reasonable interpretation of this result lies in the prevalence of promotion sales that strongly affect prices of clothing. This is a situation where the profile, rather than the overall variability in the common component, helps in understanding the observed frequency of price changes. Second, idiosyncratic shocks affecting men coats optimal prices are of a larger magnitude than those affecting sugar prices, explaining why men coats prices vary as much as sugar prices over time, despite higher menu costs. This may also be a consequence of promotion sales, as such sales do not necessarily impact the prices of all items, nor all outlets. The importance of the idiosyncratic component may then represent the outlet specific "marketing policy" regarding sales.

In order to get an idea of the relative importance of the menu cost parameter compared to real rigidities in this example, we have run the following simulation: using the estimated values of σ_ε, σ_v, and the computed values of $\bar{\rho}$ and σ_ω for sugar we have generated two samples. A "sugar sample" is constructed using the estimated value of c and σ_c from sugar and a "men coats/sugar sample" uses the estimated values of c and σ_c from men coats but the "sugar" estimates of the other parameters. We repeat this experiment 1000 times. In those simulated samples, this induces an average frequency of price change that is three times lower for men coats than for sugar, a ratio closely related to that in the estimated menu costs: 0.32 for men coats and 0.13 for sugar. Multiplying the size of idiosyncratic shocks of men coat by 3 (as our estimates suggest) brings the frequency of price changes back to its observed value. In other words, since the empirically observed frequencies of price changes are quite close for these two products, we can conclude that in this case, the nominal and real rigidities have broadly similar impacts.

Now, regarding kiwis and sirloin in Belgium which have similar estimated values of the menu costs, we observe that the difference in the frequencies of price changes of these two products stems both from differences in the magnitude of idiosyncratic shocks affecting the price of these two products (σ_ε equals 0.058 for sirloin compared to 0.203 for kiwis) and from differences in the the unconditional variability of the common factors associated with these two product categories ($std(f_t)$ equals 0.020 for sirloin compared to 0.172 for kiwis).

Unsurprisingly, the frequency of price changes seems to be essentially related to the ratio of the variability of the optimal price[16] to the adjustment cost parameter c. Indeed, the simple correlation between the frequency of price changes and this ratio is 0.708 for Belgium and 0.846 for France.

In addition, our estimations also clearly indicate the relative importance of idiosyncratic shocks for our understanding of the price change frequencies. With a very few exceptions (mainly energy products), the magnitude of idiosyncratic shocks is generally larger than the (unconditional) variability of the common component $std(f_t)$. Over the entire range of products, the ratio of σ_ε over $std(f_t)$ takes values above one for 60% of the product categories in Belgium[17], while this ratio is most often between 1 and 4 for France. Considering σ_ω instead of the unconditional standard deviation of the f_t's obviously yields much larger values for the ratio. This result is in line with the conclusion of Golosov and Lucas (2003) who state that price trajectories at the micro level are largely affected by idiosyncratic shocks.

Overall, one can summarize our findings (so far) as follows:

- the relatively high frequency of price changes observed for energy and especially oil products can be explained by the low values of the menu cost parameter, but also by the strong variability of f_t for this product category. Indeed, for Belgium, the unconditional standard deviation of f_t lies between 0.114 and 0.263 for the three energy products considered (resp. 0.090 for the energy product considered in France) while it averages to only 0.070 for the whole set of products (resp. 0.060 in France);

  Both in Belgium and France, the consumer prices of the energy products is thus largely determined by the common movements in marginal costs (which are highly correlated with the price of oil products on the interna-

[16] Measured by $\sqrt{\sigma_\varepsilon^2 + std(f_t)^2}$.

[17] The average value of this ratio over the 88 product categories considered in the Belgian sample is 1.74

tional markets as illustrated in Figure 2). The contribution of idiosyncratic shocks and the dispersion of firm specific mark-ups is of second order importance, compared to what is observed in the other product categories: the ratio of σ_ε to $std(f_t)$ takes much smaller values for these products than for the other product categories. In the case of Belgium, this might result from the fact that oil prices at the gas station are regulated (there is an agreement between the government and oil companies to set up the maximum prices of oil product). Despite these regulations, the prices of these energy products can be described as fully flexible.

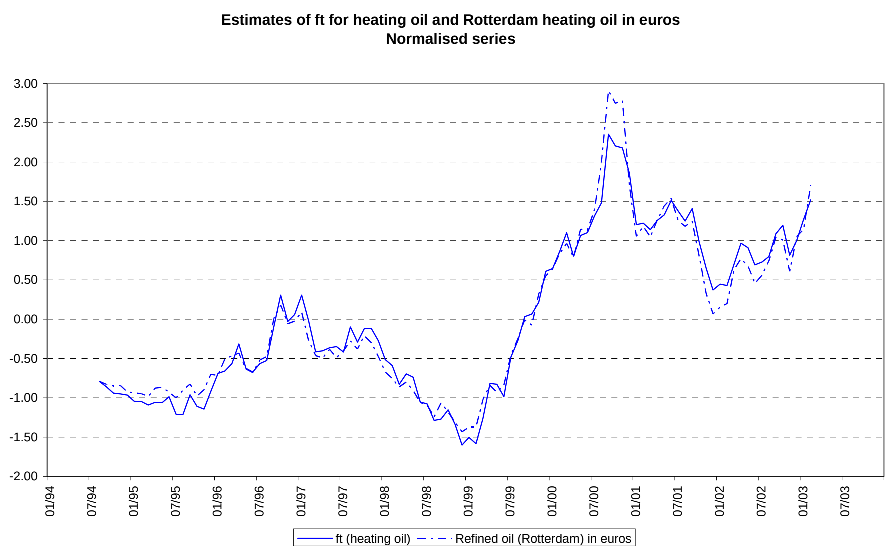

Figure 2 - Evolution of common component f_t for heating oil and of refined oil in Rotterdam

- the perishable food product categories, which rank second in terms of the frequency of price changes, are characterized by medium sized fixed menu costs (c is estimated to be 0.274 in Belgium, 0.202 in France) but these product categories are affected by relatively important common and idiosyncratic shocks. In other words, nominal rigidities appear to be the main reason for the observed "slight" stickiness of these product prices;

- non perishable food and non durable industrial goods occupy an intermediate position in terms of the frequency of price changes. This lower frequency of price changes is driven by both slightly larger menu costs but also by a lower variability of the idiosyncratic and common components of the optimal price. Then, the relative stickiness of those prices stem from both nominal and real rigidities, where the latter seems to be more "concentrated" in the common component of the optimal price, while idiosyncratic shocks appear to be an important factor of prices variability in those sectors;

- the most sticky components of the CPI, namely services and durable industrial goods are characterized by higher fixed menu costs but also, in Belgium, by smaller idiosyncratic and common shocks. This is particularly true for services.

Focusing on services in Belgium, the prices of domestic services, hourly rate in a garage, hourly rate of a plumber, hourly rate of a painter and central heating repair tariff can be clearly identified as wages. These high labour intensive services are characterized by infrequent price changes (average frequency of 5%) and correspond to the relatively low estimates obtained for c (0.34) compared to the other services (around 0.5 for most of the other services[18]) but very similar to the more flexible components of the CPI. This would indicate that for high labour intensive services, the main source of price stickiness is due to real rigidity. Indeed, σ_ε is around 0.048, as compared to an average of 0.075. Similarly, σ_ω is on average equal to 0.006 for labour intensive services, while the 88 product categories basket is characterized by an average estimate for σ_ω of around 0.018.

4.3 Model's in-sample performance

In order to assess how well the model fits the data, we compare the realized frequency and average size of price changes with those obtained from simulating the estimated model. More precisely, we simulate balanced panels of price trajectories given the estimated values of c, σ_ε, σ_c, σ_v, and f_t. The time dimension of the panel, T, is set to coincide with the length of the observation period of the product category, and the cross section dimension is set to the average number of trajectories, denoted by $\overline{N}$. For each simulated panel the frequency of price changes and the average absolute size of price changes are computed.

[18] There are 3 exceptions : annual cable subscription, school boarding fees and parking slot in a garage which are characterized by very low values of c (around 0.1).

The experiment is repeated 1000 times, and the average values of the simulated frequency and size of price changes ($Freq^*$ and $\overline{|\Delta p|}^*$, respectively) are reported in Table A in the Appendix.

We adopt the following rule of thumb: we consider that the model poorly fits the data when the difference between the simulated and realized frequencies and absolute size of price changes exceed 0.10 in absolute value term, and 100 percent in relative terms. This exercise has been done on Belgian results.

Considering the results obtained for the 98 product categories in the Belgian CPI, we can conclude that our model fits a very large spectrum of product categories: either products characterized by frequent (oil products) or infrequent price changes (services), products affected by seasonal variations in the common component f_t (such as roses), or by positive or negative trend in the common component f_t (4 head VCR or hourly rate of a plumber), by regulated prices (tobacco) as well as unregulated prices (see the figures A1-A14 in Appendix, that represent the estimated f_t for some selected products). In addition, our model is able to replicate the direction (and approximate size) of asymmetric price changes (see for example men socks, or hourly rates of a plumber or of a painter).

However, there are some instances where the match between the simulations and the realizations are not sufficiently close. First, as noted in Section 3, consistency of the estimated parameters requires both N and T to be sufficiently large. As evidenced by our Monte Carlo simulations, f_t is poorly estimated when the number of price trajectories in a given period is relatively small. In our sample, for some products with an average number of price trajectories lower than 100, the simulated frequencies or absolute size of price changes can greatly differ (see Laser Jet Printer). Second, our model is not perfectly suited to all types of pricing behaviors. For product categories characterized by highly synchronized and infrequent price changes (such as school lunch),[19] the estimated f_t seems to be overestimated during the month where price changes occurs (see Figure A.14 in Appendix). Third, some product categories are characterized by a very high degree of heterogeneity in the price dynamics, which translates into a large degree of heterogeneity in the menu cost parameter, c_{it}. When σ_c is very large as compared to c, our model could, in principle generate negative

[19] See Aucremanne and Dhyne (2004) or Dhyne and Konieczny (2006) for evidence of synchronization of price changes in the Belgian CPI.

menu costs.[20] This leads to a failure of the simulated samples to reproduce the data characteristics (see, for instance fabric for dress and hair spray).

For Belgium, the summary statistics by groups of product categories presented in Table 2 have been only computed for the subset of product categories for which the two following criteria are satisfied: (1) the simulated frequency of price changes does not deviate from the true one by more than 0.10 in absolute value, and by more than 100 percent in relative terms, (2) the simulated absolute magnitude of price changes does not deviate from its realized value by more than 0.10 in absolute value, and by more than 100 percent in relative terms. In Table 1, products that do not meet one of these criteria are underlined in grey. This leaves us with a sample of 88 product categories out of 98 under consideration.

4.4 Nominal and real rigidities and the frequency of price changes

By considering a large set of product categories representative of the CPI basket, this paper highlights the diversity of sources of infrequent price changes. While in some cases nominal rigidity, captured by the size of the menu cost parameter, may be the primary cause of infrequent price adjustments, in other cases, real rigidity seems to be the main factor behind infrequent price changes.

In order to highlight the link between the frequency of price changes and the structural parameters of our models, we estimate a simple equation relating the realized frequency of price changes to the estimated menu cost parameter, $\hat{c}$, the volatility of the idiosyncratic and the common shocks, $\hat{\sigma}_\varepsilon$ and $\hat{\sigma}_\omega$, respectively. The regressions equations are estimated by OLS as well as by the QML estimation procedure proposed by Papke and Wooldridge (1996). Table 3 reports the results (with standard errors in brackets). The QML and OLS provide qualitatively similar results, although QML procedure provides a better fit,[21] which favours a non-linear relation between the structural parameters and the frequency of price changes.

These regressions confirm that the frequency of price changes is strongly influenced by the size of the shocks, as estimated by $\hat{\sigma}_\varepsilon$ and $\hat{\sigma}_\omega$, relative to

[20] This derives from our assumption that c_{it} follows a normal distribution. Considering not normal distributions would render the theoretical derivation of the likelihood infeasible.

[21] This is particularly true of the specification that excludes the $\hat{c}/\hat{\sigma}_\varepsilon$.

the menu cost parameter. If larger menu costs tend to significantly reduce the frequency of price changes, this effect can be partly offset by larger shocks to the marginal costs/desired mark-up. Introducing the relative importance of idiosyncratic shocks and common shocks separately also indicates that it is mostly the relative size of the common shock that determines the frequency of price changes.[22]

	OLS			QML		
	(1)	(2)	(3)	(4)	(5)	(6)
const	0.216 (0.026)	0.140 (0.016)	0.151 (0.017)	−1.068 (0.322)	−1.710 (0.159)	−1.558 (0.121)
France	−0.020 (0.024)	0.004 (0.014)	−0.001 (0.015)	0.230 (0.127)	0.306 (0.063)	0.226 (0.075)
$\widehat{c}$	−0.641 (0.063)	−0.402 (0.039)	−0.439 (0.046)	−5.983 (0.604)	−4.126 (0.288)	−4.947 (0.448)
$\widehat{\sigma_\varepsilon}$	1.411 (0.259)	1.074 (0.150)	1.240 (0.194)	8.451 (2.441)	8.417 (1.402)	12.482 (1.781)
$\widehat{\sigma_\omega}$	3.004 (0.725)	0.998 (0.434)	0.836 (0.470)	14.994 (5.996)	6.989 (5.784)	1.467 (5.431)
$\frac{\sqrt{\widehat{\sigma_\varepsilon^2}+\widehat{\sigma_\omega^2}}}{\widehat{c}}$	-	0.096 (0.006)	-	-	0.393 (0.056)	-
$\frac{\widehat{\sigma_\varepsilon}}{\widehat{c}}$	-	-	0.060 (0.019)	-	-	−0.072 (0.163)
$\frac{\widehat{\sigma_f}}{\widehat{c}}$	-	-	0.076 (0.022)	-	-	0.682 (0.208)
R^2	0.693	0.901	0.894	0.836	0.937	0.953

Table 3 - Relation between frequency of price changes and structural parameters

4.5 Some Extensions

4.5.1 Gradual adjustment

As stated in Section 2, several factors, such as the structure of local competition across outlets, the degree of uncertainty in the identification of the shocks to the marginal costs, or consumers' inattention, can motivate partial adjustment to shocks. However, in order to observe such gradual movements in prices, price changes should be made on a relatively frequent basis. If a firm adjusts its price only once a year, a gradual change might not be sensible. Therefore,

[22] Using the standard deviation of $\hat{f}_t$ instead of $\hat{\sigma}_f$ does not induce any change in the conclusions.

a price setting model with partial adjustment should only be estimated for product categories with relatively frequent price changes. For these product categories, the partial adjustment parameter λ introduces an additional source of real rigidity.

In the following table, we present the estimation results associated with a set of three product categories characterized by relatively frequent price changes (heating oil, oranges and roses). We also present the estimation results for two product categories that in comparison are characterized by less frequent price changes (namely central heating repair tariff and hourly rate of a painter).

Parameters	Heating oil	Oranges	Roses	Central heating	Painter
$\widehat{c}$	0.025^{**}	0.075^{**}	0.076^{**}	0.396^{**}	0.144^{**}
$\widehat{\sigma_\varepsilon}$	0.052^{**}	0.247^{**}	0.291^{**}	0.074^{**}	0.220^{**}
$\widehat{\sigma_c}$	0.010^{**}	0.056^{**}	0.033^{**}	0.190^{**}	0.066^{**}
$\widehat{\sigma_v}$	0.044^{**}	0.109^{**}	0.247^{**}	0.151^{**}	0.221^{**}
$\widehat{\lambda}$	0.342^{**}	0.395^{**}	0.436^{**}	0.076^{**}	0.864^{**}
Logl	14755.9	−13921.2	−6098.8	−3114.5	−2311.9
$\widehat{\sigma_\omega}$	0.097	0.067	0.076	0.004	0.062
$\widehat{\widehat{\rho}}$	0.867	0.498	1.038	0.848	0.187

Table 4 - estimation results with gradual adjustment - Belgium

** = significant at the 1% level * = significant at the 5% level

The results are summarized in Table 4. The estimates of λ, the parameter of the partial adjustment, is statistically significant in the case of all the five product lines considered, with values that seem eminently sensible for product categories characterized by very frequent price changes. Our estimates indicate that for this kind of products, there is a significant amount of gradualism in the price setting behavior of firms. This clearly indicates an additional source of real rigidity. The estimate of λ for "Central heating repair tariff" is much smaller, and is in accordance with our prior belief that when a firm adjusts its price rarely, it does it (almost) fully. However, we obtain a very high estimate of λ for an "hourly rate of a plumber" which is difficult to understand from an economic point of view. This last result could be due to the fact that the estimation of a gradual adjustment price setting model on price trajectories that do not contain any price change might be quite problematic. We have conducted some simulations showing that the observation of flat price trajectories biases the estimation of the λ parameter towards one, introducing a high volatility in the unobserved common component.

4.5.2 Asymmetric menu costs

As mentioned earlier, our model does not need asymmetry in the menu costs to induce asymmetry in the direction of price changes. If the estimated common component, $\hat{f}_t$, is characterized by a positive (negative) trend, our price setting model will generate more price increases (decreases). This is consistent with the argument of Ball and Mankiw (1994).

However, in order to test whether products characterized by asymmetric price changes are characterized by asymmetric menu costs, we have estimated our baseline model introducing different menu cost parameters for price increases (c_{up}) and for price decreases (c_{down}). This estimation has been conducted on a product category characterized by rather symmetric price changes and by an f_t characterized by episodes of positive or negative trend ("oranges") and on a product characterized by rather asymmetric price changes and by an f_t characterized by a positive trend over the whole observation period ("special beer in a bar"). The results are given in Table 5.

	Oranges	Special beer
$\widehat{c_{up}}$	0.079^{**}	0.543^{**}
$\widehat{c_{down}} - \widehat{c_{up}}$	0.000	-0.002^{*}
$\widehat{\sigma_\varepsilon}$	0.159^{**}	0.052^{**}
$\widehat{\sigma_c}$	0.063^{**}	0.237^{**}
$\widehat{\sigma_u}$	0.109^{**}	0.151^{**}
$\widehat{hyper}$	-0.019^{**}	0.000
$\ell(\theta)$	-27381.4	-3076.4

TABLE 5 - ESTIMATION RESULTS WITH ASYMMETRIC MENU COSTS - BELGIUM

** = significant at the 1% level * = significant at the 5% level

The main conclusion emerging from these estimates is that menu costs associated with price decreases do not seem to differ much from the menu costs associated with price increases and they never are larger (even for the product category with rare price decreases). Even if the difference between the two menu costs is statistically significant, as in the case of special beer, the difference does not seem to be economically important. Although this conclusion is based on limited number of cases, it supports the view that asymmetric price changes may result from a trend in f_t rather than from asymmetric menu costs.

5 Conclusion

Modern macroeconomics has emphasized the role of price rigidity in the impact of monetary policy on real economic activity and inflation dynamics. The slope of the New Keynesian Phillips curve typically depends on nominal price rigidity. Most previous empirical literature approximated these nominal rigidities by the frequency of price changes. However, this holds only when firms set their prices according to a time dependent pricing rule, as assumed in most macroeconomic models. However, more recent models incorporate a state dependent pricing rule (Dotsey, King and Wolman, 1999, and Gertler and Leahy, 2006). In the case of state dependent rules, the frequency of price changes is a function of adjustment costs (nominal rigidity) and the distribution of shocks (real rigidity).

Following this new strand in theoretical models, we specify a state-dependent (s,S) type model where outlets do not necessarily instantaneously adjust their prices in response to changes in their environment.

Since the optimal price targeted by outlets is unobserved, we decompose it into three components: first, a component that is shared across all outlets selling a given fairly homogeneous product. From an economic point of view, this component reflects the average marginal cost augmented with the average *desired* mark-up associated with this particular product. We model this as a common factor (thus dealing with a non-linear panel data model containing an unobserved common factor). The second component of the unobserved optimal price is an individual/outlet specific effect, which accounts for product differentiation, local competition conditions, etc.. The third component is an idiosyncratic term, reflecting shocks that may affect the outlet specific optimal price (possibly due to outlet specific demand shocks or unexpected changes in costs, etc.).

This allows us to decompose price stickiness into a nominal rigidity component (mainly associated with a fixed menu cost) and a real rigidity component, associated with the stickiness of the various components of the (unobserved) optimal price. Making use of two large data sets composed of consumer price records used to compute the CPI in Belgium and France, we estimate these different components for a large number of homogenous products. Our results show that the now well-documented differences across products in the frequency of price changes do not strictly correspond to differences in terms of menu costs; i.e. nominal rigidity does not suffice to explain the frequency of price changes. In fact what seems to drive the frequency of price changes is the relative importance the parameter of the menu cost to the size of the shocks to the common and idiosyncratic factors.

The high frequency of price changes in the most flexible components of the CPI (energy products and perishable foods) is mainly related to large idiosyncratic and/or common shocks, and not necessarily to low adjustment costs. Conversely, the stickier components of the CPI (durable industrial goods and services) experience very low idiosyncratic and common shocks, often in addition to large adjustment costs.

Our results also strongly favor the introduction of heterogenous price behaviors in macroeconomic models. However, in contradiction to the existing view on this issue (Bils and Klenow (2004), Dhyne *et al.* (2006)), our results indicate that heterogeneity should not necessarily be only introduced through different degrees of nominal rigidity, but also through differences in real rigidities.

References

[1] Álvarez, Luis J., Emmanuel Dhyne, Marco M. Hoeberichts, Claudia Kwapil, Hervé Le Bihan, Patrick Lünnemann, Fernando Martins, Roberto Sabbatini, Harald Stahl, Philip Vermeulen and Jouko Vilmunen, (2006) : "Sticky prices in the euro area: a summary of new micro evidence", Journal of the European Economic Association 4 (2/3).

[2] Aucremanne, Luc and Emmanuel Dhyne (2004): "How Frequently Do Prices Change? Evidence Based on the Micro Data Underlying the Belgian CPI", ECB Working Paper Series No 331.

[3] Aucremanne, Luc and Martine Druant (2005): "Price setting behaviour in Belgium: what can be learned from an ad-hoc survey", ECB Working Paper Series, No 448

[4] Ball, Laurence, and Gregory Mankiw (1994): "Asymmetric Price Adjustment and Economic Fluctuations", Economic Journal 104, Mar. 1994, 247-261.

[5] Ball, Laurence and David Romer (2003): "Inflation and the Informativeness of Prices", Journal of Money, Credit, and Banking, April 2003.

[6] Baudry, Laurent, Hervé Le Bihan, Patrick Sevestre, and Sylvie Tarrieu (2004): "Price Rigidity in France - Evidence from Consumer Price Micro-Data", ECB Working Paper Series No 384.

[7] Bils, Mark and Peter Klenow (2004): "Some Evidence on the Importance of Sticky Prices", Journal of Political Economy, 112, p 947-985.

[8] Blinder, Alan.S., Elie R. D. Canetti, David E. Lebow and Jeremy B. Rudd (1998), Asking About Prices: a New Approach to Undertsanding Price Stickiness, Russel Sage Foundation, New York

[9] Cecchetti, Stephen G., (1986), The Frequency of Price Adjustments: A Study of the Newsstand Price of Magazines, Journal of Econometrics, 31, 255-274.

[10] Cornille, David and Maarten Dossche (2006): "The Pattern and Determinants of Price Setting in the Belgian Industry", ECB Working Paper Series, No 618

[11] Dhyne, Emmanuel, Luis J. Álvarez, Hervé Le Bihan, Giovanni Veronese, Daniel Dias, Johannes Hoffmann, Nicole Jonker, Patrick Lünnemann, Fabio Rumler and Jouko Vilmunen, (2006) "Price Changes in the Euro Area and the United States: Some Facts from Individual Consumer Price Data", Journal of Economic Perspective, Vol 20/2

[12] Dias, Mónica, Daniel Dias, and Pedro Neves (2004): "Stylised Features of Price Setting Behaviour in Portugal: 1992-2001", ECB Working Paper Series No 332.

[13] Dotsey, Michael, Robert G. King, and Alexander L. Wolman (1999): "State-Dependent Pricing and the General Equilibrium Dynamics of Money and Output", Quarterly Journal of Economics, 114, 655-690

[14] Fabiani, Silvia, Martine Druant, Ignacio Hernando, Claudia Kwapil, Betina Landau, Claire Loupias, Fernando Martins, Thomas Mathä, Roberto Sabbatini, and Ad Stokman (2005): "The Pricing Behaviour of Firms in the Euro Area: New Survey Evidence", ECB Working Paper Series No 535.

[15] Fougère, Denis, Hervé Le Bihan, and Patrick Sevestre (2006): "Heterogeneity in Price Stickiness: a Microeconometric Investigation", CEPR Discussion Paper No 5300.

[16] Gertler, Mark and John Leahy (2006): "A Phillips Curve with an Ss Foundation", NBER Working Paper No 11971

[17] Golosov, Mikhail and Robert E. Lucas (2003): "Menu Costs and Phillips Curves", NBER Working Paper No 10187

[18] Hall, Simon and Anthony Yates (1998): "Are there Downward Nominal Rigidities in Product Markets?", Bank of England, Working Paper No. 80

[19] Jonker, Nicole, Harry Blijenberg and Carsten Folkertsma (2004): "Empirical Analysis of Price Setting Behaviour in the Netherlands in the Period 1998-2003 Using Micro Data ", ECB Working Paper Series No 413.

[20] Kashyap, Anil K. (1995): "Sticky Prices: New Evidence from Retail Catalogs", Quarterly Journal of Economics, 245-274.

[21] Klenow, Peter and Oleksiy Kryvtsov (2005): "State-Dependent or Time-Dependent Pricing: Does it Matter for Recent U.S. Inflation?", NBER Working Paper 11043.

[22] Lach Saul and Daniel Tsiddon (1992): "The Behaviour of Prices and Inflation: An Empirical Analysis of Disaggregated Price Data", Journal of Political Economy, 100, 349-389.

[23] Levy, Daniel, Mark Bergen, Shantanu Dutta and Robert Venables (1997) "The magnitude of menu costs: direct evidence from large U.S. supermarket chains", Quarterly Journal of Economics, 112(3), 791-825

[24] Levy, Daniel., Haipeng. Chen, Sourav Ray and Mark Bergen (2005), "Asymmetric price adjustment "in the small". An implication of rational inattention", mimeo

[25] Loupias, Claire and Roland Ricart (2004): "Price setting in France: new evidence from survey data", ECB Working Paper Series„ No 423

[26] Loupias, Claire and Patrick Sevestre (2006): "Costs, demand and producer price stickiness", mimeo, Banque de France

[27] Papke, Leslie E. and Jeffrey M. Wooldridge (1996) "Econometric Methods for Fractional Response with an Application to 401(K) Plan Participation Rates", Journal of Applied Econometrics, Vol. 11, N.6, p. 619-632.

[28] Pesaran, M. Hashem.(2004), General Diagnostic Tests for Cross Section Dependence in Panels, CESifo Working Paper Series No. 1229; IZA Discussion Paper No. 1240.

[29] Pesaran, M. Hashem.(2006), Estimation and Inference in Large Heterogeneous Panels with a Multifactor Error Structure, Econometrica, 74(4), 967-1012

[30] Ratfai, Attila, (2006), Linking Individual and Aggregate Price Changes, Mimeo, forthcoming in Journal of Money, Credit and Banking

[31] Rosett, Richard, N. (1959), "A Statistical Model of Frictions in Economics", Econometrica, 27, 263-267

[32] Rotemberg, Julio J. (2003), "The benevolence of the baker: Fair pricing under treat of customer anger", mimeo

[33] Sabbatini, Roberto, Silvia Fabiani, Angela Gatulli. and Giovanni.Veronese (2005), "Producer price behaviour in Italy : Evidence from micro PPI data", Banca d'Italia, mimeo

[34] Sheshinski, Eytan and Yoram Weiss, (1977), Inflation and costs of adjustment, Review of Economic Studies 44, 281-303.

[35] Sheshinski Eytan and Yoram Weiss, (1983), Optimal pricing policy under stochastic inflation, Review of Economic Studies 51, 513-529.

[36] Stahl, Harald (2005): "Time-dependent or state-dependent price setting ? Micro evidence from German metal-working industries", Deutsche Bundesbank Discussion Paper Series 1 : Economic Studies, No 25/2005

[37] Veronese, Giovanni, Silvia Fabiani, Angela. Gattulli and Roberto Sabbatini (2005): "Consumer Price Behaviour In Italy: Evidence From Micro CPI Data", ECB Working Paper Series No 449.

[38] Yates, Anthony (1998): “Downward Nominal Rigidity and Monetary Policy”, Bank of England, Working Paper No. 82

[39] Zbaracki, Mark, Mark Ritson, Daniel Levy, Shantanu Dutta and Mark Bergen (2004): "Managerial and Customer Costs of Price Adjustment: Direct Evidence from Industrial Markets,” Review of Economics and Statistics, Volume 86, No. 2, May 2004, 514–533.

Appendix A - Technical Appendix

Proof of the first part of Lemma 1.

$$E\left[yI(y+a)\right]=\sigma\phi\left(\frac{a+\mu}{\sigma}\right)+\mu\Phi\left(\frac{a+\mu}{\sigma}\right).$$

■

$$\begin{aligned}
E\left[yI\left(y+a\right)\right] &= \int_{-a}^{+\infty} y\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2}dy \\
&= \int_{-a}^{+\infty} \frac{y-\mu}{\sigma}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2}dy + \int_{-a}^{+\infty} \frac{\mu}{\sigma}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2}dy
\end{aligned}$$

Stating that $z=\frac{y-\mu}{\sigma}$, the expression above becomes

$$\begin{aligned}
E\left[yI\left(y+a\right)\right] &= \sigma\int_{-\frac{a+\mu}{\sigma}}^{+\infty} z\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}z^2}dz+\mu\int_{-\frac{a+\mu}{\sigma}}^{+\infty}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}z^2}dz \\
&= \sigma\left[-\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}z^2}\right]_{-\frac{a+\mu}{\sigma}}^{+\infty}+\mu\int_{-\infty}^{\frac{a+\mu}{b}}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}z^2}dz \\
&= \sigma\phi\left(\frac{a+\mu}{\sigma}\right)+\mu\Phi\left(\frac{a+\mu}{\sigma}\right)
\end{aligned}$$

Proof of the second part of Lemma 1.

$$E\left[\phi\left(\frac{y+a}{b}\right)\right]=\frac{b}{\sqrt{b^2+\sigma^2}}\phi\left(\frac{a+\mu}{\sqrt{b^2+\sigma^2}}\right)$$

■

$$\begin{aligned}
E\left[\phi\left(\frac{y+a}{b}\right)\right] &= \int_{-\infty}^{+\infty}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{y+a}{b}\right)^2}\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2}dy \\
&= \frac{1}{\sigma 2\pi}\int_{-\infty}^{+\infty}e^{-\frac{1}{2}\left(\frac{\left(\sigma^2+b^2\right)y^2+\left(2a\sigma^2-2b^2\mu\right)y+a^2\sigma^2+b^2\mu^2}{b^2\sigma^2}\right)}dy \\
&= \frac{1}{\sigma 2\pi}\int_{-\infty}^{+\infty}e^{-\frac{1}{2}\left(\frac{\left(\sqrt{\sigma^2+b^2}y+A\right)^2-A^2+a^2\sigma^2+b^2\mu^2}{b^2\sigma^2}\right)}dy
\end{aligned}$$

where $A = \frac{a\sigma^2 - \mu b^2}{\sqrt{b^2+\sigma^2}}$

Stating $B = \frac{1}{2}\left(\frac{A^2 - a^2\sigma^2 - b^2\mu^2}{b^2\sigma^2}\right) = -\frac{1}{2}\frac{(a+\mu)^2}{b^2+\sigma^2}$,

$$E\left[\phi\left(\frac{y+a}{b}\right)\right] = \frac{1}{\sigma 2\pi} e^B \int_{-\infty}^{+\infty} e^{-\frac{1}{2}\left(\frac{\left(\sqrt{\sigma^2+b^2}y+A\right)^2}{b^2\sigma^2}\right)} dy$$

$$= \frac{1}{\sigma 2\pi} e^B \int_{-\infty}^{+\infty} e^{-\frac{1}{2}\frac{\sigma^2+b^2}{b^2\sigma^2}\left(y+\frac{a\sigma^2-\mu b^2}{b^2+\sigma^2}\right)^2} dy$$

Stating $\omega = \frac{b\sigma}{\sqrt{b^2+\sigma^2}}$ and $\widetilde{\mu} = -\frac{a\sigma^2-\mu b^2}{b^2+\sigma^2}$,

$$E\left[\phi\left(\frac{y+a}{b}\right)\right] = \frac{1}{\sigma 2\pi} e^B \int_{-\infty}^{+\infty} e^{-\frac{1}{2\omega^2}(y-\widetilde{\mu})^2} dy$$

$$= \frac{1}{\sigma 2\pi} e^B \omega\sqrt{2\pi} = \frac{b}{\sqrt{b^2+\sigma^2}}\frac{1}{\sqrt{2\pi}} e^B$$

$$= \frac{b}{\sqrt{b^2+\sigma^2}}\phi\left(\frac{a+\mu}{\sqrt{b^2+\sigma^2}}\right)$$

Proof of the third part of Lemma 1.

$$E\left(\Phi\left(\frac{y+a}{b}\right)\right) = \Phi\left(\frac{a+\mu}{\sqrt{b^2+\sigma^2}}\right)$$

■

$$E\left[\Phi\left(\frac{y+a}{b}\right)\right] = \int_{-\infty}^{+\infty}\int_{-\infty}^{\frac{y+a}{b}} \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}w} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2} dwdy$$

Stating that $\frac{z+y+a}{b} = w$, the expression above becomes

$$E\left[\Phi\left(\frac{y+a}{b}\right)\right] = \int_{-\infty}^{+\infty}\int_{-\infty}^{0} \frac{1}{b\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{z+y+a}{b}\right)^2} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2} dzdy$$

$$= \int_{-\infty}^{0} \frac{1}{b}\int_{-\infty}^{+\infty} \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{z+y+a}{b}\right)^2} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2} dydz$$

$$= \int_{-\infty}^{0} \frac{1}{b} E\left[\phi\left(\frac{y+a+z}{b}\right)\right] dz$$

Using the second part of Lemma 1,

$$
\begin{aligned}
E\left[\Phi\left(\frac{y+a}{b}\right)\right] &= \int_{-\infty}^{0} \frac{1}{b}\frac{b}{\sqrt{b^2+\sigma^2}}\phi\left(\frac{z+a+\mu}{\sqrt{b^2+\sigma^2}}\right)dz \\
&= \frac{1}{\sqrt{b^2+\sigma^2}}\int_{-\infty}^{0}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{z+a+\mu}{\sqrt{b^2+\sigma^2}}\right)^2}dz
\end{aligned}
$$

Stating that $\frac{z+a+\mu}{\sqrt{b^2+\sigma^2}} = \widetilde{z}$,

$$
\begin{aligned}
E\left[\Phi\left(\frac{y+a}{b}\right)\right] &= \frac{1}{\sqrt{b^2+\sigma^2}}\int_{-\infty}^{\frac{a+\mu}{\sqrt{b^2+\sigma^2}}}\frac{\sqrt{b^2+\sigma^2}}{\sqrt{2\pi}}e^{-\frac{1}{2}\widetilde{z}^2}d\widetilde{z} \\
&= \Phi\left(\frac{a+\mu}{\sqrt{b^2+\sigma^2}}\right)
\end{aligned}
$$

Proof of the uniqueness of $\tilde{f}_t$ (the non-linear cross section average estimator of f_t). Let

$$
z_{it}(f_t) = \frac{d_{it}}{\sqrt{\sigma_c^2+\sigma_\xi^2}},
$$

and

$$
\begin{aligned}
\widetilde{\Delta p}_{it} &= \frac{\Delta p_{it}}{\sqrt{\sigma_c^2+\sigma_\xi^2}},\ \tilde{\eta}_{it} = \frac{\eta_{it}}{\sqrt{\sigma_c^2+\sigma_\xi^2}}, \\
\tilde{c} &= \frac{c}{\sqrt{\sigma_c^2+\sigma_\xi^2}} \geq 0,\ \delta^2 = \frac{\sigma_\xi^2}{\sigma_c^2+\sigma_\xi^2} < 1,
\end{aligned}
$$

and note that we have

$$
\begin{aligned}
\widetilde{\Delta p}_{it} &= z_{it}(f_t) + z_{it}(f_t)\left[\Phi\left(z_{it}(f_t)-\tilde{c}\right) - \Phi\left(z_{it}(f_t)+\tilde{c}\right)\right] && (10) \\
&\quad +\delta^2\left[\phi\left(z_{it}(f_t)-\tilde{c}\right) - \phi\left(z_{it}(f_t)+\tilde{c}\right)\right] + \tilde{\eta}_{it}. && (11)
\end{aligned}
$$

The cross-sectional average estimate of f_t is now given by the solution of the non-linear equation

$$
\begin{aligned}
\Psi(\tilde{f}_t) &= \sum_{i=1}^{N} w_{it}\{z_{it}(\tilde{f}_t) + z_{it}(\tilde{f}_t)\left[\Phi\left(z_{it}(\tilde{f}_t)-\tilde{c}\right) - \Phi\left(z_{it}(\tilde{f}_t)+\tilde{c}\right)\right] && (12) \\
&\quad + \delta^2\left[\phi\left(z_{it}(\tilde{f}_t)-\tilde{c}\right) - \phi\left(z_{it}(\tilde{f}_t)+\tilde{c}\right)\right]\} - a_{Nt} && (13) \\
&= 0, && (14)
\end{aligned}
$$

where $a_{Nt} = \sum_{i=1}^{N} w_{it}\widetilde{\Delta p}_{it}$.

First it is clear that $\Psi(\tilde{f}_t)$ is a continuous and differentiable function of f_t, and it is now easily seen that

$$\lim_{f_t \to +\infty} \Psi(\tilde{f}_t) \to +\infty \text{ and } \lim_{f_t \to -\infty} \Psi(\tilde{f}_t) \to -\infty.$$

Also the first derivative of $\Psi(f_t)$ is given by[23]

$$\Psi'(\tilde{f}_t) = \frac{1}{\sqrt{\sigma_c^2 + \sigma_\xi^2}} \sum_{i=1}^{N} w_{it} q_{it},$$

where

$$q_{it} = 1 + \Phi\left(z_{it}(\tilde{f}_t) - \tilde{c}\right) - \Phi\left(z_{it}(\tilde{f}_t) + \tilde{c}\right) + (1 - \delta^2) h(z_{it}(\tilde{f}_t)),$$

and

$$h(z_{it}(\tilde{f}_t)) = z_{it}(\tilde{f}_t)\left[\phi\left(z_{it}(\tilde{f}_t) - \tilde{c}\right) - \phi\left(z_{it}(\tilde{f}_t) + \tilde{c}\right)\right].$$

But since $1 - \Phi\left(z_{it}(\tilde{f}_t) + \tilde{c}\right) = \Phi\left(-z_{it}(\tilde{f}_t) - \tilde{c}\right)$, then

$$1 + \Phi\left(z_{it}(\tilde{f}_t) - \tilde{c}\right) - \Phi\left(z_{it}(\tilde{f}_t) + \tilde{c}\right) = \Phi\left(z_{it}(\tilde{f}_t) - \tilde{c}\right) + \Phi\left(-z_{it}(\tilde{f}_t) - \tilde{c}\right) > 0,$$

and it is easily seen that $h(z_{it}(\tilde{f}_t))$ is symmetric, namely $h(z_{it}(\tilde{f}_t)) = h(-z_{it}(\tilde{f}_t))$. Focusing on the non-negative values of $z_{it}(\tilde{f}_t)$ it is easily seen that

$$h(z_{it})) = \frac{z_{it}}{\sqrt{2\pi}}\left[e^{-0.5(z_{it}-\tilde{c})^2} - e^{-0.5(z_{it}+\tilde{c})^2}\right] > 0 \text{ for } \tilde{c} > 0,$$

and by symmetry $h(z_{it})) \geq 0$, for all $\tilde{c} \geq 0$. Hence, $q_{it} > 0$ for all i and t, and $\tilde{c} \geq 0$. Therefore, it also follows that $\Psi'(f_t) > 0$, for all value of $w_{it} \geq 0$ and $c \geq 0$. Thus, by the fixed point theorem, $\Psi(f_t)$ must cut the horizontal axis but only once.

Proof of the consistency of $\tilde{f}_t$ as an estimator of f_t as $N \to \infty$.

Let

$$\begin{aligned}\Psi(f_t) \quad = \quad & \sum_{i=1}^{N} w_{it}\left\{z_{it}(f_t) + z_{it}(f_t)\left[\Phi\left(z_{it}(f_t) - \tilde{c}\right) - \Phi\left(z_{it}(f_t) + \tilde{c}\right)\right]\right.\\ & \left.+\delta^2\left[\phi\left(z_{it}(f_t) - \tilde{c}\right) - \phi\left(z_{it}(f_t) + \tilde{c}\right)\right]\right\} - a_{Nt},\end{aligned}$$

[23] Recall that the weights, w_{it}, are non-zero pre-determined constants, and in particular do not depend on f_t.

and note that

$$\Psi(f_t) = -\sum_{i=1}^{N} w_{it}\eta_{it}.$$

Consider now the mean-value expansion of $\Psi(f_t)$ around $\tilde{f}_t$

$$\Psi(f_t) - \Psi(\tilde{f}_t) = \Psi'(\bar{f}_t)(f_t - \tilde{f}_t),$$

where $\bar{f}_t$ lies on the line segment between f_t and $\tilde{f}_t$. Since $\Psi(\tilde{f}_t) = 0$ and $\Psi'(\bar{f}_t) > 0$ for all $\bar{f}_t$ (as established above) we have

$$\tilde{f}_t - f_t = \frac{-\sum_{i=1}^{N} w_{it}\tilde{\eta}_{it}}{\Psi'(\bar{f}_t)}.$$

Recall that $\tilde{\eta}_{it} = \left(\sigma_c^2 + \sigma_\xi^2\right)^{-1/2}\left[\Delta p_{it} - E\left(\Delta p_{it}\left|\mathbf{h}_{it}\right.\right)\right]$, where $\mathbf{h}_{it} = (f_t, \mathbf{x}_{it}, p_{i,t-1})$, and hence $E\left(\tilde{\eta}_{it}\right) = 0$. Further, conditional on f_t and $\mathbf{x}_{it}$, price changes, Δp_{it}, being functions of independent shocks v_i and ε_{it} over i, will be cross sectionally independent. Therefore, η_{it} will also be cross sectionally independent; although they need not be identically distributed even if the underlying shocks, v_i and ε_{it}, are identically distributed over i.

Given the above results we now have (for each t and as $N \to \infty$)

$$\left(\sum_{i=1}^{N} w_{it}^2\right)^{-1/2}\left(\tilde{f}_t - f_t\right) \backsim N\left(0, \vartheta_{\tilde{f}}^2\right),$$

where

$$\vartheta_{\tilde{f}}^2 = \lim_{N\to\infty}\left\{\frac{\left(\sum_{i=1}^{N} w_{it}^2\right)^{-1}\sum_{i=1}^{N} w_{it}^2 Var(\tilde{\eta}_{it})}{\left[\Psi'(f_t)\right]^2}\right\}.$$

Note that as $N \to \infty$, $\sum_{i=1}^{N} w_{it}\tilde{\eta}_{it} \xrightarrow{p} 0$, and hence $\tilde{f}_t \xrightarrow{p} f_t$, since $\Psi'(f_t) > 0$ for all f_t.It must also be that $\bar{f}_t \xrightarrow{p} f_t$.

In the case where $w_{it} = 1/N$, we have

$$\vartheta_{\tilde{f}}^2 = \lim_{N\to\infty}\left\{\frac{N^{-1}\sum_{i=1}^{N} Var(\tilde{\eta}_{it})}{\left[\Psi'(f_t)\right]^2}\right\}.$$

It also follows that

$$\tilde{f}_t - f_t = O_p\left(\frac{1}{\sqrt{N}}\right).$$

■

Appendix B - The data

The Belgian CPI data set :

The Belgian CPI data set contains monthly individual price reports collected by the Federal Public Service "Economy, SMEs, Self-Employed and Energy" for the computation of the Belgian National and Harmonized Index of Consumer Prices. In its complete version, it covers the 1989:01 - 2005:12 period. Considering the whole sample, would have involved analyzing more than 20,000,000 price records. For this project, we restricted the analysis to the product categories included in the Belgian CPI basket for the base year 1996, and restricted our period of observation to the 1994:07 - 2003:02 period. Our data set covers only the product categories for which the prices are recorded throughout the entire year in a decentralized way, i.e. 65.5%. of the Belgian CPI basket for the base year 1996. The remaining 34.5% relate to product categories that are monitored centrally by the Federal Public Services, such as housing rents, electricity, gas, telecommunications, health care, newspapers and insurance services and to product categories that are not available for sale during the entire year (some fruits and vegetables, winter and summer fees in tennis club). Price reports take into account all types of rebates and promotions, except those relating to the winter and summer sales period, which typically take place in January and July. In addition to the price records, the Belgian CPI data sets provides information on the location of the seller, a seller identifier, the packaging of the product (in order to identify promotions in quantity) and the brand of the product. For all products, the price concept used in this paper correspond to the log of price per unit.

The French CPI data set :

The French CPI data set contains more than 13,000,000 monthly individual price records collected by the INSEE for the computation of the French National and Harmonized Index of Consumer Prices. It covers the period July 1994:07 - February 2003. This data set covers 65.5%. of the French CPI basket. Indeed, the prices of some categories of goods and services are not available in our sample: centrally collected prices - of which major items are car prices and administered or public utility prices (e.g. electricity)- as well as other types of products such as fresh food and rents. At the COICOP 5-digit level, we have access to 128 product categories out of 160 in the CPI. As a result, the coverage rate is above 70% for food and non-energy industrial goods, but closer to 50%

in the services, since a large part of services prices are centrally collected, e.g. for transport or administrative or financial services.

Each individual price quote consists of the exact price level of a precisely defined product. What is meant by “product” is a particular product, of a particular brand and quality, sold in a particular outlet. The individual product identification number allows us to follow the price of a product through time, and to recover information on the type of outlet (hypermarket, supermarket, department store, specialized store, corner shop, service shop, etc.), the category of product and the regional area where the outlet is located (for confidentiality reasons, a more precise location of outlets was not made available to us). The sequences of records corresponding to such defined individual products are referred to as price trajectories. Importantly, if in a given outlet a given product is definitively replaced by a similar product of another brand or of a different quality, a new identification number is created, and a new price trajectory is started. On top of the above mentioned information, the following additional information is recorded : the year and month of the record, a qualitative “type of record” code and (when relevant) the quantity sold. When relevant, division by the indicator of the quantity is used in order to recover a consistent price per unit. The “type of record” code indicates the nature of the price recorded: regular price, sales or rebates, or “pseudo-observation” (a "pseudo-observation" is essentially an observation which has been imputed by the INSEE; see Baudry et al. (2004) for more details on the way we have tackled such imputed values to avoid creating "false" price changes).

Confidentiality restrictions

Due to strong confidentiality restrictions, we are not allowed to provide anyone with the micro price reports underlying this work. However, a data set containing simulated data and the MatLab code of the estimation procedures are available on request (emmanuel.dhyne@nbb.be). A SAS code is also available.

Appendix C - Detailed results

Description of Table A

Columns (2) to (6) refer to the results obtained by Full ML :

- c represents the estimated value of the average menu cost ;

- sig_e represents the estimated value of σ_ε ;

- sig_c represents the estimated value of σ_c ;

- sig_u represents the estimated value of σ_ν ;

- $Logl$ represents the maximized value of the likelihood function ;

Columns (7) and (8) refer to the results associated to the time-series representation of f_t.

- sig_ω represents the estimated value of σ_ω;

- $S(rho_k)$ represents the estimated value of $\overline{\rho} = \sum_{i=1}^{K} \rho_i$

Columns (9) and (10) present the correlation between f_t and the log of the product category price index or between f_t and $\overline{p}_t$.

Columns (11) to (13) provide descriptive statistics of the data set (the average number of observations each month, $Nbar$, the frequency of price changes, $Freq$, the average size of price changes in absolute term, $|Dp|$, and the share of price increases, $\%up$.

Columns (14) to (15) provide averages of the frequency of price changes, $Freq^*$, the average size of price changes in absolute term, $|Dp|^*$, and the share of price increases, $\%up^*$ obtained on the basis of simulated data generated using the estimated structural parameters and the estimated f_t of each product categories. The simulation exercise is replicated 1000 times.

Grey cells indicate product categories for which the model fits the data poorly (low correlation of $f_t$with the log of price index or with $\overline{p}_t$ or poor replication of the data characteristics by simulated data).

Description of Table B

Columns (2) to (6) refer to the results obtained by Full ML :

- c represents the estimated value of the average menu cost ;

- sig_e represents the estimated value of σ_ε ;

- sig_c represents the estimated value of σ_c ;

- sig_u represents the estimated value of σ_ν ;

- $Logl$ represents the maximized value of the likelihood function ;

Columns (7) and (8) refer to the results associated to the time-series representation of f_t.

- sig_ω represents the estimated value of σ_ω;

- $S(rho_k)$ represents the estimated value of $\overline{\rho} = \sum_{i=1}^{K} \rho_i$

Columns (9) to (11) provide descriptive statistics of the data set (the average number of observations each month, $Nbar$, the frequency of price changes, $Freq$, the average size of price changes in absolute term, $|Dp|$, and the share of price increases, $\%up$.

Description of Tables C and D

Columns (2) to (8) provide basic statistics describing the estimated f_t :

- $stdft$ represents the unconditional standard deviation ;

- r_i represents the autocorrelation of order i.

	Estimated value of									Observed data				Simulated data		
Product category	c	sig_e	sig_c	sig_u	Logl	sig_w	S(rho_k)	$r_{ft,ln(IP)}$	$r_{ft,pt}$	Nbar	Freq	|Dp|	%up	Freq*	|Dp|*	%up*
Energy																
Butane	0.007**	0.040**	0.006**	0.215**	6560	0.028	0.880	0.999	0.999	128	0.742	0.029	0.539	0.909	0.055	0.530
Gasoline 1000-2000 l	0.025**	0.036**	0.011**	0.040**	13885	0.063	0.930	1.000	1.000	144	0.730	0.073	0.545	0.747	0.080	0.538
Eurosuper (RON95)	0.009**	0.014**	0.002**	0.019**	41334	0.022	0.790	1.000	1.000	247	0.720	0.027	0.521	0.771	0.030	0.528
Perisable food																
Paprika peppers	0.046**	0.202**	0.032**	0.117**	-14700	0.145	0.774	0.998	1.000	443	0.842	0.282	0.530	0.891	0.305	0.510
Skate (wing)	0.038**	0.141**	0.034**	0.145**	-9162	0.029	0.657	0.985	0.998	183	0.688	0.136	0.524	0.845	0.186	0.505
Oranges	0.079**	0.159**	0.063**	0.109**	-27424	0.040	0.734	0.994	1.000	447	0.619	0.183	0.528	0.731	0.232	0.505
Carrots	0.114**	0.173**	0.088**	0.125**	-28928	0.085	0.751	0.998	0.999	443	0.574	0.224	0.516	0.669	0.275	0.503
Apples : Granny Smith type	0.088**	0.126**	0.068**	0.075**	-21021	0.053	0.744	0.998	0.999	443	0.564	0.170	0.542	0.649	0.200	0.504
Kiwis	0.141**	0.203**	0.112**	0.135**	-35651	0.046	0.863	0.996	0.999	443	0.542	0.244	0.531	0.639	0.310	0.507
Margarine (super)	0.135**	0.046**	0.087**	0.132**	-16650	0.010	0.913	0.885	0.898	438	0.189	0.053	0.616	0.196	0.080	0.507
Turkey filet	0.282**	0.098**	0.159**	0.114**	-16682	0.018	0.396	0.959	0.968	448	0.154	0.141	0.561	0.172	0.182	0.516
Sirloin	0.166**	0.058**	0.094**	0.096**	-16897	0.011	0.369	0.906	0.923	509	0.149	0.082	0.568	0.173	0.107	0.515
Cheese (type Gouda)	0.343**	0.115**	0.190**	0.168**	-23328	0.019	0.833	0.906	0.818	491	0.143	0.168	0.558	0.160	0.214	0.509
Unskimmed fruit yoghurt (150g)	0.276**	0.080**	0.162**	0.195**	-16238	0.011	0.423	0.913	0.929	414	0.141	0.090	0.538	0.145	0.140	0.487
Dairy butter	0.171**	0.050**	0.097**	0.105**	-15028	0.012	0.725	0.947	0.962	474	0.132	0.067	0.602	0.146	0.092	0.521
Emmentaler	0.285**	0.087**	0.155**	0.138**	-13823	0.021	0.801	0.903	0.847	353	0.126	0.124	0.564	0.142	0.165	0.514
Sausage	0.390**	0.117**	0.212**	0.099**	-20864	0.013	0.902	0.983	0.994	496	0.113	0.149	0.621	0.137	0.217	0.524
Cheese (type Edam)	0.322**	0.086**	0.173**	0.135**	-12950	0.017	0.805	0.967	0.972	334	0.109	0.112	0.635	0.119	0.160	0.531
Belgian Waffle	0.400**	0.088**	0.212**	0.230**	-12810	0.019	0.407	0.788	0.801	441	0.094	0.112	0.564	0.094	0.159	0.530
Coarse pâté made with pork	0.396**	0.098**	0.203**	0.133**	-17209	0.018	0.631	0.960	0.973	484	0.090	0.130	0.637	0.100	0.184	0.541
Rice pudding	0.457**	0.075**	0.216**	0.218**	-5724	0.024	0.789	0.924	0.935	283	0.053	0.096	0.771	0.054	0.143	0.608
Carré glacé	0.391**	0.059**	0.172**	0.103**	-4509	0.019	0.929	0.966	0.973	263	0.041	0.095	0.832	0.042	0.123	0.677
Eclair	0.444**	0.070**	0.194**	0.101**	-4731	0.031	0.505	0.904	0.923	263	0.040	0.105	0.788	0.042	0.148	0.624
Swiss cake	0.506**	0.065**	0.223**	0.267**	-4189	0.021	-0.093	0.932	0.928	278	0.036	0.091	0.835	0.034	0.125	0.614
Grey bread	0.129**	0.020**	0.055**	0.140**	-2857	0.013	0.777	0.936	0.945	269	0.033	0.037	0.927	0.044	0.049	0.629
Special bread	0.398**	0.031**	0.181**	0.468**	-3046	0.027	0.662	0.773	0.772	298	0.028	0.047	0.932	0.029	0.067	0.597
Bread roll	0.583**	0.072**	0.242**	0.157**	-4830	0.017	0.887	0.965	0.986	269	0.026	0.128	0.824	0.027	0.152	0.717

Table A - Estimation Results - Belgium

Product category	Estimated value of									Observed data				Simulated data		
	c	sig_e	sig_c	sig_u	Logl	sig_w	S(rho_k)	$r_{ft,ln(IP)}$	$r_{ft,pt}$	Nbar	Freq	|Dp|	%up	Freq*	|Dp|*	%up*
Non perishable food																
Frankfurters	0.237**	0.071**	0.154**	0.142**	-17986	0.017	0.775	0.860	0.948	369	0.175	0.076	0.587	0.176	0.122	0.512
Biscuits	0.225**	0.067**	0.146**	0.188**	-22331	0.019	0.863	0.985	0.986	444	0.175	0.076	0.620	0.175	0.116	0.550
Fruit juice	0.255**	0.080**	0.153**	0.235**	-22172	0.018	0.769	0.952	0.897	475	0.162	0.106	0.526	0.167	0.144	0.516
Fishcakes	0.282**	0.081**	0.161**	0.175**	-11923	0.027	0.717	0.913	0.923	377	0.143	0.123	0.574	0.145	0.151	0.529
Loire Valley Wine	0.310**	0.086**	0.182**	0.216**	-14752	0.007	0.923	0.965	0.998	349	0.136	0.101	0.598	0.140	0.149	0.516
Ice cream	0.321**	0.090**	0.176**	0.208**	-11697	0.025	0.805	0.961	0.973	318	0.126	0.136	0.557	0.133	0.170	0.527
Tinned apricot halves	0.284**	0.076**	0.156**	0.161**	-11960	0.019	0.827	0.939	0.934	398	0.118	0.099	0.579	0.125	0.140	0.529
Peeled tinned tomatoes - 400 g	0.450**	0.107**	0.252**	0.320**	-16043	0.025	0.662	0.964	0.964	457	0.113	0.128	0.621	0.113	0.192	0.542
Peas (tinned)	0.363**	0.094**	0.196**	0.228**	-14878	0.020	0.860	0.962	0.955	465	0.112	0.128	0.594	0.117	0.173	0.536
Tobacco (50 g)	0.106**	0.012**	0.056**	0.185**	-241	0.006	0.719	0.999	0.999	243	0.098	0.035	0.995	0.088	0.040	0.870
Sausage	0.444**	0.112**	0.233**	0.180**	-18770	0.007	0.962	0.998	1.000	479	0.093	0.134	0.648	0.105	0.205	0.529
Lemonade	0.431**	0.089**	0.212**	0.183**	-6497	0.024	0.737	0.536	0.432	295	0.068	0.106	0.627	0.070	0.157	0.497
Non durable goods																
Roses	0.078**	0.180**	0.034**	0.210**	-7743	0.044	1.190	0.991	0.998	160	0.678	0.218	0.523	0.781	0.270	0.515
Chrysanthemums	0.082**	0.152**	0.041**	0.150**	-5542	0.041	0.711	0.988	1.000	150	0.622	0.192	0.519	0.725	0.235	0.503
Compact Disc	0.150**	0.064**	0.097**	0.070**	-7501	0.013	0.912	0.952	0.954	173	0.217	0.083	0.520	0.240	0.113	0.513
Hair spray 400 ml	0.102**	0.140**	0.157**	0.165**	-28623	0.005	0.722	0.945	1.000	363	**0.154**	**0.063**	0.570	**0.599**	**0.200**	0.503
Catfood	0.2122**	0.066**	0.1208**	0.1619**	-13341	0.019	0.913	0.868	0.743	371	0.148	0.097	0.515	0.155	0.122	0.500
Nail varnish	0.317**	0.064**	0.171**	0.172**	-7156	0.015	0.873	0.990	0.989	255	0.094	0.072	0.726	0.093	0.118	0.618
Enamel painting	0.349**	0.053**	0.182**	0.169**	-6837	0.007	0.951	0.997	0.999	217	0.069	0.058	0.860	0.068	0.097	0.643
Acrylate painting	0.400**	0.061**	0.206**	0.192**	-4642	0.005	0.825	0.997	0.999	185	0.066	0.061	0.826	0.062	0.104	0.595
Consumption of water	0.488**	0.067**	0.242**	0.643**	-2316	0.026	0.598	0.839	0.919	69	0.059	0.057	0.875	0.056	0.130	0.637
Engine oil	0.575**	0.082**	0.272**	0.246**	-5767	0.004	0.956	0.995	1.000	210	0.047	0.079	0.839	0.047	0.151	0.652
Dracaena	0.613**	0.087**	0.282**	0.441**	-3510	0.004	0.770	0.927	0.996	131	0.044	0.071	0.637	0.039	0.150	0.533
Dry battery	0.933**	0.129**	0.416**	0.354**	-7859	0.007	0.955	0.982	1.000	251	0.040	0.126	0.764	0.038	0.247	0.671
Woollen suit	0.405**	0.052**	0.188**	0.224**	-4645	0.002	0.660	0.757	0.954	186	0.040	0.039	0.681	0.037	0.086	0.521
Small anorak (9 month)	0.148**	0.055**	0.102**	0.187**	-7958	0.004	0.819	-0.627	1.000	185	**0.030**	0.073	0.570	**0.221**	0.092	0.510
Men socks	0.500**	0.068**	0.203**	0.254**	-5611	0.003	0.942	0.991	1.000	239	0.030	0.073	0.721	0.025	0.137	0.664

TABLE A - CONTINUED

	Estimated value of									Observed data				Simulated data		
Product category	c	sig_e	sig_c	sig_u	Logl	sig_w	$S(rho_k)$	$r_{ft,ln(IP)}$	$r_{ft,pt}$	Nbar	Freq	|Dp|	%up	Freq*	|Dp|*	%up*
Fabric for dress	0.115**	0.058**	0.044**	0.143**	-5869	0.003	0.819	0.991	1.000	139	**0.029**	**0.035**	0.803	**0.213**	**0.124**	0.512
Men T shirt	0.170**	0.087**	0.131**	0.225**	-11079	0.004	0.887	0.941	1.000	232	**0.028**	0.103	0.581	**0.312**	0.144	0.505
Colour film (135-24)	0.315**	0.045**	0.131**	0.148**	-3902	0.002	0.864	0.537	0.963	174	0.027	0.056	0.460	0.027	0.082	0.509
Zip fastener	0.210**	0.022**	0.085**	0.063**	-3486	0.008	0.666	0.977	0.982	204	0.024	0.048	0.828	0.023	0.054	0.728
Durable goods																
LaserJet Printer	0.4887**	0.1129**	0.3071**	0.221**	-3595	0.042	0.774	0.568	0.796	68	0.141	**0.084**	0.458	0.138	**0.197**	0.458
4 head VCR	0.596**	0.096**	0.311**	0.208**	-6071	0.029	0.748	0.986	0.988	192	0.078	0.097	0.275	0.074	0.186	0.324
Compact hi-fi rack	0.587**	0.089**	0.293**	0.250**	-6255	0.006	0.994	0.993	1.000	185	0.062	0.077	0.368	0.059	0.162	0.354
Natural gas convector	0.320**	0.046**	0.160**	0.150**	-4249	0.018	0.653	0.981	0.984	165	0.062	0.052	0.861	0.061	0.092	0.662
Calculator	0.727**	0.134**	0.352**	0.305**	-5023	0.007	1.005	0.958	1.000	152	0.057	0.124	0.506	0.062	0.240	0.471
Toaster 800 W	0.395**	0.059**	0.193**	0.174**	-6618	0.005	0.941	0.871	0.994	215	0.056	0.064	0.560	0.051	0.100	0.495
Suitcase	0.554**	0.063**	0.283**	0.186**	-3967	0.008	0.845	0.981	0.986	115	0.056	0.061	0.619	0.049	0.102	0.571
Electric coffee machine 900 W	0.443**	0.070**	0.219**	0.203**	-6477	0.005	0.900	0.769	0.993	225	0.056	0.061	0.568	0.055	0.118	0.499
Children's bicycle 24"	0.458**	0.066**	0.221**	0.158**	-3444	0.020	0.419	0.961	0.973	154	0.054	0.066	0.797	0.052	0.124	0.637
Electric fryer	0.553**	0.080**	0.264**	0.221**	-6328	0.003	0.968	0.562	0.998	221	0.049	0.066	0.619	0.046	0.135	0.534
Dictionary	0.583**	0.100**	0.259**	0.324**	-3930	0.033	0.659	0.871	0.875	162	0.046	0.157	0.394	0.049	0.208	0.516
Slatted base	0.538**	0.065**	0.248**	0.269**	-3797	0.018	0.577	0.848	0.812	163	0.040	0.056	0.729	0.036	0.115	0.509
Enameled steel pot	0.609**	0.082**	0.277**	0.365**	-5374	0.004	0.905	0.992	0.999	215	0.037	0.067	0.718	0.037	0.143	0.577
Hammer	0.888**	0.093**	0.406**	0.263**	-5173	0.016	0.687	0.964	0.966	185	0.036	0.065	0.734	0.032	0.161	0.645
Glass 4 mm (in sqm)	0.422**	0.055**	0.185**	0.152**	-1590	0.009	0.933	0.992	0.997	100	0.035	0.078	0.847	0.036	0.117	0.668
Dining room oak furniture	0.105**	0.125**	0.162**	0.161**	-14540	0.010	0.894	0.860	1.000	168	**0.032**	0.040	0.813	**0.566**	0.180	0.513
Spherical glasses	0.641**	0.074**	0.293**	0.219*	-3577	0.007	0.549	0.926	0.982	157	0.032	0.056	0.735	0.032	0.123	0.562
Wallet	0.140**	0.047**	0.085**	0.177**	-5672	0.005	0.891	0.978	1.000	162	**0.032**	0.050	0.836	**0.182**	0.084	0.564
Torus glasses	0.502**	0.055**	0.223**	0.212**	-4014	0.015	-0.003	0.866	0.874	159	0.031	0.055	0.635	0.028	0.097	0.599
Cup and saucer	0.109**	0.086**	0.167**	0.163**	-16952	0.005	0.880	0.974	1.000	210	**0.030**	0.071	0.680	**0.469**	0.122	0.516
Services																
School boarding fees	0.118**	0.019**	0.061**	0.100**	-2762	0.005	0.676	0.994	0.987	141	0.074	0.024	0.954	0.077	0.040	0.707
Hourly rate of a painter	0.261**	0.033**	0.127**	0.167**	-2754	0.010	0.544	0.984	0.990	129	0.055	0.040	0.814	0.051	0.069	0.727
Hourly rate in a garage	0.357**	0.049**	0.171**	0.140**	-4289	0.004	0.965	0.999	1.000	183	0.053	0.059	0.963	0.052	0.101	0.731

TABLE A - CONTINUED

Product category	Estimated value of									Observed data				Simulated data		
	c	sig_e	sig_c	sig_u	Logl	sig_w	$S(rho_k)$	$r_{ft,ln(IP)}$	$r_{ft,pt}$	Nbar	Freq	|Dp|	%up	Freq*	|Dp|*	%up*
Annual cable subscription	0.133**	0.019**	0.062**	0.068**	-1187	0.013	0.711	0.878	0.932	66	0.051	0.029	0.844	0.055	0.047	0.674
Central heating repair tariff	0.371**	0.068**	0.175**	0.153**	-3142	0.004	0.855	0.995	1.000	123	0.051	0.053	0.752	0.059	0.128	0.602
Hourly rate of a plumber	0.308**	0.043**	0.148**	0.146	-2826	0.006	0.735	0.997	0.999	132	0.051	0.050	0.745	0.050	0.083	0.675
Passport stamp	0.208**	0.026**	0.082**	0.067**	-351	0.033	0.874	0.991	0.992	60	0.042	0.132	0.957	0.055	0.138	0.844
Sole meunière	0.429**	0.053**	0.194**	0.205**	-3313	0.019	0.530	0.950	0.960	153	0.040	0.066	0.811	0.038	0.106	0.681
Dry cleaning for shirt	0.520**	0.069**	0.232**	0.18	-3934	0.005	0.995	0.996	0.999	147	0.036	0.068	0.874	0.035	0.127	0.637
Pepper steak	0.359**	0.041**	0.156**	0.134**	-2705	0.004	0.978	0.996	0.999	160	0.034	0.053	0.892	0.033	0.082	0.715
Permanent wave	0.5937**	0.064**	0.266**	0.274**	-4164	0.003	0.919	0.989	1.000	198	0.034	0.066	0.901	0.031	0.121	0.699
Domestic services	0.404**	0.045**	0.179**	0.127**	-4669	0.006	0.824	0.980	0.998	143	0.033	0.050	0.834	0.032	0.092	0.726
Funerals	0.327**	0.033**	0.145**	0.138**	-2078	0.019	-0.498	0.912	0.936	118	0.033	0.037	0.951	0.032	0.074	0.695
School lunch	0.505**	0.062**	0.222**	0.187**	-3612	0.006	0.952	0.997	0.999	147	0.033	0.081	0.855	0.033	0.123	0.703
Self-service meal	0.285**	0.030**	0.124**	0.139**	-1713	0.019	0.331	0.573	0.576	94	0.033	0.045	0.729	0.028	0.062	0.545
Parking spot in a garage	0.126**	0.037**	0.146**	0.185**	-7994	0.006	0.944	0.960	1.000	147	**0.032**	0.059	0.959	**0.290**	0.053	0.568
Balancing of wheels	0.756**	0.109**	0.332**	0.278**	-5461	0.003	0.950	0.984	0.999	179	0.032	**0.075**	0.702	0.034	**0.193**	0.533
Special beer (in a bar)	0.545**	0.054**	0.239**	0.146**	-3426	0.009	0.939	0.992	0.995	221	0.030	0.084	0.876	0.028	0.110	0.743
Aperitive (in a bar)	0.486**	0.051**	0.210**	0.191**	-4277	0.006	0.942	0.997	0.999	227	0.029	0.084	0.879	0.029	0.111	0.764
Videotape rental	0.639**	0.060**	0.248**	0.240**	-2670	0.005	0.889	0.868	0.966	116	0.018	0.085	0.550	0.012	0.103	0.535

TABLE A - CONTINUED

	Estimated values of							Observed data		
Product category	c	sig_e	sig_c	sig_u	Logl	sig_w	$S(rho_k)$	Freq	|Dp|	%up
Energy										
Eurosuper	0.004	0.018	0.003	0.026	183835	0.018	0.912	0.799	0.023	0.560
Perishable food										
Roast-beef	0.225	0.096	0.147	0.196	-100706	0.009	0.742	0.220	0.125	0.570
Lamb	0.257	0.117	0.173	0.300	-45846	0.017	0.925	0.242	0.165	0.560
Rabbit/Game	0.123	0.115	0.100	0.105	-14314	0.023	0.843	0.446	0.155	0.529
Non perishable food										
Rusks and grilled breads	0.217	0.083	0.140	0.222	-7804	0.015	0.854	0.207	0.121	0.579
Flour	0.164	0.067	0.109	0.285	-12644	0.010	0.918	0.227	0.121	0.561
Coffee	0.202	0.087	0.142	0.233	-37938	0.011	0.901	0.252	0.119	0.479
Fruit juices	0.192	0.072	0.123	0.228	-11853	0.011	0.474	0.212	0.129	0.550
Sugar	0.126	0.031	0.075	0.096	-7143	0.005	0.855	0.189	0.047	0.655
Non durable goods										
Men coats	0.317	0.102	0.146	0.405	-2173	0.037	0.745	0.187	0.440	0.503
Men suits	0.333	0.113	0.168	0.355	-1922	0.036	0.709	0.219	0.372	0.494
Children trousers	0.467	0.138	0.247	0.356	-5849	0.037	0.652	0.175	0.400	0.495
Blankets and coverlets	0.392	0.105	0.200	0.569	-6685	0.028	0.645	0.135	0.393	0.572
Blank tapes and disks	0.272	0.084	0.167	0.309	-12802	0.014	0.956	0.195	0.173	0.483
Flowers	0.167	0.086	0.121	0.398	-4269	0.020	0.009	0.269	0.194	0.519
Babies apparel	0.324	0.078	0.176	0.334	-2970	0.031	0.103	0.148	0.334	0.586
Men socks	0.521	0.102	0.251	0.399	-3021	0.042	0.269	0.113	0.339	0.555
Car tyres	0.176	0.070	0.122	0.229	-17631	0.013	0.948	0.255	0.111	0.521
Durable goods										
box-mattress	0.259	0.104	0.148	0.412	-3811	0.028	0.560	0.239	0.249	0.547
Washing machine	0.208	0.049	0.113	0.231	-3913	0.016	0.705	0.164	0.135	0.467
Vacuum-cleaner	0.362	0.083	0.190	0.431	-5255	0.025	0.810	0.145	0.247	0.476
Electrical tools	0.327	0.069	0.178	0.436	-5529	0.025	0.817	0.132	0.348	0.534
Jewellery	0.373	0.086	0.205	0.325	-16007	0.019	1.045	0.139	0.215	0.505

TABLE B - ESTIMATION RESULTS - FRANCE

Product category	c	sig_e	sig_c	sig_u	Logl	sig_w	$S(rho_k)$	Freq	|Dp|	%up
Energy										
Eurosuper	0.004	0.018	0.003	0.026	183835	0.018	0.912	0.799	0.023	0.560
Perishable food										
Roast-beef	0.225	0.096	0.147	0.196	-100706	0.009	0.742	0.220	0.125	0.570
Lamb	0.257	0.117	0.173	0.300	-45846	0.017	0.925	0.242	0.165	0.560
Rabbit/Game	0.123	0.115	0.100	0.105	-14314	0.023	0.843	0.446	0.155	0.529
Non perishable food										
Rusks and grilled breads	0.217	0.083	0.140	0.222	-7804	0.015	0.854	0.207	0.121	0.579
Flour	0.164	0.067	0.109	0.285	-12644	0.010	0.918	0.227	0.121	0.561
Coffee	0.202	0.087	0.142	0.233	-37938	0.011	0.901	0.252	0.119	0.479
Fruit juices	0.192	0.072	0.123	0.228	-11853	0.011	0.474	0.212	0.129	0.550
Sugar	0.126	0.031	0.075	0.096	-7143	0.005	0.855	0.189	0.047	0.655
Non durable goods										
Men coats	0.317	0.102	0.146	0.405	-2173	0.037	0.745	0.187	0.440	0.503
Men suits	0.333	0.113	0.168	0.355	-1922	0.036	0.709	0.219	0.372	0.494
Children trousers	0.467	0.138	0.247	0.356	-5849	0.037	0.652	0.175	0.400	0.495
Blankets and coverlets	0.392	0.105	0.200	0.569	-6685	0.028	0.645	0.135	0.393	0.572
Blank tapes and disks	0.272	0.084	0.167	0.309	-12802	0.014	0.956	0.195	0.173	0.483
Flowers	0.167	0.086	0.121	0.398	-4269	0.020	0.009	0.269	0.194	0.519
Babies apparel	0.324	0.078	0.176	0.334	-2970	0.031	0.103	0.148	0.334	0.586
Men socks	0.521	0.102	0.251	0.399	-3021	0.042	0.269	0.113	0.339	0.555
Car tyres	0.176	0.070	0.122	0.229	-17631	0.013	0.948	0.255	0.111	0.521
Durable goods										
box-mattress	0.259	0.104	0.148	0.412	-3811	0.028	0.560	0.239	0.249	0.547
Washing machine	0.208	0.049	0.113	0.231	-3913	0.016	0.705	0.164	0.135	0.467
Vacuum-cleaner	0.362	0.083	0.190	0.431	-5255	0.025	0.810	0.145	0.247	0.476
Electrical tools	0.327	0.069	0.178	0.436	-5529	0.025	0.817	0.132	0.348	0.534
Jewellery	0.373	0.086	0.205	0.325	-16007	0.019	1.045	0.139	0.215	0.505

TABLE B- ESTIMATION RESULTS - FRANCE

	Estimated values of							Observed data		
Product category	c	sig_e	sig_c	sig_u	Logl	sig_w	$S(rho_k)$	Freq	|Dp|	%up
Services										
Moving services	0.280	0.070	0.162	0.407	-2673	0.040	0.676	0.168	0.224	0.553
cinemas	0.294	0.089	0.175	0.140	-7513	0.031	0.167	0.157	0.101	0.604
monument or museum entrance	1.363	0.486	0.486	0.507	-4899	0.032	0.751	0.055	0.281	0.658
classic lunch in a restaurant	0.203	0.102	0.146	0.228	-174744	0.006	0.936	0.083	0.219	0.688
coffee and hot drinks in bars	0.244	0.038	0.116	0.220	-12013	0.011	0.808	0.083	0.133	0.682
men hairdresser	0.267	0.041	0.128	0.159	-12126	0.010	0.883	0.066	0.086	0.729
sanitation services	0.121	0.032	0.080	0.140	-1990	0.008	0.195	0.196	0.085	0.736

TABLE B - CONTINUED

Product category	stdft	r1	r2	r3	r4	r6	r12
Energy							
Butane	0.153	0.983	0.959	0.937	0.918	0.890	0.801
Gasoline 1000-2000 l	0.263	0.973	0.939	0.905	0.867	0.799	0.501
Eurosuper (RON95)	0.114	0.978	0.954	0.935	0.909	0.855	0.692
Perishable food							
Paprika peppers	0.249	0.685	0.288	0.003	-0.131	-0.440	0.715
Skate (wing)	0.072	0.843	0.815	0.764	0.716	0.649	0.830
Oranges	0.111	0.881	0.660	0.423	0.242	0.081	0.745
Carrots	0.179	0.861	0.626	0.399	0.214	0.059	0.231
Apples : Granny Smith type	0.140	0.885	0.678	0.515	0.404	0.266	0.612
Kiwis	0.172	0.947	0.862	0.763	0.662	0.551	0.820
Margarine (super)	0.024	0.896	0.830	0.779	0.776	0.748	0.500
Turkey filet	0.046	0.893	0.867	0.872	0.860	0.801	0.677
Sirloin	0.020	0.690	0.757	0.705	0.703	0.647	0.565
Cheese (type Gouda)	0.035	0.709	0.789	0.714	0.755	0.705	0.479
Unskimmed fruit yoghurt (150g)	0.023	0.828	0.806	0.769	0.771	0.742	0.685
Dairy butter	0.030	0.889	0.873	0.883	0.872	0.841	0.732
Emmentaler	0.037	0.638	0.651	0.761	0.664	0.657	0.491
Sausage	0.062	0.978	0.963	0.946	0.927	0.891	0.777
Cheese (type Edam)	0.050	0.910	0.918	0.908	0.889	0.896	0.845
Belgian Waffle	0.027	0.526	0.615	0.502	0.515	0.438	0.387
Coarse pâté made with pork	0.063	0.935	0.934	0.936	0.931	0.918	0.884
Rice pudding	0.059	0.852	0.836	0.868	0.864	0.854	0.780
Carré glacé	0.076	0.952	0.940	0.937	0.935	0.914	0.915
Eclair	0.070	0.829	0.827	0.858	0.799	0.814	0.793
Swiss cake	0.054	0.827	0.859	0.852	0.848	0.860	0.790
Grey bread	0.030	0.870	0.866	0.861	0.851	0.827	0.716
Special bread	0.037	0.576	0.639	0.597	0.619	0.596	0.422
Bread roll	0.080	0.969	0.958	0.960	0.952	0.961	0.937
Non perishable food							
Frankfurters	0.035	0.868	0.796	0.767	0.715	0.656	0.333
Biscuits	0.075	0.968	0.947	0.923	0.903	0.870	0.903
Fruit juice	0.043	0.866	0.849	0.821	0.780	0.748	0.633
Fishcakes	0.046	0.785	0.785	0.742	0.732	0.645	0.385
Loire Valley Wine	0.030	0.960	0.962	0.936	0.928	0.892	0.823
Ice cream	0.085	0.950	0.939	0.920	0.902	0.865	0.816
Tinned apricot halves	0.043	0.857	0.847	0.858	0.779	0.765	0.622
Peeled tinned tomatoes - 400 g	0.075	0.937	0.913	0.896	0.890	0.831	0.784
Peas (tinned)	0.062	0.920	0.912	0.905	0.865	0.836	0.715
Tobacco (50 g)	0.077	0.997	0.994	0.990	0.986	0.980	0.969
Sausage	0.061	0.994	0.990	0.984	0.978	0.966	0.909
Lemonade	0.026	0.124	0.211	0.331	0.359	0.344	0.183
Non durable goods							
Roses	0.139	0.665	0.410	0.209	-0.104	-0.548	0.936
Chrysanthemums	0.126	0.784	0.432	-0.015	-0.425	-0.887	0.914
Compact Disc	0.029	0.860	0.827	0.814	0.796	0.797	0.654
Hair spray 400ml	0.024	0.977	0.968	0.949	0.943	0.920	0.841
Catfood	0.028	0.579	0.621	0.577	0.596	0.596	0.395
Nail varnish	0.088	0.978	0.970	0.965	0.960	0.969	0.960
Enamel painting	0.074	0.995	0.989	0.983	0.978	0.967	0.920
Acrylate painting	0.055	0.994	0.990	0.985	0.979	0.970	0.953
Consumption of water	0.080	0.879	0.886	0.890	0.868	0.834	0.811
Engine oil	0.089	0.999	0.998	0.997	0.996	0.994	0.988
Dracaena	0.019	0.969	0.962	0.948	0.946	0.929	0.889
Dry battery	0.130	0.998	0.997	0.995	0.994	0.989	0.977
Woollen suit	0.006	0.880	0.803	0.779	0.745	0.642	0.643
Small anorak (9 month)	0.015	0.958	0.939	0.917	0.899	0.869	0.823
Men socks	0.050	0.998	0.995	0.992	0.989	0.982	0.957
Fabric of dress	0.027	0.993	0.989	0.986	0.981	0.977	0.956
Men T shirt	0.017	0.978	0.948	0.919	0.892	0.847	0.705
Colour film (135-24)	0.005	0.842	0.835	0.772	0.682	0.624	0.530
Zip fastener	0.034	0.968	0.958	0.951	0.941	0.937	0.901

Table C - Statistical properties of the common component $\widehat{f}_t$ - Belgium

Product category	stdft	r1	r2	r3	r4	r6	r12
Durable goods							
Laser Jet Printer	0.060	0.625	0.541	0.485	0.493	0.296	-0.171
4 head VCR	0.177	0.979	0.969	0.964	0.968	0.978	0.974
Compact hi-fi rack	0.126	0.999	0.997	0.996	0.994	0.992	0.988
Natural gas convector	0.092	0.979	0.966	0.961	0.957	0.947	0.949
Calculator	0.053	0.991	0.980	0.971	0.961	0.937	0.864
Toaster 800 W	0.013	0.935	0.866	0.814	0.744	0.611	0.215
Suitcase	0.046	0.964	0.944	0.930	0.914	0.888	0.833
Electric coffee machine 900 W	0.010	0.908	0.837	0.791	0.700	0.589	0.098
Children's bicycle 24''	0.070	0.947	0.922	0.917	0.925	0.916	0.882
Electric fryer	0.017	0.979	0.953	0.928	0.900	0.827	0.585
Dictionary	0.053	0.779	0.594	0.535	0.453	0.303	0.190
Slatted based	0.033	0.815	0.694	0.613	0.643	0.652	0.580
Enameled steel pot	0.034	0.992	0.988	0.981	0.973	0.954	0.896
Hammer	0.069	0.961	0.958	0.943	0.942	0.936	0.916
Glass 4 mm (in sqm)	0.070	0.991	0.984	0.979	0.970	0.942	0.858
Dining room oak furniture	0.098	0.992	0.983	0.971	0.960	0.939	0.891
Spherical glasses	0.022	0.930	0.887	0.800	0.735	0.740	0.642
Wallet	0.069	0.996	0.991	0.985	0.978	0.965	0.938
Torus glasses	0.027	0.771	0.767	0.617	0.532	0.606	0.504
Cup and saucer	0.068	0.996	0.991	0.986	0.980	0.969	0.944
Services	0.057	0.946	0.929	0.917	0.902	0.899	0.877
School boarding fees	0.044	0.975	0.972	0.968	0.964	0.956	0.986
Hourly rate of a painter	0.062	0.981	0.979	0.974	0.969	0.962	0.954
Hourly rate in a garage	0.106	0.999	0.999	0.998	0.998	0.997	0.996
Annual cable subscription	0.029	0.858	0.835	0.779	0.756	0.735	0.674
Central heating repair tariff	0.059	0.995	0.994	0.990	0.987	0.981	0.972
Hourly rate of a plumber	0.057	0.994	0.988	0.984	0.979	0.972	0.961
Passport stamp	1.044	0.959	0.914	0.868	0.821	0.722	0.551
Sole meunière	0.067	0.910	0.903	0.915	0.913	0.890	0.897
Dry cleaning for shirt	0.051	0.996	0.993	0.991	0.989	0.983	0.955
Pepper steak	0.052	0.998	0.996	0.994	0.992	0.988	0.970
Permanent wave	0.072	0.999	0.998	0.997	0.996	0.995	0.993
Domestic services	0.066	0.995	0.994	0.991	0.989	0.986	0.981
Funerals	0.055	0.884	0.881	0.858	0.853	0.892	0.867
School lunch	0.072	0.990	0.984	0.979	0.975	0.972	0.995
Self-service meal	0.025	0.545	0.343	0.289	0.183	0.319	0.402
Parking spot in a garage	0.094	0.997	0.993	0.988	0.982	0.974	0.957
Balancing of wheels	0.026	0.991	0.983	0.974	0.966	0.950	0.932
Special beer (in a bar)	0.069	0.988	0.983	0.984	0.981	0.982	0.967
Aperitive (in a bar)	0.076	0.997	0.995	0.994	0.993	0.990	0.977
Videotape rental	0.011	0.868	0.852	0.823	0.758	0.729	0.547

TABLE C - CONTINUED

Product category	stdft	r1	r2	r3	r4	r6	r12
Energy							
Eurosuper	0.090	0.943	0.890	0.836	0.782	0.680	0.402
Perisable food							
Roast-beef	0.054	0.933	0.871	0.808	0.745	0.647	0.433
Lamb	0.108	0.940	0.880	0.817	0.760	0.628	0.256
Rabbit/Game	0.071	0.902	0.838	0.769	0.712	0.609	0.273
Non perishable food							
Rusks and grilled breads	0.036	0.793	0.707	0.643	0.604	0.481	0.246
Flour	0.054	0.892	0.820	0.760	0.685	0.580	0.333
Coffee	0.055	0.881	0.775	0.658	0.549	0.380	-0,071
Fruit juices	0.034	0.866	0.809	0.753	0.702	0.635	0.454
Sugar	0.060	0,935	0,871	0.807	0.743	0.638	0.383
Non durable goods							
Men coats	0.065	0.096	-0.134	-0.078	-0.255	0.272	0,688
Men suits	0.086	0.227	-0.085	-0.048	-0.104	0.740	0.590
Children trousers	0.112	0.722	0.567	0.554	0.488	0.681	0.528
Blankets and coverlets	0.045	0.190	0.109	0.401	0.168	0.253	0.585
Blank tapes and disks	0.040	0.885	0.877	0.817	0.780	0.683	0.379
Flowers	0.058	0.667	0.350	0.117	-0,068	0.313	0.347
Babies apparel	0.051	0.598	0.642	0.531	0.560	0.422	0.250
Men socks	0.043	0.077	-0,054	0.006	0.116	0.271	0.233
Car tyres	0.053	0,925	0,895	0.854	0.829	0.748	0.569
Durable goods							
box-mattress	0.037	0.172	0.298	0.145	0.212	0.541	0.395
Washing machine	0.035	0.717	0.637	0.577	0.462	0.439	0.287
Vacuum-cleaner	0.032	0.454	0.463	0.460	0.383	0.338	0.254
Electrical tools	0.030	0.403	0.406	0.382	0.375	0.262	0.192
Jewellery	0.031	0.662	0.635	0.549	0.499	0.483	0.387
Services							
Moving services	0.149	0.926	0.870	0.808	0.755	0.692	0.485
cinemas	0.041	0.437	0.322	0.269	0.287	0.241	0.106
monument or museum entrance	0.129	0.919	0.874	0.826	0.769	0.681	0.434
classic lunch in a restaurant	0.025	0.905	0.802	0.697	0.595	0.396	0.106
coffee and hot drinks in bars	0.099	0.927	0.865	0.806	0.753	0.649	0.400
men hairdresser	0.043	0.893	0.814	0.749	0.676	0.568	0.305
sanitation services	0.038	0.460	0.306	0.230	0.192	0.106	0.085

Table D - Statistical properties of the common component $\widehat{f}_t$ - France

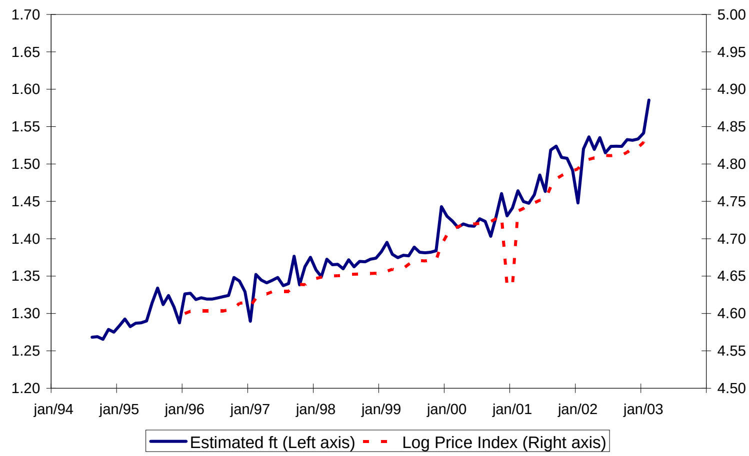

Figure A.1. - Estimated f_t and log price index - Bread roll (Belgium)

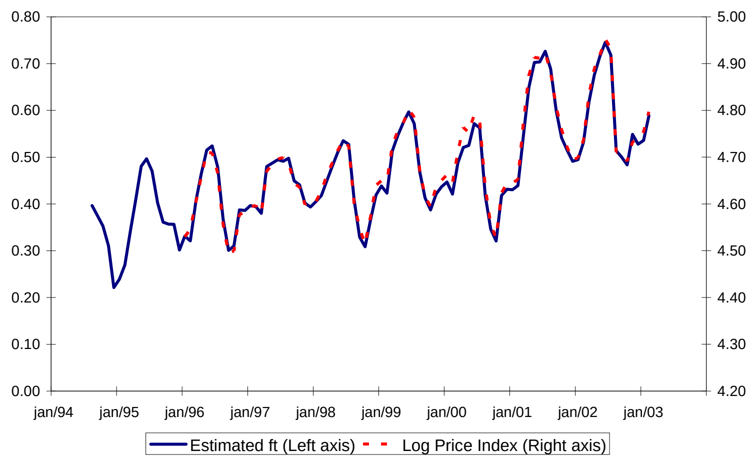

Figure A.2. - Estimated f_t and log price index - Oranges (Belgium)

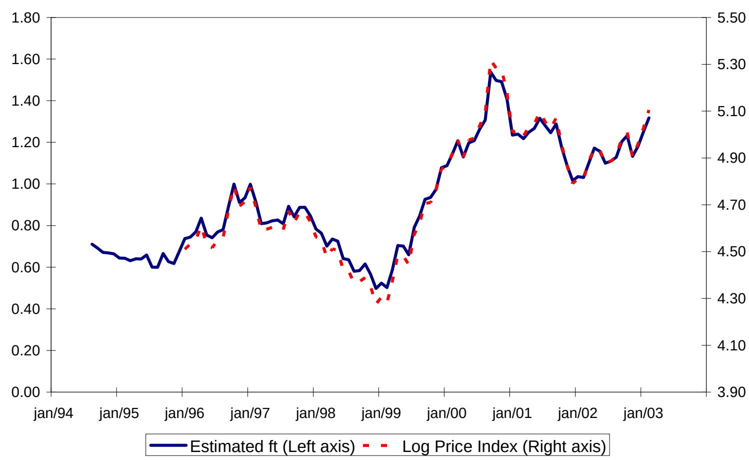

Figure A.3. - Estimated f_t and log price index - Gasoline (Belgium)

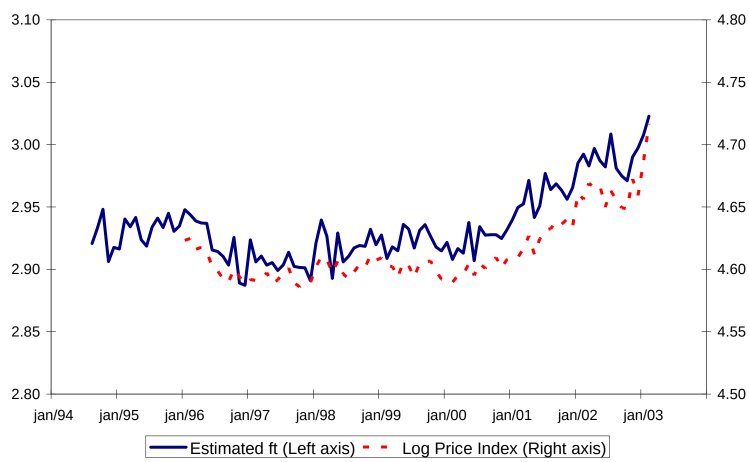

Figure A.4. - Estimated f_t and log price index - Compact Disc (Belgium)

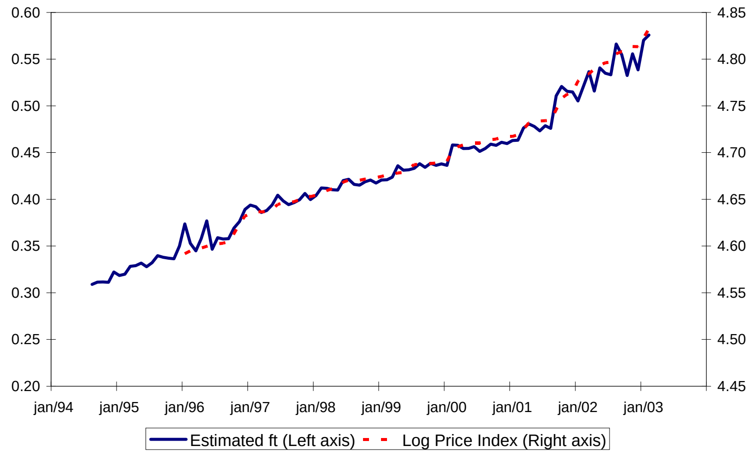

Figure A.5. - Estimated f_t and log price index - Special beer in a bar (Belgium)

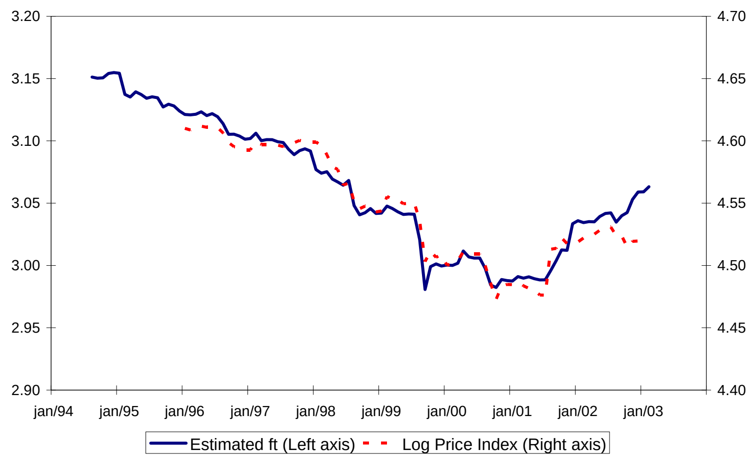

Figure A.6. - Estimated f_t and log price index - Calculator (Belgium)

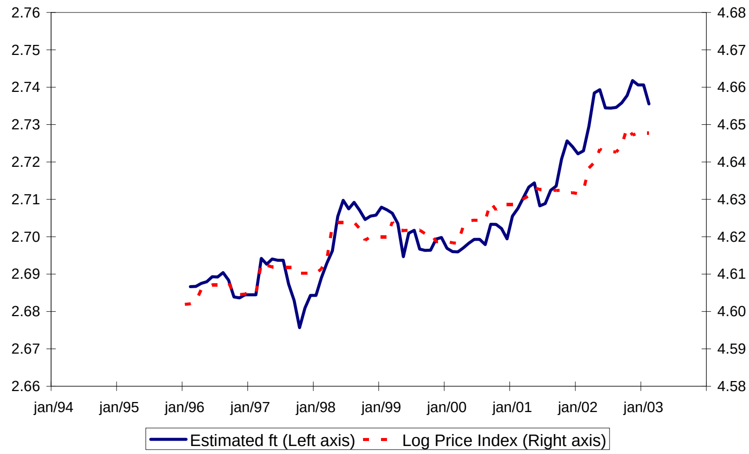

Figure A.7. - Estimated f_t and log price index - Men T-Shirt (Belgium)

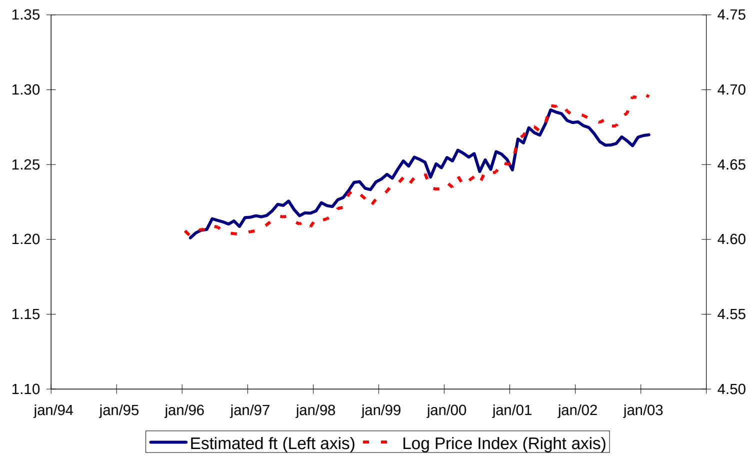

Figure A.8. - Estimated f_t and log price index - Hair spray (Belgium)

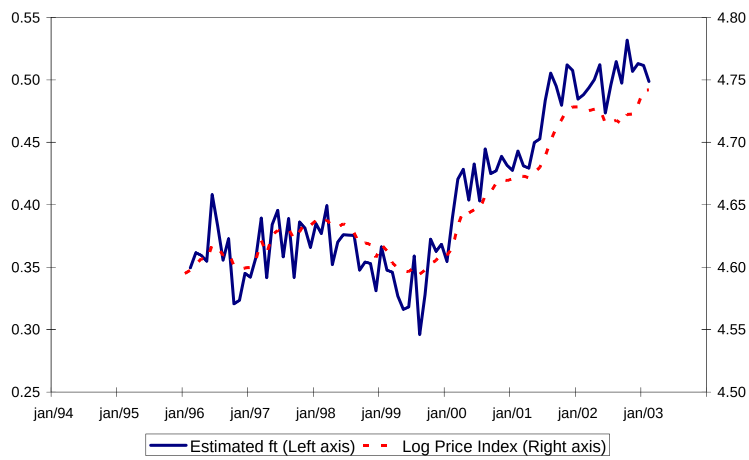

Figure A.9. - Estimated f_t and log price index - Tinned peas (Belgium)

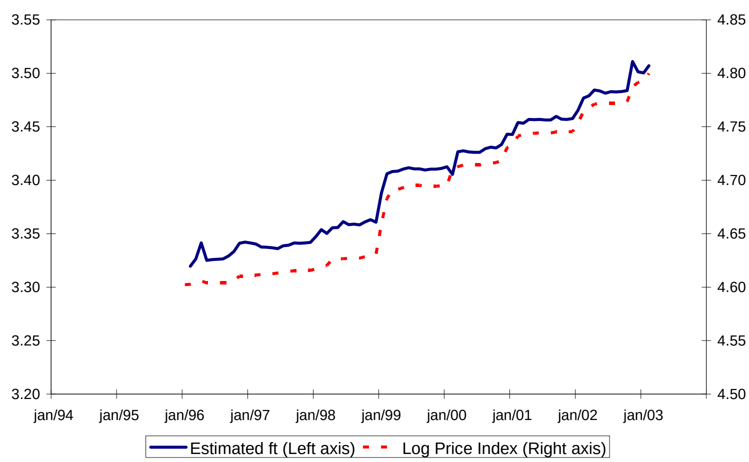

Figure A.10. - Estimated f_t and log price index - Hourly rate of a plumber (Belgium)

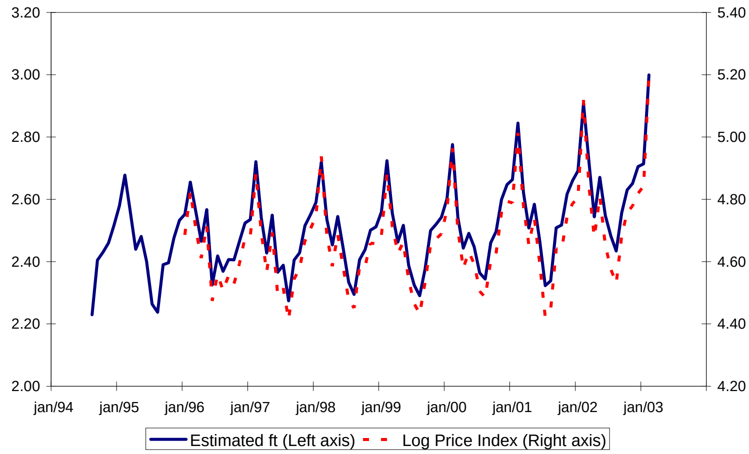

Figure A.11. - Estimated f_t and log price index - Roses (Belgium)

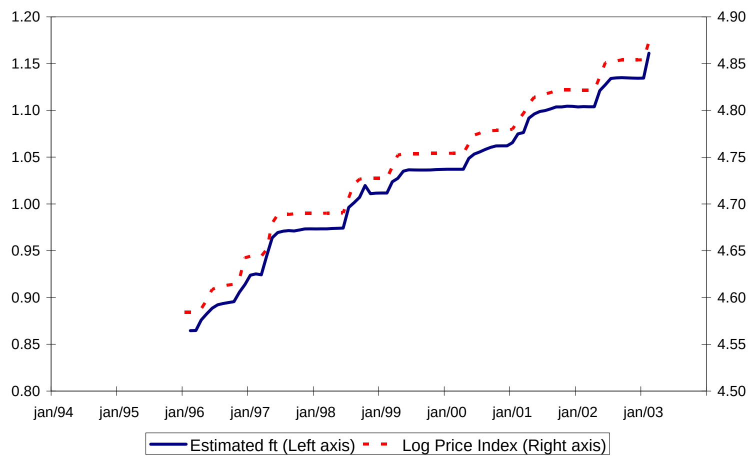

Figure A.12. - Estimated f_t and log price index - Tobacco (Belgium)

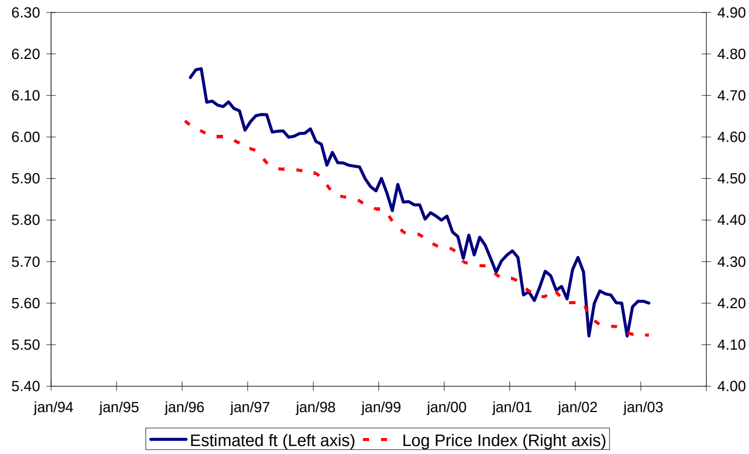

Figure A.13. - Estimated f_t and log price index - 4 head VCR (Belgium)

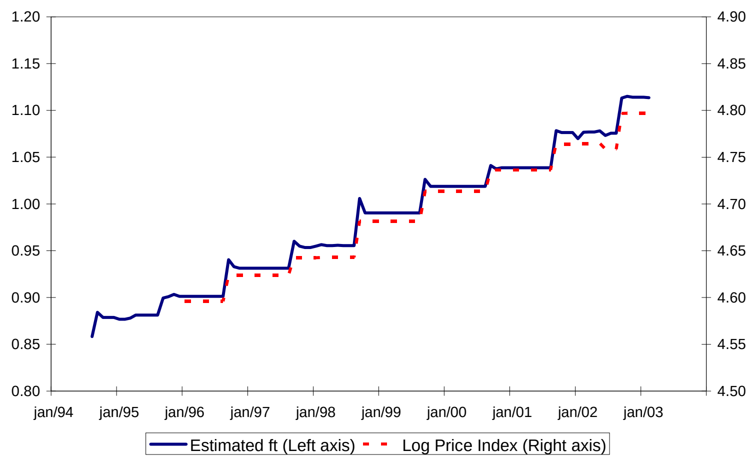

Figure A.14. - Estimated f_t and log price index - School lunch (Belgium)

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