The Timing of Price Changes and the Role of Heterogeneity

Daniel Kaufmann

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The Timing of Price Changes and the Role of Heterogeneity *

Daniel Kaufmann †
Swiss National Bank

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Abstract

While price-setting models usually suggest constant or increasing hazard functions for price changes, empirical studies often find decreasing hazards, possibly due to misspecified or neglected heterogeneity. This paper attempts to disentangle the downward bias into various sources: observed and unobserved heterogeneity which can be either constant or time-varying. Based on micro data from the Swiss CPI, the paper finds that in order to resolve the downward bias of the hazard function for price changes, we have to (i) control for time-varying heterogeneity in addition to cross-sectional factors and (ii) exclude temporary price changes such as sales prices from the data set. Among the time-varying factors affecting the probability of price changes, various proxies of firms' marginal costs seem to be key. The empirical findings presented in this paper are consistent with recent menu cost models which stress the role of time-varying heterogeneity and temporary price cuts for price setting.

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Keywords: price setting, hazard function, downward bias, heterogeneity, sales prices, state-dependent pricing

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†Swiss National Bank, Economic Analysis, P.O. Box, CH-8022 Zurich, Switzerland. Phone: +41 (0)44 631 34 51. E-mail: daniel.kaufmann@snb.ch.

1 Introduction

Price rigidities are at the heart of modern general equilibrium macro models and they have recently found broad empirical support in studies using micro data from the consumer price index. For example, Dhyne et al. (2006) for the euro area, Nakamura and Steinsson (2008) for the US and Kaufmann (2009a) for Switzerland show that prices are adjusted rarely, but when they are adjusted the change tends to be significant. Also, the latter two show that inflation is correlated with the frequency of price changes. This suggests that the timing of price changes differs among firms facing different economic conditions and therefore might change over time.

Modelling the timing of price changes has repeatedly attracted the attention of macroeconomists. The modelling strategies range from assuming simple exogenous rules on the probability of price adjustments to presenting optimising firms which weigh up the cost of a price adjustment against the present value of the benefit. The first class, generally known as time-dependent pricing (TDP), uses exogenous rules for the timing of price changes. Firms are allowed to change their prices randomly (Calvo, 1983) or after fixed intervals (Taylor, 1980). The second class, known as state-dependent pricing (SDP), suggests that firms face fixed or random menu costs when they decide on whether or not to change prices. These menu costs cause them to change their prices infrequently. According to both classes of models, the optimal price may deviate from the current price. Only for SDP, however, will a shock to the optimal price affect the timing and the size of price changes while for TDP this only affects the size. SDP implies that if the gap between the optimal and current price grows sufficiently large, the firm will adjust, since the cost of changing the price is smaller than the overall benefit of the adjustment. This opens the way for incorporating the state of the economy when deciding on the timing of price changes.

While SDP models are more appealing from a conceptual point of view, it is difficult for them to replicate the sluggishness of inflation observed at the aggregate level with reasonably sized menu costs (c.f. e.g. Caplin and Spulber, 1987; Golosov and Lucas, 2007). Caballero and Engel (2007) emphasise that the increase in the extensive margin, that is the number of firms adjusting prices, leads to a faster reaction of aggregate inflation to macroeconomic shocks. They further conclude that models with a negative extensive margin effect promise to replicate sluggish aggregate inflation compared with relatively flexible prices at the firm level. This raises the question of whether this type of price-setting behaviour is found in real-world data and calls for an analysis of the probability that firms adjust prices.

It is useful to describe the extensive margin by the hazard function. In discrete time, the hazard function gives the probability that a price changes after a certain number of periods, conditional on the fact that no price adjustment has occurred before. TDP implies constant hazards or a probability mass at a certain duration while SDP usually implies upward-sloping hazards. An upward-sloping hazard function implies that the probability of a price change increases the longer the price has remained fixed, as the optimal price deviates more and more from the one in use. Surprisingly perhaps, many empirical studies (c.f. e.g. Àlvarez et al., 2005; Lünnemann and Mathä, 2005; Baumgartner et al., 2005; Campbell and Eden, 2005) found downward-sloping hazards at the aggregate level which is counter-intuitive for individual price-setting behaviour and not in line with most of the theoretical literature.

However, theoretical menu cost models do not provide unambiguous predictions for the shape of the hazard function. Nakamura and Steinsson (2008) show that permanent shocks to marginal costs tend to yield upward-sloping hazard functions while idiosyncratic shocks tend to flatten the hazard out. Large idiosyncratic shocks to marginal costs could even yield unambiguously decreasing hazard functions, but the required size of the shocks seems to be too large to be realistic. This suggests that the downward-sloping hazards found in early empirical applications cannot be explained by first generation menu cost models.

There is another explanation why the empirical hazard functions are downward sloping. It is well known from duration analysis that unobserved heterogeneity leads to biased estimates so that the hazards tend to be downward sloping (cf. Lancaster, 1990). The price-setting literature has taken two different paths to resolve this issue. Hazard functions were estimated at a very disaggregate level, having the disadvantage that there often are not enough observations to estimate a hazard rate for every duration in the sample. Other authors attempted to resolve the bias by incorporating a random effect in the hazard model. Although these approaches succeeded in significantly reducing the downward bias, the empirical evidence on the shape of the hazard function remains mixed. For Belgium, Aucremanne and Dhyne (2005) find mildly upward-sloping hazards. For Portugal, Dias et al. (2007) find that the hazard function is roughly constant but varies with the state of the economy at the aggregate level. At a highly disaggregated level, Fougère et al. (2007) argue that the hazards in France are mostly constant. Nakamura and Steinsson (2008) stress that, in a low inflation environment, decreasing hazard functions may well describe the price-setting behaviour at least in some sectors. Even if temporary price changes due to sales are excluded from the analysis, the hazards tend to be downward sloping. Overall, evidence of increasing hazards is scarce, especially for low inflation countries.

As a response to these empirical findings, researchers have developed SDP models that feature alternative shapes for the hazard. Dotsey et al. (2008), for example, are able to generate downward-sloping and flat hazards at the aggregate level even though the individual firm faces an upward-sloping hazard similar to standard menu cost models. The reasoning is related to the explanation of the downward bias in empirical hazards given above. The heterogeneity across firms is explicitly modelled by allowing for idiosyncratic productivity shocks so that firms differ in their likelihood to change their prices. At the aggregate level, these differences lead to constant or downward-sloping hazard functions.[1] Kehoe and Midrigan (2007), on the other hand, present a model with a negative extensive margin effect. They argue that including a motive for temporary price cuts is able to replicate important empirical findings on price-setting behaviour. Since these temporary price cuts are inherently shorter than regular price spells, their theoretical hazard function is higher in the first period.

This paper attempts to disentangle the downward bias of the hazard functions often found in the literature into various sources: observed and unobserved heterogeneity which can be either constant or time-varying. A special focus is put on the impact of sales prices. The hazard functions are estimated based on Swiss consumer price index (CPI) micro data. In this context, it has proved useful to use multiple price spells for each individual product in order to identify the unobserved heterogeneity. However, if one uses multiple price spells, firms, products and the state of the economy are likely to change over time so that accounting only for time-constant heterogeneity is restrictive. The paper argues that this is a major reason why hazard functions tend to be downward-sloping, even when one controls for time-constant unobserved heterogeneity.

The findings suggest that the downward bias of the hazard for regular price changes can be resolved completely by accounting for time-varying heterogeneity. It is shown that macroeconomic and sector-specific factors are important to explain the price-setting behaviour of firms. This implies that even in a low-inflation environment such as Switzerland the state of the economy influences the timing of price changes. However, including sales (temporary price cuts) in the analysis leads to decreasing hazard functions. This is due to the fact that sales prices are usually short-lived. This feature is found to be important for processed food items (which make up roughly 10% of the Swiss CPI in 2007) but not for other sectors.

The economic impact of the time-varying factors is illustrated by calculating the implied mean duration under different assumptions. Changing average inflation of wholesale consumer goods from 0.1% to 0.5% per quarter reduces the mean duration for processed food, industrial product and services prices by at least 2 quarters. For unprocessed food the effect is somewhat smaller. Increasing wage inflation from 0.7% to 2.7% per quarter reduces the mean duration for services by almost 2 quarters. The effect is similar in size for industrial products and processed food.

[1] Note that in such a case just accounting for time-constant unobserved heterogeneity in an empirical model would not resolve the downward-biased hazard function because the heterogeneity varies over time.

Meanwhile, markup erosion due to sectoral inflation seems to be less important, and indexation to the overall price level affects the timing of price changes only in food sectors.

Finally, it is shown that time-varying factors explain additional 30% to 50% of aggregate price stickiness compared to a purely time-dependent pricing model. This seems sizeable for a low inflation environment and supports the relevance of state-dependent pricing.

The remainder of this paper is structured as follows. Section 2 describes the empirical strategy. Section 3 gives some theoretical considerations on price-setting, motivating candidate covariates to be included in the regressions. The data and the results are presented in Section 4 and Section 5 respectively. Section 6 concludes.

2 Econometric approach

The main purpose of this paper is to estimate hazard functions based on Swiss CPI micro data. A hazard function gives the probability that a price changes conditional on the time that has elapsed since the price was last changed. The hazard function is modelled in discrete time using a multiple-spell version of the Prentice-Gloeckler-Meyer model (Prentice and Gloeckler, 1978; Meyer, 1990). Thus we can specify the hazard as

$$h_{ij}(t|v_i) \quad = \quad 1 - \exp\left(-v_i \exp(\mathbf{x}_{ijt}\mathbf{b} + \lambda_t)\right) \quad , \tag{1}$$

where v_i is a random variable capturing unobserved heterogeneity at the level of individual products which is assumed to follow a log-normal distribution ($v_i = \exp(u_i),\ u_i \sim N(0, \sigma_u^2)$) while t indexes the duration since the last price adjustment, i individual products, and j the price spells of the individual products. In addition, $\mathbf{x}_{ijt}$ denotes a vector of (time-varying) covariates (TVC) and λ_t captures the piecewise-constant baseline hazard over the interval $[t,\ t+1)$ which is assumed to be common for all individual products and usually modelled by dummy variables for every duration in the sample. The covariates and $\log(v_i)$ shift the hazard function proportionally up and down. Note that, in order to obtain an estimate of the hazard function, one has to assume a value for all covariates and for the unobserved heterogeneity term v_i (usually the mean which is normalised to unity).

The random effect is included in the hazard specification because neglected heterogeneity leads to biased estimates. If firms and products are not homogeneous but differ with respect to unobserved factors, estimated hazard functions tend to be downward-sloping. There is a selection effect because the share of individuals with lower intrinsical probability to fail increases as one uses longer durations for estimating the hazard function (cf. Lancaster, 1990). This is illustrated in Figure 1. Panel (a) gives the individual hazard functions for two groups of firms. While both hazard functions are constant for simplicity, group 1 has a lower probability of price changes than group 2. Panel (b) displays the corresponding individual survivor functions which describe the probability that a price remains unchanged for a certain number of periods. We can see that there are fewer high probability firms in the sample at longer durations (group 2 $<$ group 1), implying that high probability firms are becoming more and more underrepresented in the sample at higher durations. The effect on the population hazard is displayed in panel (c). While the population hazard lies between the hazards of the two groups, it decreases in t and converges to the hazard of group 1, implying that the number of high-probability firms (group 2) converges faster to zero than the number of low probability firms (group 1). If the time-constant unobserved heterogeneity is appropriately controlled for in the example above, the downward bias disappears. If the heterogeneity is observed, we would estimate separate hazard functions for the two groups or add a control variable to the regression. Unobserved heterogeneity, on the other hand, is usually modelled by including a time-constant random effect. Using multiple price spells of each individual product helps to identify the random effect.

It is central to note that the unobserved heterogeneity is assumed to be constant across time and consequently across spells j of individual i. If there is neglected time-varying heterogeneity, one would expect a downward bias similar to neglected time-constant heterogeneity. To control for time-varying heterogeneity, we include TVC which are likely to affect the timing of price changes of a firm. If the TVC influence the price-setting behaviour, including such TVC and evaluating the hazard function at reasonable values of these variables should further reduce the downward bias.

In order to formalise the likelihood contribution and estimate the parameters, it is convenient to use the survivor function which is directly linked to the hazard function. The survivor function can be written as

$$\begin{aligned} S_{ij}(t|v_i) &= \prod_{\ell=1}^{t} 1 - h_{ij}(t|v_i) \\ &= \exp\left(-v_i \sum_{\ell=1}^{t} \exp(\mathbf{x}_{ij\ell}\mathbf{b} + \lambda_\ell)\right) \quad . \end{aligned} \tag{2}$$

Thus, the conditional likelihood contribution for individual product i is

$$L_i|v_i = \prod_{j\in\{\delta_{ij}=1\}} S(K_{ij}-1|v_i) - S(K_{ij}|v_i) \prod_{j\in\{\delta_{ij}=0\}} S(K_{ij}|v_i) \quad . \tag{3}$$

The first product of the likelihood contribution contains all non-censored spells and consequently the terms give the probability that a price spell j of price series i ends at duration K_{ij}. The second product contains all right-censored spells so that the terms give the probability of an unchanged price at duration K_{ij}. Right-censored spells imply that no price adjustment takes place during the time we observe a price. K_{ij} denotes the minimum of the spell duration and the censoring duration while δ_{ij} is a dummy variable which equals 1 if a spell is non-censored. The likelihood contribution is conditioned on the unobserved heterogeneity term v_i. Since we assume a log-normal distribution for the random effect, the parameters can be estimated by standard binary-response random-effects estimation procedures (cf. Jenkins, 2004). For robustness checks, other distributions can be assumed for the unobserved heterogeneity. However, the likelihood function is more complicated and estimation requires non-standard procedures (cf. Kaufmann, 2009b).

In order to test whether the time-constant unobserved heterogeneity is present in the data, it is useful to derive the likelihood contribution for $\sigma^2 \to 0$ (that is, when the variance of the unobserved heterogeneity term tends to zero). As a result, $v_i \to 1$ (that is, the unobserved heterogeneity term converges to a constant, here the mean which is normalised to unity). In this case, the conditional likelihood function is equal to the unconditional likelihood function:

$$\lim_{\sigma^2 \to 0} L_i | v_i \quad = \quad L_i \quad = \prod_{j \in \{\delta_{ij}=1\}} S(K_{ij}-1) - S(K_{ij}) \prod_{j \in \{\delta_{ij}=0\}} S(K_{ij}) \quad . \tag{4}$$

It appears that the restricted model is simply the standard complementary log-log model applied to a reorganised data set (cf. Allison, 1982; Jenkins, 1995). The null hypothesis of the likelihood-ratio test reads H_0: $\sigma^2 = 0$. The test statistic then is constructed as

$$\xi \quad = \quad 2 \cdot \left[\ell(\hat{\sigma}^2) - \ell(0) \right] \quad , \tag{5}$$

where $\ell(0)$ is the log-likelihood value of the restricted model, and $\ell(\hat{\sigma}^2)$ is the log-likelihood value of the unrestricted model. Because the variance is bounded at zero and we are testing against this boundary, the test statistic has not an asymptotic χ^2 distribution with one degree of freedom but instead is a 50:50 mixture of a χ^2 with no degrees of freedom (i.e., a point mass at zero) and a χ^2 with 1 degree of freedom (cf. Gutierrez et al., 2001).

3 Price-setting in theory

The model presented in the previous section makes it possible to control for time-varying covariates and theory suggests that they affect the timing of price changes. This section motivates some candidate measures which can be included in the regressions. A general result for menu cost models is that the probability of a price change depends on the gap between the optimal price and the current price. If this gap becomes sufficiently large, the benefit of a price adjustment is larger than the menu costs and thus the firm adjusts its price. Ideally, one would use the difference of the value function evaluated at the optimal price and the current price as implied by Dotsey et al. (1999). However, the value function depends on the profit function and on all expected future states. As the value function and firms' expectations are unobserved, this model is difficult to replicate empirically.

The empirical model allows for every firm to have an individual, time-constant adjustment threshold (modelled by the random effect). This is in line with standard menu-cost models of the Ss-type where the adjustment rule simply states that the firm resets the price if the gap between the optimal price and the current one gets sufficiently large (c.f. Caplin and Spulber, 1987; Caballero and Engel, 2007). The optimal price, in turn, is defined as the price the firm would choose, conditional on the current state of the economy given zero adjustment costs, i.e. the optimal price under fully flexible prices.

Under the assumption that a (monopolistically competitive) firm has zero adjustment costs, its optimal price ($p_t^\star$) is a constant markup over current nominal marginal costs:

$$p_t^\star = \mu + \psi_t \quad , \tag{6}$$

where μ is the firm's desired markup and ψ_t are the firms' nominal marginal cost. As in the previous section, t denotes the time that has elapsed since the last price change, and small letters denote logarithms. To describe nominal marginal costs, let us assume a retail firm that buys products from wholesalers in order to resell them to its retail customers.[2] The retail goods are produced according to the production function

$$Y_t = A_t K_t^a N_t^b Q_t^c \quad , \tag{7}$$

where A_t denotes technology, K_t are capital services, N_t is labour input, Q_t is the quantity of wholesale input, and Y_t denotes real retail sales to the firm's customers. The marginal product of

[2] The derivation follows Galí and Gertler (1999) and Leith and Malley (2007).

wholesale input (MPQ_t) is given by

$$MPQ_t = \frac{Y_t}{Q_t} \cdot c \quad . \tag{8}$$

Let us define the wholesale price as $\tilde{P}_t$ and the retail price as P_t. If factor markets are complete, then real marginal costs can be written as

$$\begin{aligned} MC_t &= \frac{\tilde{P}_t}{P_t MPQ_t} \\ &= \frac{\tilde{P}_t Q_t}{P_t Y_t} \cdot \frac{1}{c} \quad . \end{aligned} \tag{9}$$

and, taking logs, as

$$mc_t \quad = \quad \tilde{p}_t - p_t + q_t - y_t - \log(c) \quad . \tag{10}$$

Moving p_t to the left-hand side and taking first differences gives

$$\Delta\psi_t \quad = \quad \Delta\tilde{p}_t + \Delta q_t - \Delta y_t \quad , \tag{11}$$

where $\Delta\tilde{p}_t + \Delta q_t$ denotes the log difference of nominal wholesale sales to the firm – decomposed into price and quantity – and Δy_t denotes the log difference of real retail output. Assuming that q_t and y_t move proportionally so that firms hold a constant amount of inventories, one can approximate nominal marginal costs by wholesale prices. A similar argument can be made for labour input. As a result, nominal marginal costs can alternatively be approximated by wages.

What is left to show is how to construct the measure of the gap between the optimal and current price. Let the price set at the beginning of the price spell be denoted by p_0. In the first period, it is assumed that p_0 coincides with the optimal price such that $p_0^\star = p_0 = \mu + \psi_0$. Since μ and p_0 are constant for all t, the change in nominal marginal cost accumulated since the last price adjustment gives the gap between the optimal price after t periods and p_0:

$$p_t^\star - p_0 \quad = \quad \sum_{\ell=1}^{t} \Delta\psi_\ell \quad . \tag{12}$$

Recall that the Ss-rule states that a firm adjusts its price if this gap crosses some threshold. The conditional probability of price changes is therefore a function of this gap: $h(p_t^\star - p_0)$. The econometric model proposed in Section 2 assumes that this function is that of a discrete-time proportional hazard model. That is, the gap between optimal and current price shifts the probability of price changes proportionally up and down.

4 Data

This paper analyses price spells based on micro data from the Swiss CPI. The data was collected by the Swiss Federal Statistical Office (FSO).[3] Basically, the data set contains price series of individual products, where an individual product is defined as a good or service of the same quantity and quality at a particular outlet. A full description of the CPI data is given in Kaufmann (2009a).

The remainder of this section starts by presenting various sampling restrictions. These restrictions, by accounting for some cross-sectional and time-varying heterogeneity *a priori*, should help to reduce the downward bias of the hazard functions. Then, the aggregate control variables motivated by economic theory are introduced. Finally, some descriptive statistics of the micro data and the control variables are presented.

4.1 Sampling decisions on CPI micro data

The baseline shape of the hazard function is assumed to be common for all individual products. To relax this assumption the sample is split up into four sectors for which separate regressions are run: processed food, unprocessed food, industrial products and services. Energy prices are excluded from the analysis because either they are almost perfectly flexible on a quarterly basis (fuel) or they are administered (electricity).

In order to reduce some time-varying heterogeneity, only data from the years 2000 to 2007 are used. Another reason to focus on this period is that there were major methodological revisions in the data collection process in 2000 (cf. FSO, 2000). Most importantly, end-of-season sales prices began to be collected after the revision, and the collection frequency of many CPI items was raised to quarterly or monthly intervals.

The model uses multiple spell data for each individual product to identify unobserved factors. However, the investigation is limited to five adjoining price spells which are randomly chosen from each individual price series. This should reduce time-varying heterogeneity because the further apart the price spells are situated the more likely potentially important time-varying factors will be missed. In addition, the resulting data set is somewhat more tractable and estimation time is reduced. There is a trade-off between using more spells and obtaining more precise estimates, on the one hand, and reducing time-varying heterogeneity, on the other. Using only one spell per individual product would reduce the time-varying heterogeneity the most. However, the random

[3]Source: FSO; data collection for the Swiss CPI 1993–2007.

effect is hardly identified in this case. Therefore, a middle route is taken by using only five spells for each individual product so that the estimates are reasonably precise and there are no convergence problems when estimating the coefficients.

Sales prices are expected to differ from regular price changes so that they reflect a special form of time-varying heterogeneity of the firm. Therefore, the investigation uses two different samples to analyse the influence of sales prices, one that excludes sales prices, and one that includes them. In the first sample, price spells labelled by the FSO as sales are dropped. These include temporary price cuts as well as end-of-season sales. In addition, v-shaped sales prices, defined as prices which fall only for one period and then return to their original values, are discarded in line with the bulk of the literature on price-setting. Finally, price spells prior to sales are discarded because they are likely to be shorter than regular price spells and mirror the actual decision of incorporating a sales price.[4]

Although the CPI is calculated on a monthly basis, a majority of prices is collected quarterly only. Therefore, this study is based on quarterly data. For prices collected monthly, the month within the quarter is chosen randomly. All price series collected less often than quarterly are discarded.

When the FSO starts collecting prices of a new product or a product has been replaced by a close substitute, the first price spell is left-censored. That is, the exact start date of the spell is unknown. In line with the literature on price-setting behaviour, such spells are discarded from the sample. Right-censored spells are included in the analysis. These are spells with unknown end dates, resulting from product turnover or at the end of the sample.

4.2 Control variables

The discussion in Section 3 suggests that the timing of price adjustments depends crucially on costs. Since it is uncertain which input factors are most important for firms, two different candidates are included: wholesale prices of consumer goods and wages.[5]

Because aggregate wholesale prices and wages are only rough and certainly imperfect approximations of nominal marginal costs, alternative proxies are considered. Dias et al. (2007) include accumulated sectoral inflation rates because higher sectoral prices lead *ceteris paribus* to higher nominal marginal costs and thus to an erosion of the markup with the current price kept fixed. Our sample therefore includes inflation rates at two different levels of disaggregation.

[4]Some authors suggest evening out temporary price cuts by replacing the sales price by the regular price observed in the previous period (cf. e.g. Nakamura and Steinsson, 2008; Kaufmann, 2009a). This implies a narrower definition of sales than the one described above.

[5]The wholesale price index is a combination of the Swiss producer and import price indices. The FSO terminology defines it as the price index of total supply.

In addition, total CPI inflation is included. The literature suggests that firms might choose to link their prices partly to the overall price level because it may be easier to use a rule of thumb than to reoptimise a price (cf. e.g. Dennis, 2008, for a model which encompasses several variants of indexation). This implies that the probability of a price change might increase with higher CPI or sectoral inflation.

The analysis includes the following specification of the regressors:[6]

$$\mathbf{x}_{ijt} \quad = \quad \left[\Sigma\pi_{ijt} \quad \Sigma\pi_{ijt}^{sub} \quad \Sigma\pi_{ijt}^{eii} \quad \Sigma\Delta\tilde{p}_{ijt} \quad \Sigma\Delta w_{ijt} \quad \boldsymbol{\theta}_i \quad \boldsymbol{\tau}_{ijt} \quad \mathbf{Sale}_{ij}\right] \tag{13}$$

where π_{ijt} is q/q CPI inflation, π_{ijt}^{sub} and π_{ijt}^{eii} denote q/q inflation rates at the subsector and elementary index item level, $\Delta\tilde{p}_{ijt}$ is the q/q rate of change in consumer goods prices at the wholesale stage, and Δw_{ijt} is the q/q rate of change in wages.[7] All TVC are measured in absolute percentage changes and are accumulated from the beginning of the spell, as indicated by the sum, Σ. The subscripts highlight the fact that the covariates can differ across individual products i, spells j, and time t, where the latter denotes the duration of the price spell (not the actual time the spell was recorded). In addition, $\boldsymbol{\theta}_i$ is a vector of time-constant product and firm-specific dummies for the outlet size and for the origin (domestically produced versus imported). $\boldsymbol{\tau}_{ijt}$ denotes yearly dummies, seasonal dummies for every quarter and a dummy for a VAT change in the first quarter of 2001. Finally, for the samples that include sales prices, some specifications include spell-specific sales dummy variables ($\mathbf{Sale}_{ij}$) which are described in detail in Table 1.

4.3 Descriptive statistics

Tables 7 and 8 display some descriptive statistics of the data sets. It is interesting to see that the average accumulated price erosion due to disaggregated inflation ($\Sigma\pi_t^{sub}, \Sigma\pi_t^{eii}$) is largest for unprocessed food, the category with the lowest average duration (Table 7). Moreover, for processed food items, which change only rarely, the accumulated inflation in the subsectors is relatively low. This indicates that higher markup erosion may lead to faster price adjustments. As the other TVC are not available at a disaggregated level, a higher average price duration is by construction associated with higher average accumulated TVC across sectors.

Inflation was very low in Switzerland in the sampling period. Average absolute accumulated inflation over a price spell was 1.1% or lower in the sector samples. Accumulated wholesale price inflation of consumer goods was even lower for an average price spell (below 0.6% in the various sector samples). Wages actually changed most over an average price spell. For processed food,

[6] For more information on the definition, transformation and source of the data cf. Tables 1 and 2.

[7] The definition of subsectors and elementary index items are given in Tables 3 to 6.

average accumulated wage inflation amounted to 3.2% while in the other sector samples the real price erosion due to wage inflation amounted to 2.3% to 2.8%, on average.

Table 8 shows that sales prices are common for processed food, unprocessed food and industrial products. In each category about 5% of all observations are considered sales according to the FSO definition ($Sale^{FSO}$). Temporary price cuts ($Sale^{V}$), on the other hand, are more common in the food sectors than for industrial products. The share of sales prices is lowest for services.

5 Results

The results are presented for various specifications in order to show which kind of heterogeneity distorts the hazard functions most. Six different specifications are estimated. First, unobserved and observed heterogeneity are ignored. Next, a random effect is added to the regressions to account for unobserved heterogeneity. Then, the effect of observed heterogeneity is examined by adding time-constant and time-varying covariates to the regressions. Finally, the model is estimated with and without sales-specific dummy variables on the sample including sales prices. The estimation results are given in Tables 9 to 14.[8] As the benchmark case, and for the sake of comparability with Nakamura and Steinsson (2008), the focus is on the processed food sector, while results for other sectors are discussed when they differ. The section ends with an assessment of the relevance of state-dependent pricing.

The baseline hazard specification (λ_t) is a set of dummy variables up to 14 quarters and a dummy for durations that are larger than 14 quarters. The 14 dummies capture over 95% of all spell durations in the various samples. The control group for which the baseline hazard is calculated is one where all dummy variables are set to zero except the hazard dummies which are set to 1 at the corresponding duration. When the specifications contain TVC, they are set to their mean value observed in the estimation period and then accumulated in order to calculate the hazard function. The hazard is evaluated at the mean of the unobserved heterogeneity term which is normalised to unity. 95% confidence intervals are given for the baseline hazard functions in graphical representations. They are based on the delta method (cf. Kaufmann, 2009c).

5.1 The role of cross-sectional heterogeneity

Panel (a) in Figure 2 displays the estimated hazard for processed food when sales prices are excluded and neither unobserved nor observed heterogeneity is controlled for.[9] The figure suggests

[8]Note that only the sign but not the magnitude of the reported coefficients can be interpreted as marginal effects (cf. Kaufmann, 2009c).

[9]The regression results are given in Table 9.

that the hazard is clearly downward sloping. The hazard amounts to 0.16 at one quarter and then gradually falls to 0.09 after 14 quarters.

Panel (b) shows the results for the specification with a random effect added to the regression. The downward bias is clearly reduced but not resolved.[10] Between one and 14 quarters the hazard still decreases from 0.14 to 0.11. Based on the confidence intervals one would clearly reject the hypothesis that the hazard is constant or upward sloping. A more formal test whether unobserved firm and product-specific factors influence price setting is a likelihood-ratio test for the null hypothesis that the variance of the unobserved heterogeneity term is zero. Table 10 gives the likelihood-ratio test statistics (LR: $\sigma^2 = 0$) and the corresponding p-value. Clearly, the variance of the unobserved heterogeneity term is significantly different from zero. This shows that firm or product-specific cross-sectional differences are important in describing firms' price-setting behaviour.

In panel (c) observed cross-sectional information is included in the regressions.[11] This is done by adding dummy variables for product origin, outlet size, VAT changes, yearly and seasonal factors (cf. Table 1 for the exact definition). Although yearly, seasonal and VAT dummies are TVC in principle, they are included in this specification since they are all set to zero when evaluating the hazard. The results show that the shape of the hazard hardly changes from panel (b) to panel (c). It falls even more strongly from 0.13 to 0.08. Therefore, the downward-sloping pattern does not seem to be caused by misspecified cross-sectional heterogeneity.

Some further insights on price-setting are obtained from the estimated parameters given in Table 11. In particular, firm size seems to play an important role. Generally, large firms change prices more often than medium-sized and small ones. This does not hold for all sectors, however. For services, small suppliers change their prices most often, followed by large firms and medium-sized firms. One reason may be that among service firms, there are many small outlets selling food-related products (such as take-away food). As food prices are very volatile, small firms change prices relatively often in the service sector. These results corroborate the findings in Kaufmann (2009a).

The results summarised in Table 11 also suggest that it might be relevant in a small open economy model to distinguish between domestic and international firms and price-setters. The regressions include a dummy variable if more than 75% of a CPI index item contains foreign goods. Foreign goods prices are more likely to change than domestic ones in most sectors. An exception is unprocessed food, where prices of domestically produced goods prices are more likely

[10] The regression results are given in Table 10.
[11] The regression results are given in Table 11.

to change than imported goods.

5.2 The role of time-varying heterogeneity

Modern price-setting theories suggest that firms change their behaviour as the state of the economy changes. This implies that time-varying factors influence the price-setting behaviour and the shape of the hazard. The set of time-varying factors considered includes inflation at different levels of aggregation, and two measures of cost pressure. For all three factors, a time path must be assumed in order to calculate the hazard function. In this paper, all variables are set to the average q/q rate of change which is accumulated over a typical price spell in the sample. Thus the hazard functions reflect a situation which can be interpreted as the equilibrium implied by the estimated model. The assumptions for the TVC are obtained by calculating the average q/q change in the sample.[12]

The specification used in this section differs from some contributions to the literature in that accumulated time-varying factors are included in the regressions. The hazards are computed at reasonable TVC values, which is important because setting the TVC to zero would result in strongly downward or upward-sloping hazards, depending on the sign of the coefficient on the accumulated covariates. The hazard function is conditioned on the time-varying covariates as well as on other information. In this sense, the hazard function is a mixture between the part explained by the time-varying covariates (which is potentially upward sloping), the remaining covariates (which only affect the level of the hazard) and the baseline hazard itself (where the shape is completely unrestricted). The shape of the hazard function can be affected by the time-varying covariates only because they have accumulated since the beginning of the price spell. Therefore, a positive coefficient and a positive average trend growth rate increase the slope of the hazard function.

On an intuitive basis, the reason why neglecting time-varying heterogeneity may lead to a downward bias of the hazard function is the following. A typical menu cost model predicts that a firm selling an individual product takes into account the state of the economy when readjusting prices. In the extreme case where there are no shocks and trend inflation is at zero, a firm does not adjust the price at all. Suppose that two years later trend inflation is at 2%. A standard menu cost model then predicts that the probability of a price adjustment is indeed positive. This simple example shows that the probability of price adjustment may not only differ across products but also – for each individual product – over time. The problem is related to the number of price spells we use for each individual product. Restricting the analysis to one spell for each individual product

[12] The assumption can be roughly obtained by dividing the average accumulated rate of change by the average duration of a price spell given in Tables 7 and 8.

(cf. e.g. Dias et al., 2007) would resolve the issue. However, the random effect is hardly identified in this case, which leads to serious convergence problems. If we use more than one price spell for each firm, then the state of the economy is likely to change over time. That is, we may observe price spells generated conditional on low and high inflation, for example. The hazard model, however, only accounts for time-constant heterogeneity. If time-varying heterogeneity is neglected, this leads to the same downward bias as neglecting time-constant unobserved heterogeneity, because the hazard functions are estimated over periods characterised by changes in the state of the economy.

Panel (a) in Figure 3 shows that the downward bias of the hazard is resolved completely in the processed food sector.[13] Only at quarters 5 to 7 is the hazard somewhat lower on average than for other quarters. Thus, the data rejects decreasing hazard rates for regular price changes if time-varying factors are controlled for.

As an experiment, one can evaluate a situation where firms face higher trend values for the covariates. Calculating the hazards for a specification with doubled trend values of the TVC gives the results displayed in panel (b) of Figure 3. The hazard is strongly increasing, which indicates that the effect is economically large.

Non-decreasing hazard functions for regular price changes in the processed food sector are probably the most common case if firms expect the price level or costs to follow their long-run trends. Moreover the shape of the hazard function clearly depends on the state of the economy. The Swiss economy experienced a period of very low CPI and wholesale inflation from 2000 to 2007. Both averaged 0.26% q/q during that period. Consistent with this stable environment, the estimated hazard is roughly constant. As the simulation shows, hazards could be steeper in economies with higher inflation rates.

The estimates for the other sectors reveal similar results (cf. Figures 4 to 9). However, the baseline hazards differ somewhat from one sector to another. At the mean values of the TVC, all hazards are clearly non-decreasing. For all sectors except services, one has to control for TVC in order to resolve the downward bias of the hazard function. Abstracting from the spikes at 4, 8 and 12 quarters, a constant hazard cannot be rejected for services (Figure 9 a). The estimated hazards increase somewhat for unprocessed food (Figure 5 a) and, to a smaller extent, for industrial products (Figure 7 a). Even at very moderate rates of inflation and cost pressure, firms are more likely to change prices the longer a price has remained constant in these sectors.

Even after controlling for seasonal effects at the sector level, the hazards for services, unprocessed food and industrial products exhibit significant peaks at durations of 4, 8 and 12

[13] The regression results are given in Table 12. Note that a positive coefficient on the accumulated time-varying covariates implies a more upward-sloping hazard because average trend growth rate is positive for all time-varying covariates included.

quarters. This means that the seasonality is not homogeneous at the sector level and it is an indication that some firms have fixed patterns of price setting, changing their prices every one, two or three years. Interestingly, this pattern is much weaker in processed food prices than in prices for industrial products or services. The significance of the seasonal dummies in the regressions (cf. Table 12) and the distinctive pattern of the hazards are an indication of price setting consistent with Taylor (1980).

5.3 The role of sales prices

Panel (a) in Figure 10 displays the hazard function estimated for processed food from the sample including sales prices.[14] The hazard function is clearly downward-sloping. For the first one or two quarters the hazard is significantly higher than for subsequent quarters. Once spell-specific dummies are added for sales prices, the downward-sloping pattern disappears (panel b).[15]

Figure 11 displays the hazard functions for five different specifications, each including one of the dummies $Sale^{eofs}$, $Sale^{FSOV}$, $Sale^{other}$, $Sale^{pre}$, and $Sale^{V}$, which denote end-of-season sales, v-shaped sales as reported by the FSO, other sales identified by the FSO, v-shaped sales according to the author's calculations, and price spells preceding sales prices (cf. Table 1 for the exact definition).[16] Panel (a) shows that controlling for end-of-season sales in the processed food sector hardly changes the hazard function. This was to be expected because end-of-season sales are more common for items other than food (e.g. clothing and footwear or furniture). The hazard is slightly less downward sloping when one controls for other sales (panel b) while controlling for price spells preceding sales prices (panel c) leads to a hazard function which is more downward sloping. Panels (d) and (e) show that controlling for temporary price cuts leads to considerably fewer downward-sloping hazards. This is actually a rather mechanical effect, because temporary price cuts are shorter by definition than normal sales spells. Still, the results suggest that temporary price cuts rather than normal sales price spells are responsible for the downward-sloping pattern of hazard functions in the processed food sector. This result is consistent with the findings by Nakamura and Steinsson (2008) and with the theoretical contribution by Kehoe and Midrigan (2007).

The results for the other sectors are displayed in Figures 12 to 17. Interestingly, the downward-sloping pattern due to sales seems to be specific to the processed food sector even though sales are very common for unprocessed food and industrial products, too. Although the hazard is somewhat more downward sloping for unprocessed food (Figure 12) when sales prices are

[14]The regression results are given in Table 13.
[15]The regression results are given in Table 14.
[16]The regression results are not reported for reasons of brevity. They are available upon request.

included in the analysis, one would not reject a constant hazard overall. Only for the duration of one quarter is the hazard somewhat higher excluding sales dummies, but the difference is small. The same applies for industrial products and for services where sales are much less common.

Still, the question remains as to whether sales prices are simply another kind of (seasonal) heterogeneity or whether they are strategically used by firms to react to sector-specific or macroeconomic shocks as suggested by Kehoe and Midrigan (2007). If temporary price cuts are a seasonal phenomenon one could use a firm-specific seasonal random effect which should resolve the downward-sloping pattern. However, if these temporary price cuts are strategically used to react to the state of the economy one has to differentiate between price increases and decreases and estimate separate hazard functions. Assessing these questions is beyond the scope of this paper.

5.4 The relevance of state-dependent pricing

Menu cost models imply that the average price duration varies with the state of the economy. Several papers have shown that the frequency of price changes is correlated with inflation (c.f. Nakamura and Steinsson, 2008; Kaufmann, 2009a). However, these estimates only include one variable describing the state of the economy (aggregate inflation). Therefore, it is not possible to assess the economic impact of changes in other variables. This section assesses whether the state-dependent effects are plausible and whether the impact on average price duration is economically significant. Finally, it gives an idea how much of the variability of aggregate price stickiness is explained by state-dependent factors.

Table 14 gives the regression results for the baseline model in the various sector samples. The data set includes sales prices, but these are controlled for by adding dummy variables. The results indicate that the two cost measures ($\Sigma\Delta\tilde{p}_t,\ \Sigma\Delta w_t$) have a positive impact on the probability of price changes. All coefficients are significant at least at the 5% level. The importance of input costs is also highlighted by the positive effect of the VAT change in 2001 for unprocessed food and industrial products.

The overall effect of accumulated total inflation ($\Sigma\pi_t$) is positive for the food sectors, but not statistically different from zero for industrial products and for services. This means that only for food items does there seem to be some indexation to the total price level which affects the timing of price changes. Of course, firms might still decide to follow indexation schemes in order to set the size of the price change rather than its timing. The results change at a more disaggregated level. The disaggregated inflation rates ($\Sigma\pi_t^{sub},\ \Sigma\pi_t^{eii}$), which measure the rate of markup erosion or indexation to a price index of some subsectors, significantly increase the probability of price changes for services and unprocessed food. For processed food there is no significant effect of disaggregate inflation. Only for industrial products is the coefficient on $\Sigma\pi_t^{sub}$ of the wrong sign and statistically significant.

Based on the coefficients, it is difficult to assess the magnitude of the effect of these covariates. Although marginal effects are relatively straightforward to calculate, they depend on the specific duration at which we evaluate the hazard. It is more illustrative to calculate the implied mean durations for different paths of the TVC. This is obtained by summing the survivor function up to the largest dummy controlled for in the baseline hazard specification which, in our case, is equal to 15:[17]

$$D = 1 + \sum_{\ell=1}^{15} S(\ell | v_i = 1) \ . \tag{14}$$

Tables 15 to 19 give the estimated mean durations for various paths of the covariates along with confidence intervals. Again, they are based on the delta method (cf. Kaufmann, 2009c). The first column gives different trend assumptions for the q/q rates of change of the TVC. The baseline assumption in the first row is the mean value in the sample. For the other assumptions the mean value was multiplied by 2, 3 and 4. The remaining time-varying covariates are set to their mean value. Therefore, the effects have a *ceteris paribus* interpretation, which may be restrictive because changing input costs could lead, for example, to changes in sectoral inflation. The second column gives the corresponding mean duration and the third and fourth columns give 95% confidence bounds. In addition, the table reports a test statistic for the null hypothesis that the corresponding mean duration is equal to the baseline mean duration in the first row.

The implied mean durations for the baseline case are somewhat higher compared to the values derived in Kaufmann (2009a). This is basically due to the fact that the hazard is evaluated at specific values of the covariates and all dummy variables are set to zero. In the descriptive analysis in Kaufmann (2009a) the duration is a mixture of all these characteristics. Still, the relative magnitude of the durations among sectors is in line with the descriptive results.

The results indicate that cost pressure is an important determinant of the timing of price changes (cf. Table 15). The model predicts that changing average inflation of wholesale consumer goods from 0.1% to 0.5% per quarter reduces the mean duration of processed food prices by more than 2 quarters. The negative test statistic, which exceeds the 5% critical value (1.96) in absolute terms, illustrates that the reduction is statistically significant. For industrial products and services the mean duration is reduced by 2 quarters. For unprocessed food the effect is smaller. In all cases the null hypothesis that there is no effect is rejected at standard significance levels.

[17] The survivor is equal to unity on the interval [0, 1), $S(0|v_i) = 1$. Intuitively, if a price changes every period then $S(t|v_i) = 0, \ \forall t > 0$ and thus the expected duration is one period.

Increasing wage inflation by roughly 2% reduces the mean duration by 1.7 quarters for prices of services and industrial products (cf. Table 16). This is consistent with the idea that labour input is a large share of input costs. For processed food, the effect is statistically significant and the mean duration is reduced by 2.5 quarters. Meanwhile, the effect is economically negligible for unprocessed food although statistically significant.

The results also show the mean durations for different paths of index item level inflation and subsector level inflation which both capture markup erosion or potential indexation to a sectoral price index (cf. Tables 17 and 18). The effect of elementary index item level inflation is of the wrong sign for processed food but not significant. For the remaining sectors the effect is significant but economically less important than the cost measures presented above. An exception is unprocessed food where the magnitude of the effect is similar to the magnitude of the effect of cost inflation. The effect of the subsectors' inflation rates is of the wrong sign for industrial products and processed food. Only subsector inflation for services reduces the mean price duration by 2.4 quarters when inflation of subsectors increases from 0.5% to 1.8%.

For CPI inflation, which measures indexation to the total price level, the mean duration is considerably reduced in the two food sectors while there is only a minor decrease (industrial products) or an increase (services) in the duration for other sectors (cf. Table 19). For the latter two sectors, however, the effect is not statistically significant.

Overall, the results suggest that cost inflation is a major determinant across many sectors. The effects are economically large and precisely estimated. Wage inflation is important in sectors in which labour input seems to make up a large share of cost. Once the cost measures are accounted for, markup erosion due to sectoral inflation or indexation to the total price level does not seem to play a major role for the timing of price changes.

In order to evaluate whether the time-dependent or state-dependent price-setting behaviour explains important aspects of aggregate price rigidity, we can use the model to predict the overall frequency of price changes over time. This is done by calculating the probability of price adjustment for every individual product in the sample at every given point in time, conditional on the observed values of the covariates. Then the probabilities are aggregated by taking an average over all individual products for each time period. This is then compared to the frequency of price changes calculated as the fraction of price changes in total prices.

Table 20 gives linear regressions of the predicted frequency of price changes as implied by various specifications of the hazard model on the actual frequency. First we note that the unconditional hazard model explains relatively little of the observed frequency of price changes. The R^2 ranges from 0.008 for industrial products to 0.137 for services. Additional time-dependent factors (e.g. seasonal factors) and cross-sectional variability (e.g. firm size) increase the explanatory power considerably for unprocessed food and industrial products but not for processed food and services. This implies that a purely time-dependent pricing model explains around 20% of the aggregate behaviour of the frequency of price changes for unprocessed food and industrial products. For services, the R^2 amounts to 12%.

The most interesting result is that including time-varying covariates raises the R^2 for processed food, unprocessed food and industrial products by 30% to 50%, implying that time-dependent pricing cannot fully replicate the behaviour of the frequency of price changes. This corroborates the finding that time-varying factors have large effects on the timing of price changes. For services, however, the R^2 changes only marginally and thus time-dependent pricing may accurately describe the price-setting behaviour in this sector.

5.5 Robustness checks

To check the robustness of the key results, some regressions are repeated under alternative distributional assumptions, and for an alternative sample period.[18] In addition, the TVC were included for positive and negative changes separately.[19]

In the regressions described in the previous section, the distribution of the unobserved heterogeneity term was assumed to be log-normal. Assuming a gamma distributed heterogeneity term does not significantly change the results. Hazards are calculated at the median of the unobserved heterogeneity term. The implied mean duration is somewhat smaller in the processed food sector than when the log-normal distribution is assumed. However, the effects of TVC on the implied mean duration are of the same sign and magnitude. The main result, that the hazards are non-decreasing once TVC are controlled for, is also robust under this alternative assumption. One advantage of the gamma distribution is that we are able to obtain a closed form solution for the unconditional hazard rate by integrating out the random effect such that it does not depend on the value assumed for v_i (c.f. Kaufmann, 2009c). This does not change any of the qualitative results. As the unconditional hazard is aggregated over all individuals it is more downward sloping than the conditional hazard. However, for the price-setting behaviour of the individual firm the conditional hazard rate is the relevant one.

The models are estimated in a sample covering the period from 1993 to 2000. Again, the results are remarkably similar. In the earlier sample, it is more difficult, however, to identify an influence of changes in costs on price-setting. The estimates are often not significant. There was hardly

[18] The likelihood function under alternative distributional assumptions is derived in Kaufmann (2009b).
[19] The regression results are not reported for reasons of brevity. They are available upon request.

any variation in consumer goods inflation at the wholesale stage over this period and its average trend change was -0.01% q/q compared to 0.26% q/q from the 2000 to 2007 period. Also, CPI inflation was very moderate. Of course, the aggregate measure is only a good approximation if there are relatively large cost shocks which affect a majority of firms in the sample. In the earlier sample, such shocks presumably did not occur frequently. Still, the majority of coefficients have the expected sign. The results regarding sales are difficult to compare across the two samples, however, because end-of-season sales were not recorded in the earlier time period. Instead, the FSO asked the firm's staff what the product would cost if it was not on sale. The overall qualitative conclusions for temporary price cuts remain the same.

Finally, the covariates were allowed to have asymmetric effects on the hazard function, depending on whether accumulated changes were positive or negative. Often, negative accumulated changes of cost pressure and inflation have a lower impact than positive accumulated changes. The main conclusions for the overall hazard and the effects on the implied duration do not change, however.

6 Conclusions

This paper presents hazard function estimates based on Swiss CPI micro data. The underlying duration model is able to account for unobserved heterogeneity as well as for a range of observed factors. The purpose of the paper is to disentangle the downward bias caused by neglected heterogeneity into various sources and to give an idea of the economic importance of time-varying factors on price setting. In contrast to other studies, there is no evidence of downward-sloping hazard functions for regular price changes even in a low-inflation environment.

First, it is shown that the hazard functions are downward sloping if heterogeneity is completely ignored. This is the standard result often found for hazard functions in price setting. Once a random effect is added to account for some cross-sectional heterogeneity the downward bias is considerably reduced in most sectors but only resolved in some. Adding observed cross-sectional information does not change this result so that one can be confident that the random effect does capture the relevant heterogeneity well.

In a second step, time-varying covariates measuring cost pressures, markup erosion and indexation are added. At the trend-values of these covariates, the estimated hazards for regular price changes are generally non-decreasing or even upward-sloping in some sectors. That is, the downward bias is resolved completely for regular price changes. This highlights the importance of time-varying hereogeneity of firms, which is stressed by recent theoretical contributions to the price-setting literature.

A typical feature of the hazard function are the spikes after 4, 8 and 12 quarters, which suggests that some firms do change their prices at fixed intervals. Although the model controls for sector-specific seasonality, this does not fully describe the price-setting behaviour. Firm-specific differences of fixed price-setting intervals appear to remain an important characteristic. The typical pattern is present for unprocessed food, industrial products and services. Processed food is an exception, however, since the spikes are much less pronounced.

Including sales price spells in the analysis leads to downward-sloping hazards, but only for processed food. Because sales spells are usually shorter than regular price spells the hazard falls considerably in the first two quarters and then remains roughly constant. It is found that temporary price cuts are mainly responsible for the downward-sloping pattern. End-of-season and other sales are less important. Once spell-specific sales dummies are added, the downward-sloping pattern disappears. This is consistent with recent contributions to price-setting theory, which suggest the inclusion of temporary price cuts in the model. It remains an open question, however, whether temporary price cuts are only a seasonal or a state-dependent phenomenon.

The timing of Swiss firms' price setting is influenced by the state of the economy as well as sectoral and firm-specific characteristics. The most important determinant is found to be a proxy for marginal cost. It affects most sectors in a similar magnitude and the effect is economically large. Changing average inflation of wholesale consumer goods from 0.1% to 0.5% per quarter reduces the mean duration for processed food, industrial product and services prices by at least 2 quarters. For unprocessed food the effect is somewhat smaller. Wage inflation reduces the mean duration by 2 quarters for services and industrial products and by 2.5 quarters for processed food. Meanwhile, the effect of markup erosion is relatively small except for services and unprocessed food. There is evidence that indexation leads to more regular price changes, but only in the food sector.

The estimated models are then used to predict the aggregate frequency of price changes over time. It is shown that even in a low inflation environment state-dependent pricing explains an additional 30% to 50% of the variance of the frequency of price changes compared to a purely time-dependent pricing model. An exception is the service sector, where the additional covariates explain only a small share of aggregate price stickiness.

The main conclusion of this paper is that including (time-varying) macroeconomic information considerably reduces the downward bias of the hazard functions. Neglecting time-varying heterogeneity leads to the same downward bias as neglecting time-constant unobserved heterogeneity because the hazard functions are estimated over periods characterised by changes in the state of the economy. This suggests that state-dependent pricing explains a considerable part of price-setting behaviour even in a low inflation environment.

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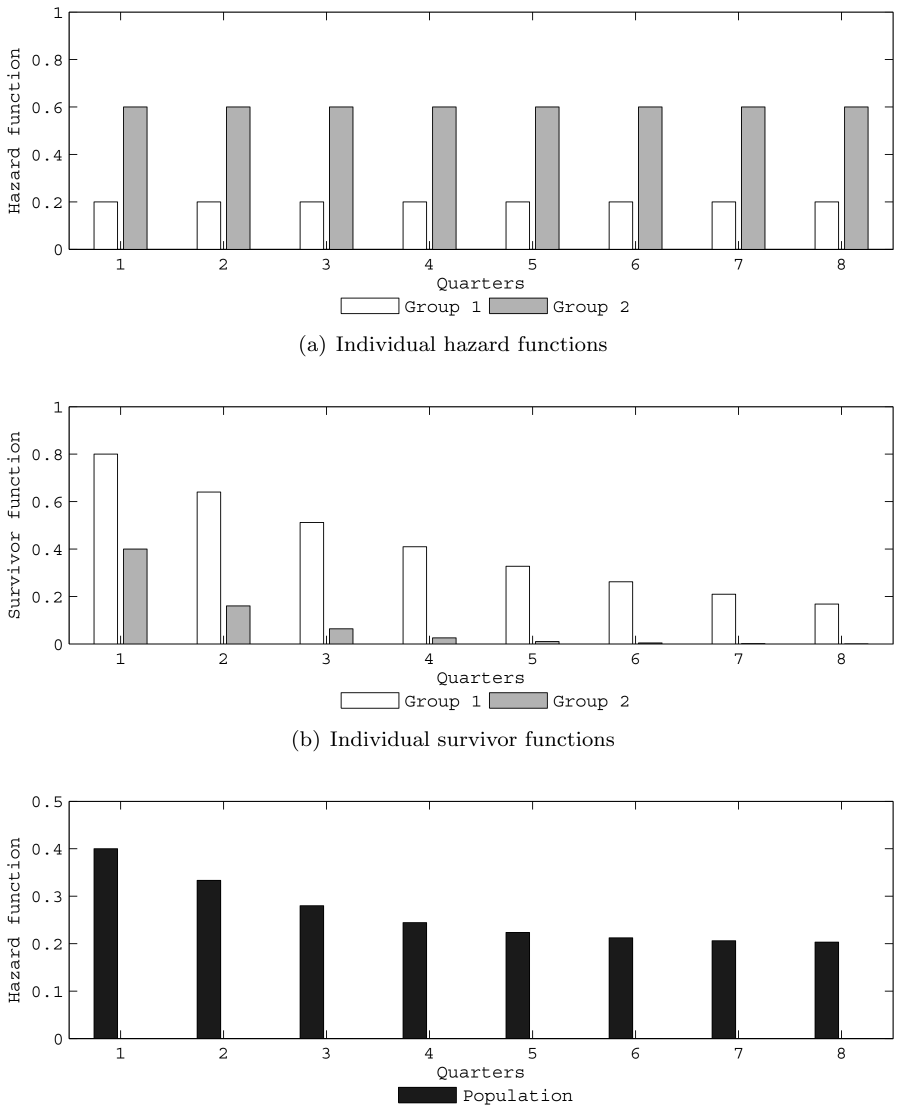
Appendices

A Figures



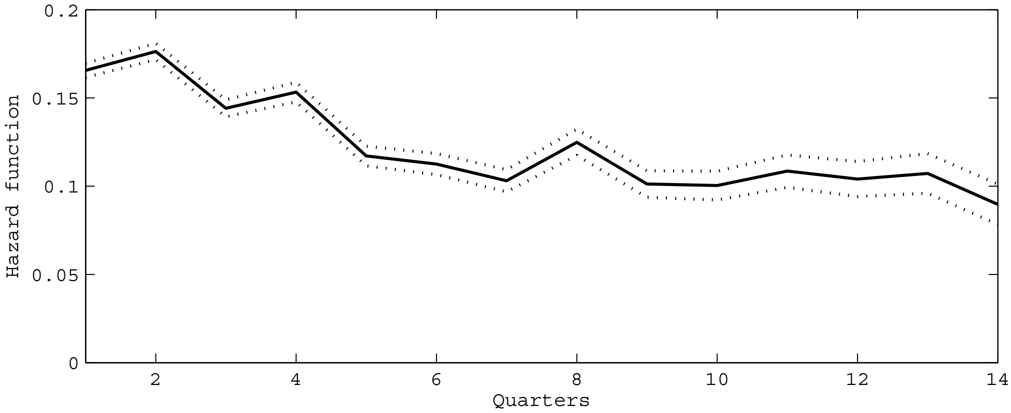
(a) Individual hazard functions

(b) Individual survivor functions

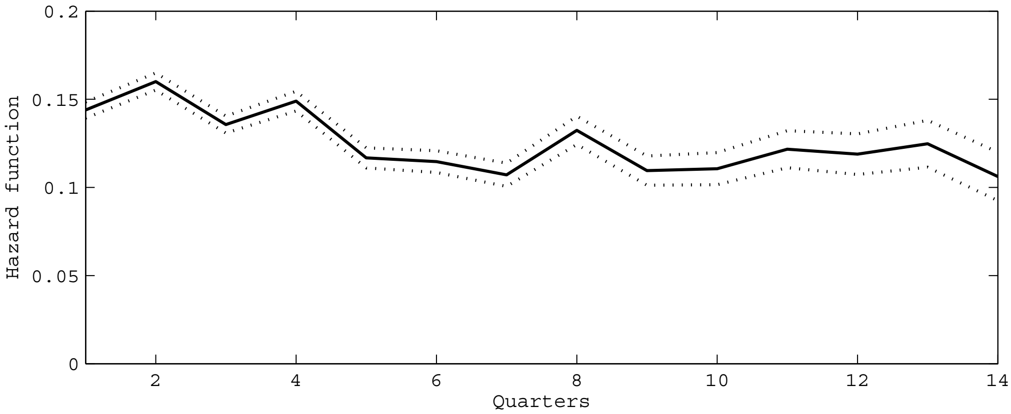
(c) Population hazard function

Figure 1: Downward bias due to unobserved heterogeneity in theory

Note: The figures give (a) theoretical hazard functions for two individual groups of firms, (b) the corresponding survivor functions and (c) the overall population hazard if the firm-specific heterogeneity is neglected.



(a) Excl. unobserved heterogeneity, excl. covariates



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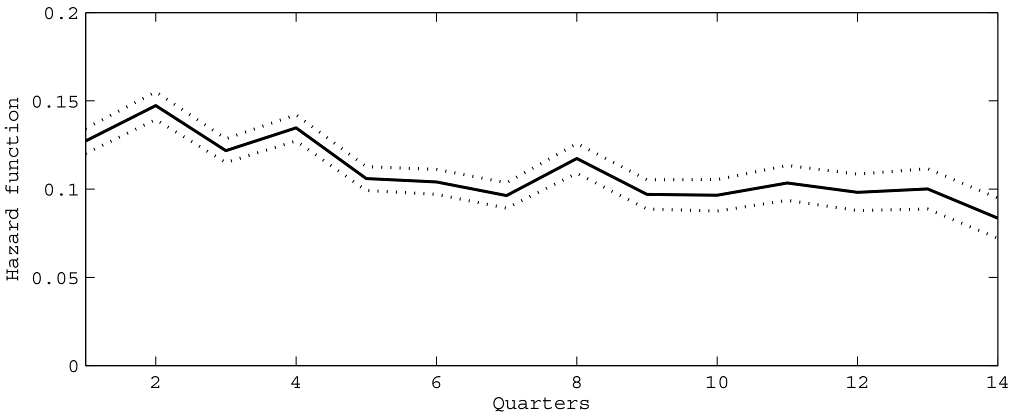
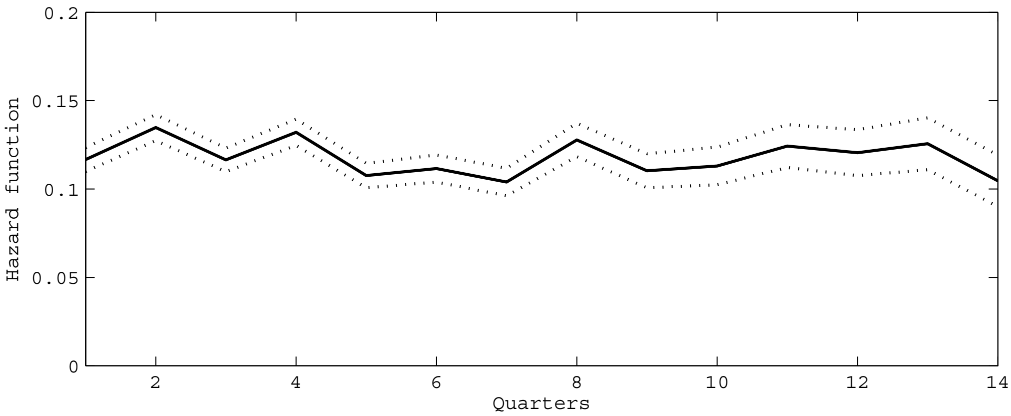


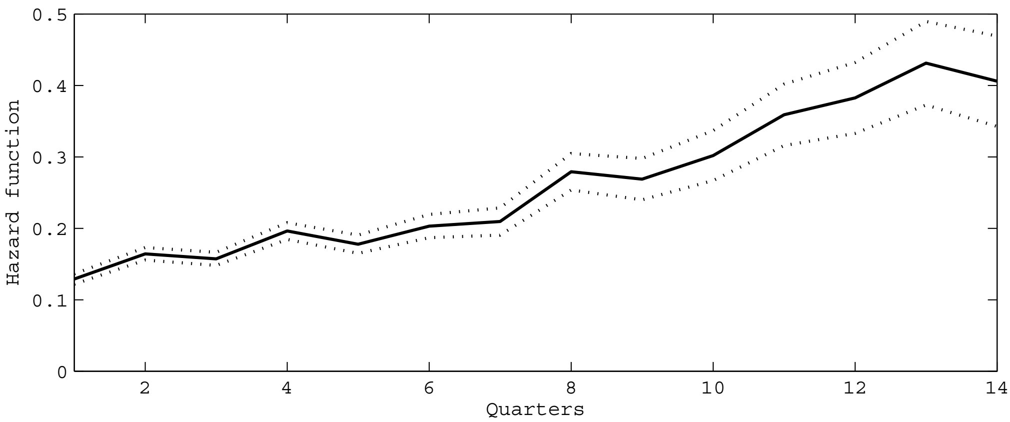
(c) Incl. unobserved heterogeneity, incl. dummy variables

Figure 2: Effect of cross-sectional heterogeneity on the hazard function (processed food)

Note: The figures give estimated hazard functions for three specifications where sales prices are excluded from the sample. (a) Unobserved and observed heterogeneity are neglected. (b) Unobserved heterogeneity is controlled for while observed heterogeneity is neglected. (c) Unobserved heterogeneity is controlled for and various dummy variables are included in the regression to control for observed heterogeneity. The dotted lines give 95% confidence intervals.



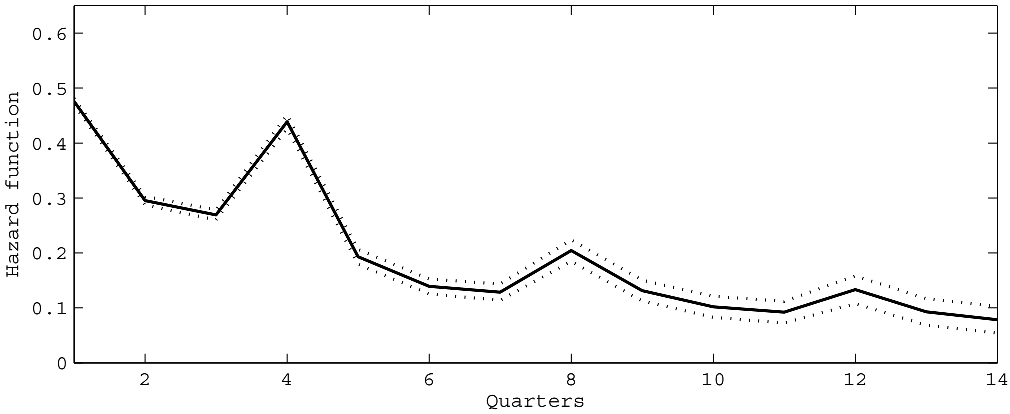
(a) Incl. unobserved heterogeneity, incl. TVC (at the mean)



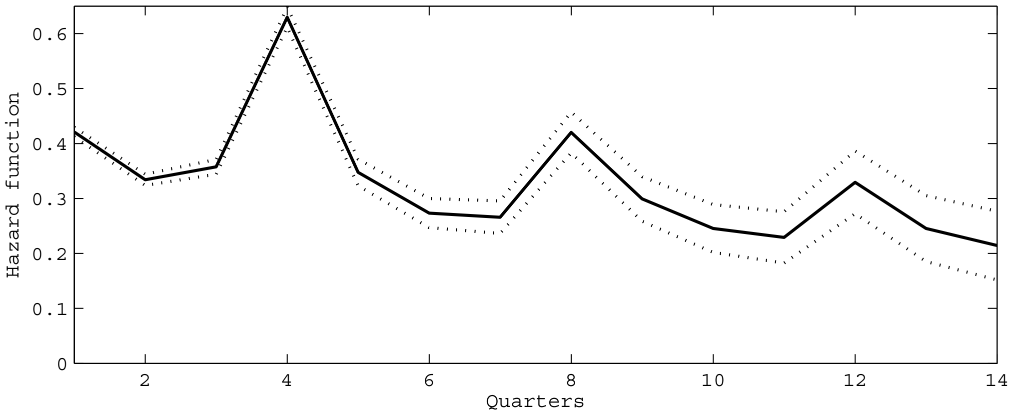
(b) Incl. unobserved heterogeneity, incl. TVC (at twice the mean)

Figure 3: Effect of time-varying heterogeneity on the hazard function (processed food)

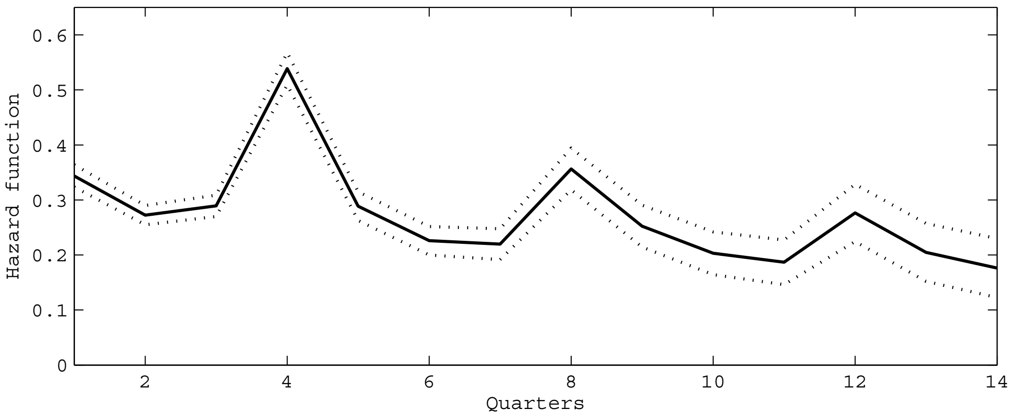
Note: The figures give estimated hazard functions for two specifications where sales prices are excluded. (a) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. (b) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to twice their mean values to evaluate the hazard. The dotted lines give 95% confidence intervals.



(a) Excl. unobserved heterogeneity, excl. covariates



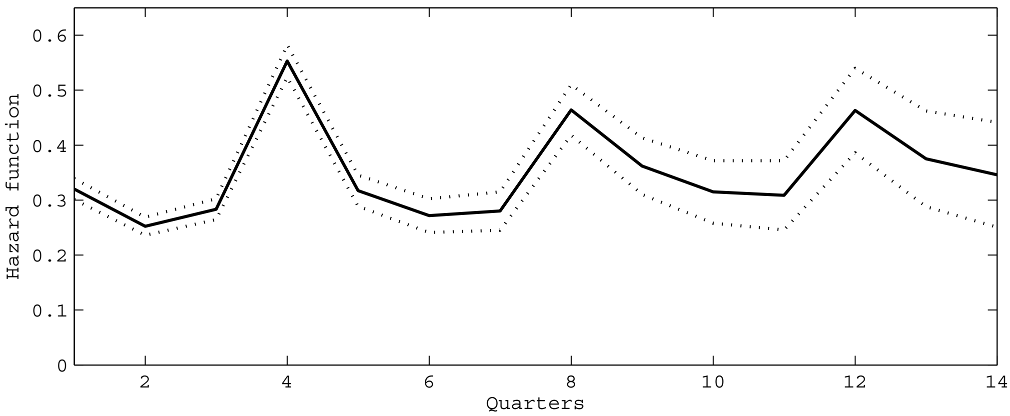
(b) Incl. unobserved heterogeneity, excl. covariates



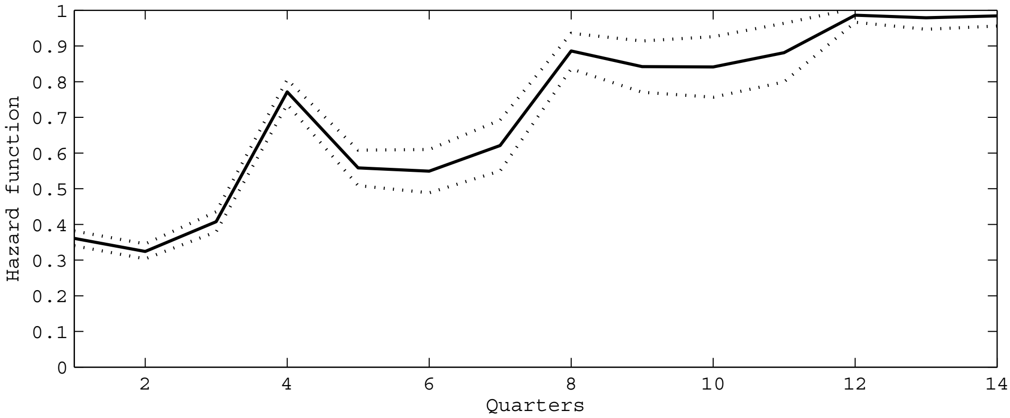
(c) Incl. unobserved heterogeneity, incl. dummy variables

Figure 4: Effect of cross-sectional heterogeneity on the hazard function (unprocessed food)

Note: The figures give estimated hazard functions for three specifications where sales prices are excluded from the sample. (a) Unobserved and observed heterogeneity are neglected. (b) Unobserved heterogeneity is controlled for while observed heterogeneity is neglected. (c) Unobserved heterogeneity is controlled for and various dummy variables are included in the regression to control for observed heterogeneity. The dotted lines give 95% confidence intervals.



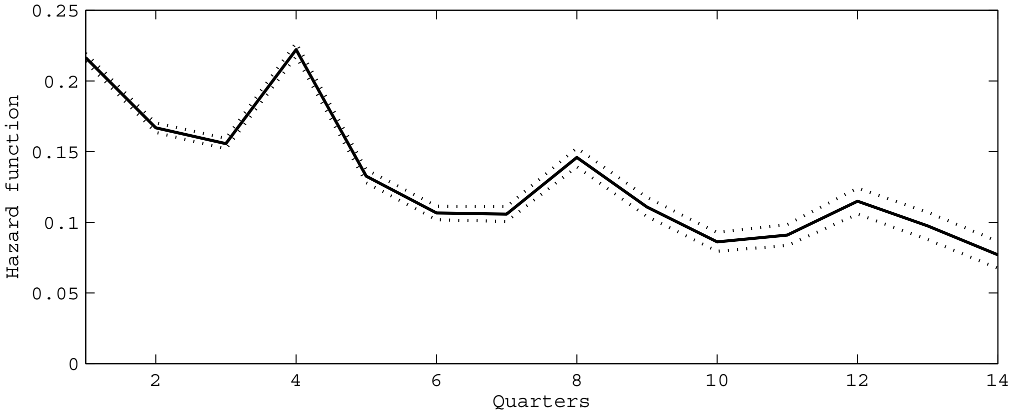
(a) Incl. unobserved heterogeneity, incl. TVC (at the mean)



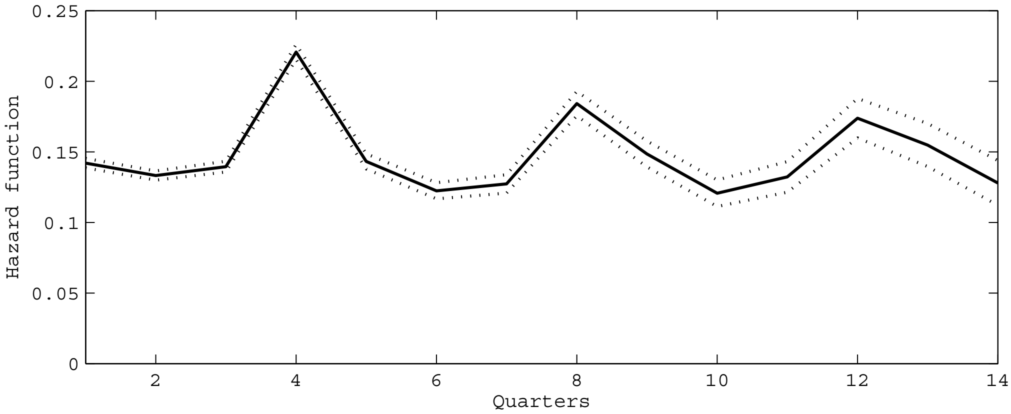
(b) Incl. unobserved heterogeneity, incl. TVC (at twice the mean)

Figure 5: Effect of time-varying heterogeneity on the hazard function (unprocessed food)

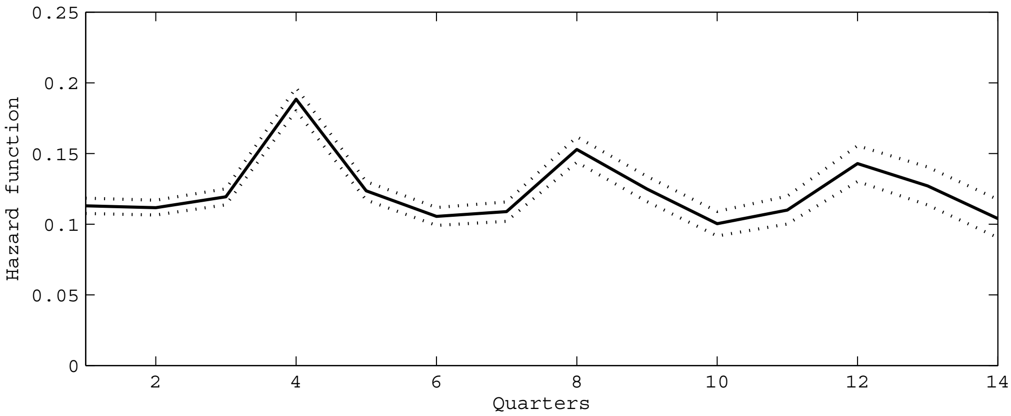
Note: The figures give estimated hazard functions for two specifications where sales prices are excluded. (a) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. (b) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to twice their mean values to evaluate the hazard. The dotted lines give 95% confidence intervals.



(a) Excl. unobserved heterogeneity, excl. covariates



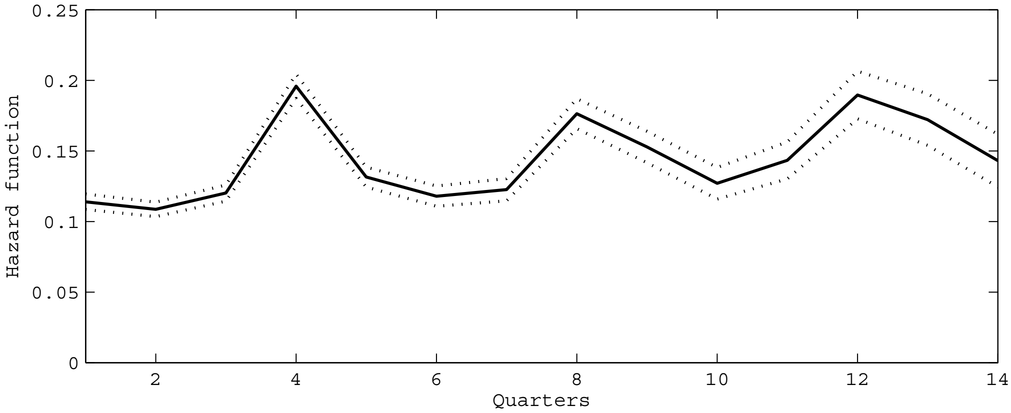
(b) Incl. unobserved heterogeneity, excl. covariates



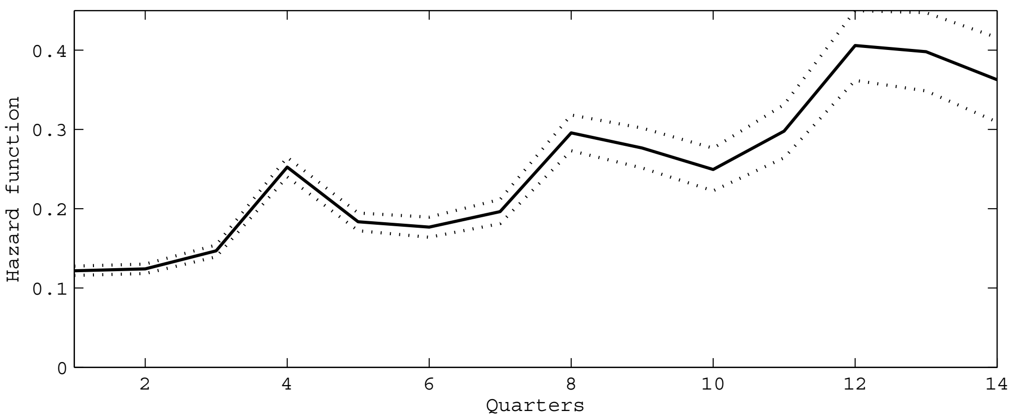
(c) Incl. unobserved heterogeneity, incl. dummy variables

Figure 6: Effect of cross-sectional heterogeneity on the hazard function (industrial products)

Note: The figures give estimated hazard functions for three specifications where sales prices are excluded from the sample. (a) Unobserved and observed heterogeneity are neglected. (b) Unobserved heterogeneity is controlled for while observed heterogeneity is neglected. (c) Unobserved heterogeneity is controlled for and various dummy variables are included in the regression to control for observed heterogeneity. The dotted lines give 95% confidence intervals.



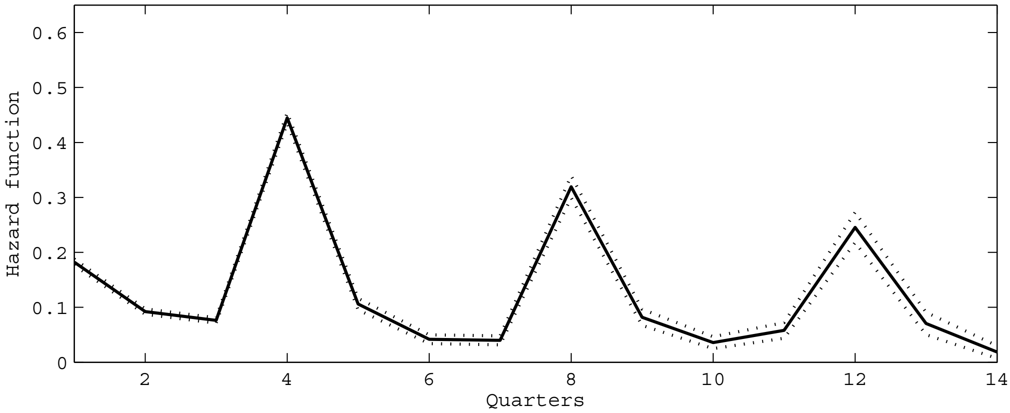
(a) Incl. unobserved heterogeneity, incl. TVC (at the mean)



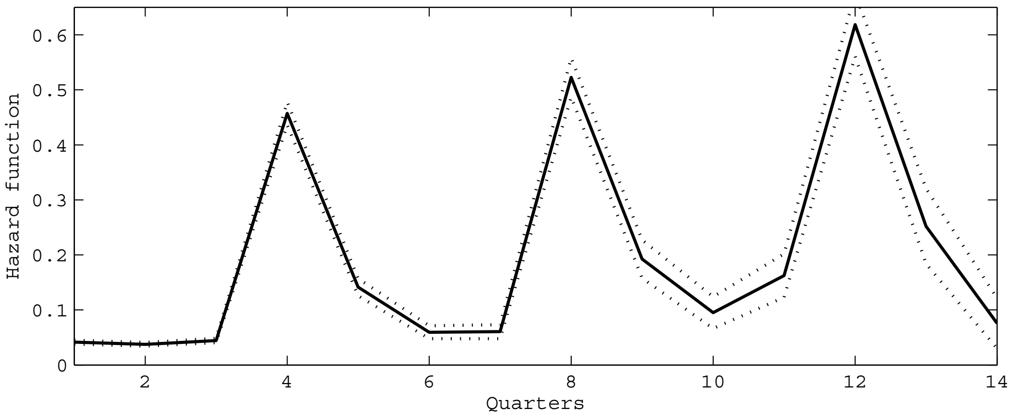
(b) Incl. unobserved heterogeneity, incl. TVC (at twice the mean)

Figure 7: Effect of time-varying heterogeneity on the hazard function (industrial products)

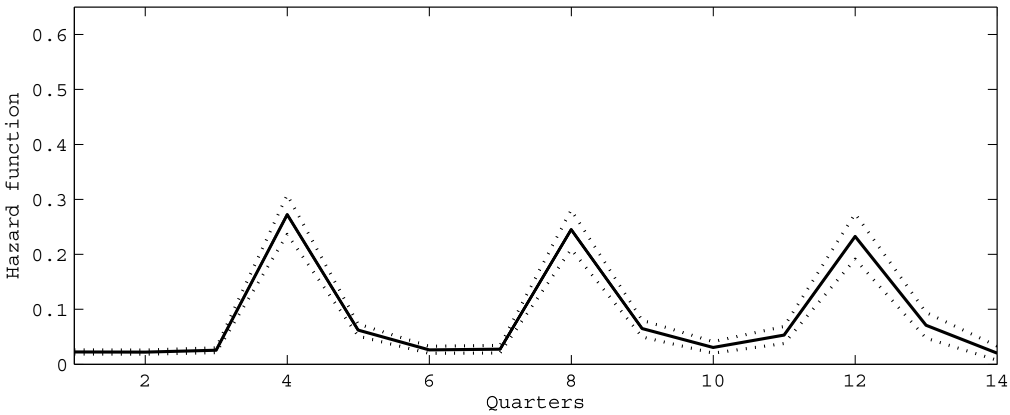
Note: The figures give estimated hazard functions for two specifications where sales prices are excluded. (a) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. (b) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to twice their mean values to evaluate the hazard. The dotted lines give 95% confidence intervals.



(a) Excl. unobserved heterogeneity, excl. covariates



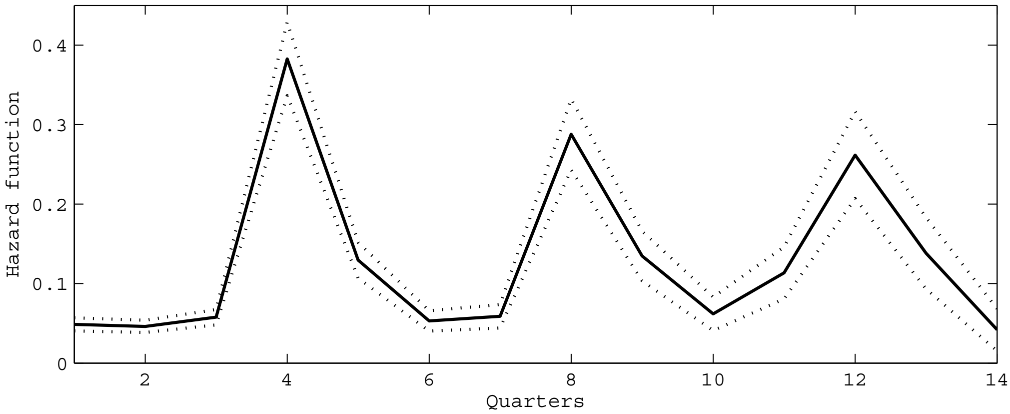
(b) Incl. unobserved heterogeneity, excl. covariates



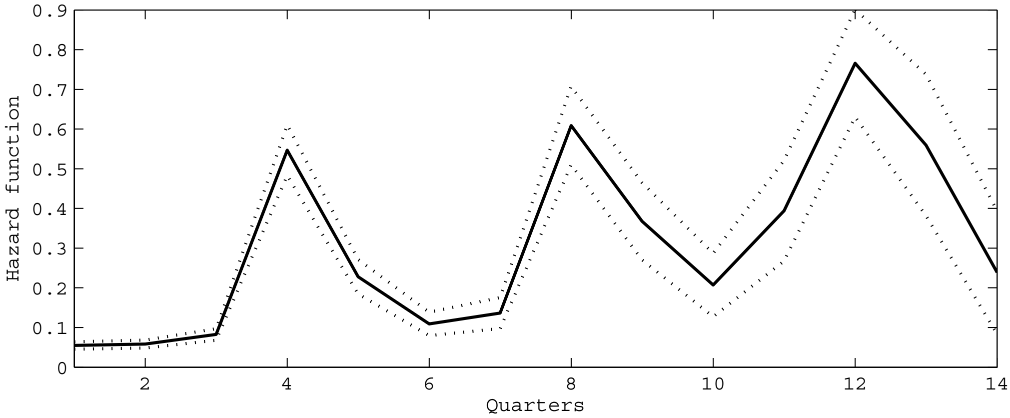
(c) Incl. unobserved heterogeneity, incl. dummy variables

Figure 8: Effect of cross-sectional heterogeneity on the hazard function (services)

Note: The figures give estimated hazard functions for three specifications where sales prices are excluded from the sample. (a) Unobserved and observed heterogeneity are neglected. (b) Unobserved heterogeneity is controlled for while observed heterogeneity is neglected. (c) Unobserved heterogeneity is controlled for and various dummy variables are included in the regression to control for observed heterogeneity. The dotted lines give 95% confidence intervals.



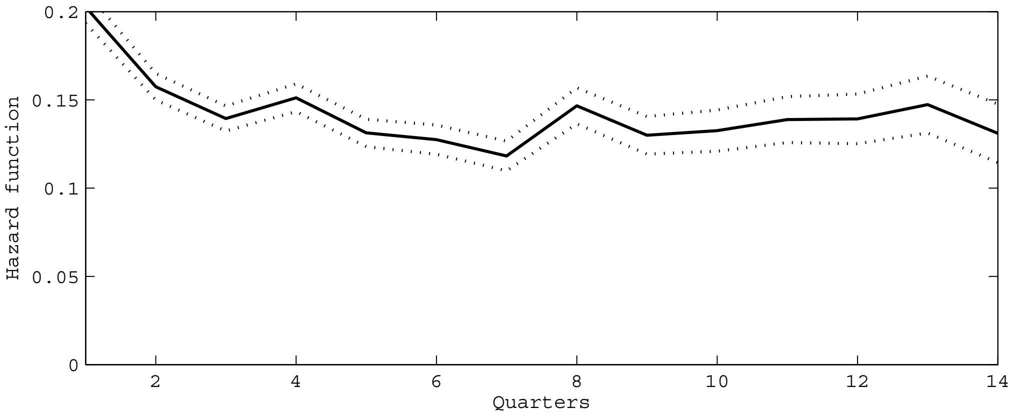
(a) Incl. unobserved heterogeneity, incl. TVC (at the mean)



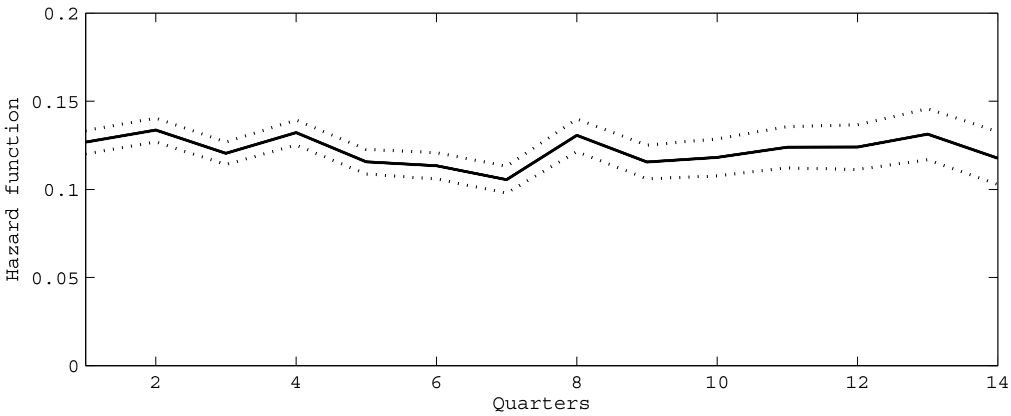
(b) Incl. unobserved heterogeneity, incl. TVC (at twice the mean)

Figure 9: Effect of time-varying heterogeneity on the hazard function (services)

Note: The figures give estimated hazard functions for two specifications where sales prices are excluded. (a) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. (b) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to twice their mean values to evaluate the hazard. The dotted lines give 95% confidence intervals.



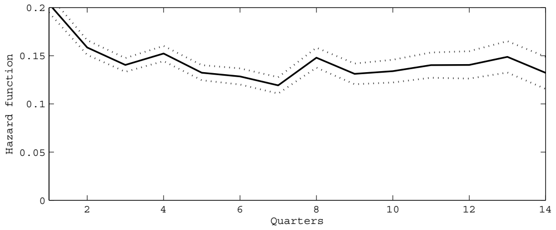
(a) Sales sample, no sales dummies, incl. unobserved heterogeneity and TVC



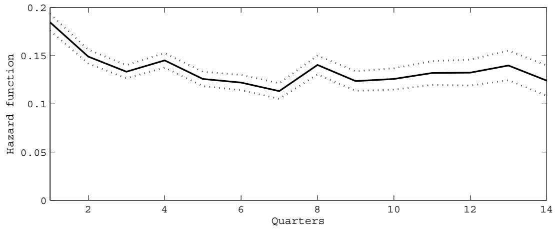
(b) Sales sample, sales dummies, incl. unobserved heterogeneity and TVC

Figure 10: Overall effect of sales prices on the hazard function (processed food)

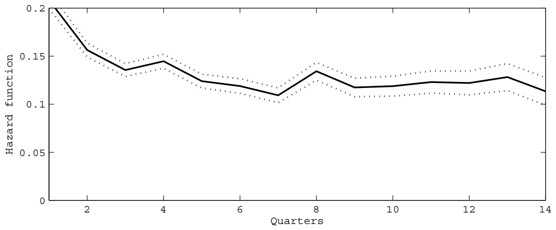
Note: The figures give estimated hazard functions for two specifications where sales prices are included. (a) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. (b) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. In addition, spell-specific dummy variables are included to control for sales prices. The dotted lines give 95% confidence intervals.



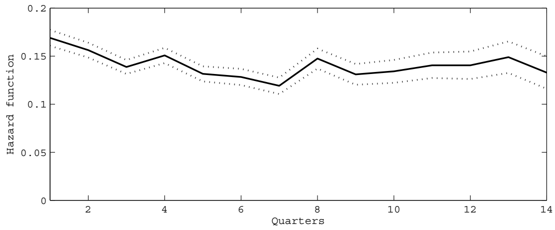
(a) Sales sample, $Sale^{eofs}$ dummy, incl. unobserved heterogeneity and TVC



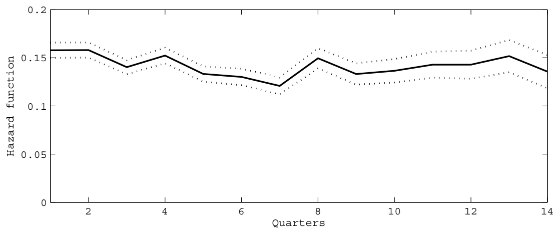
(b) Sales sample, $Sale^{other}$ dummy, incl. unobserved heterogeneity and TVC



(c) Sales sample, $Sale^{pre}$ dummy, incl. unobserved heterogeneity and TVC



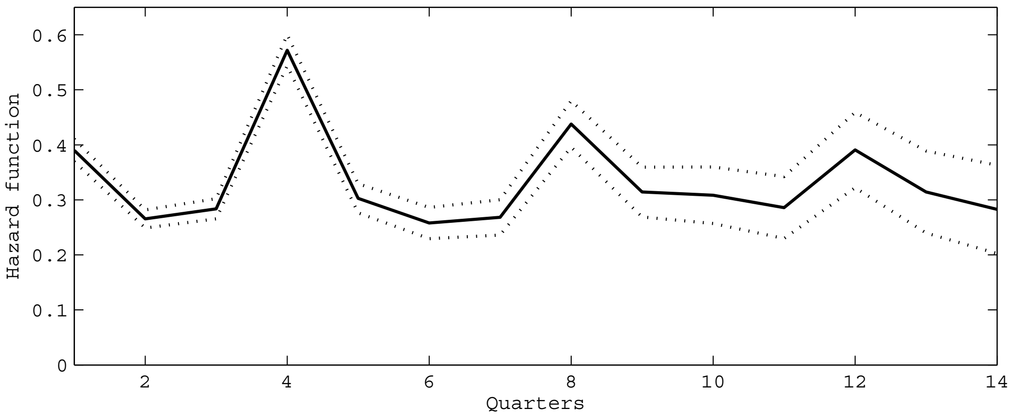
(d) Sales sample, $Sale^{FSOV}$ dummy, incl. unobserved heterogeneity and TVC



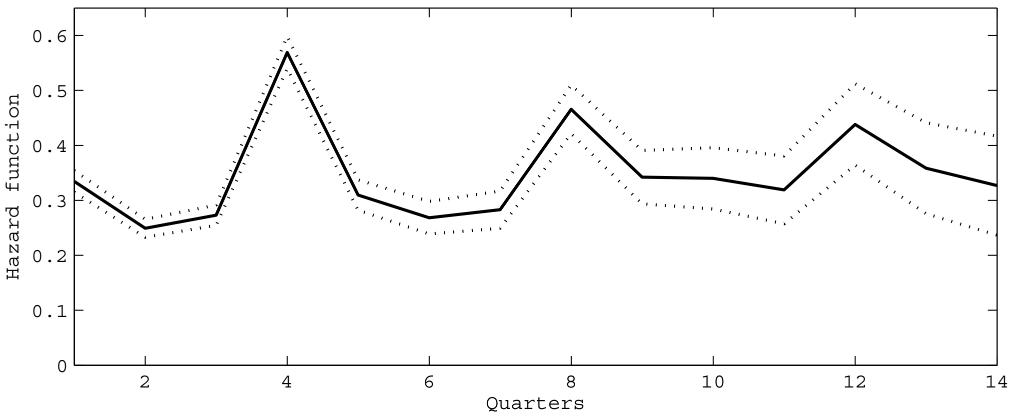
(e) Sales sample, $Sale^{V}$ dummy, incl. unobserved heterogeneity and TVC

Figure 11: Effect of various types of sales prices on the hazard function (processed food)

Note: The figures give estimated hazard functions for five specifications where sales prices are included. (a) Only a dummy for sales spells assumed to be end-of-season sales ($Sales^{eofs}$) is included. (b) Only a dummy capturing the remaining cases of FSO sales prices is included. (c) Only a dummy for price spells which precede a sales price ($Sales^{pre}$) is included. (d) Only a dummy is included if it is a temporary price cut and the FSO denotes it as sales ($Sale^{FSOV}$). (e) Only a dummy for temporary price cuts ($Sales^{V}$) is included. In all specifications unobserved heterogeneity is controlled for, and the standard dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. The dotted lines give 95% confidence intervals.



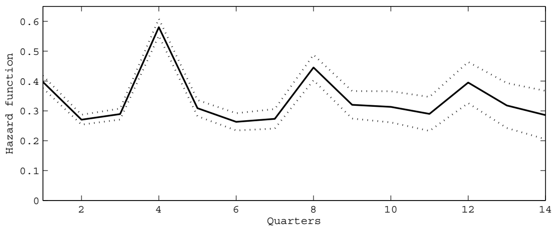
(a) Sales sample, no sales dummies, incl. unobserved heterogeneity and TVC



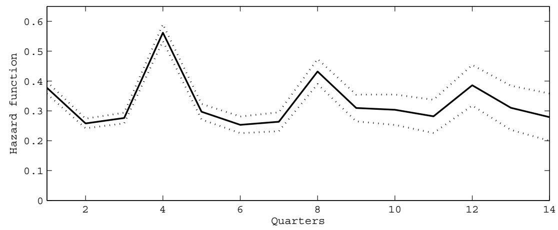
(b) Sales sample, sales dummies, incl. unobserved heterogeneity and TVC

Figure 12: Overall effect of sales prices on the hazard function (unprocessed food)

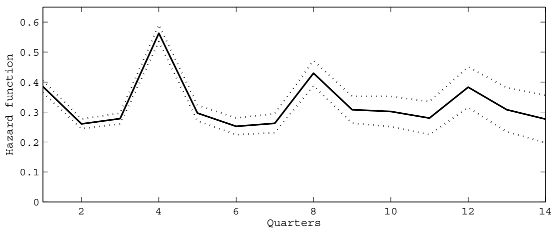
Note: The figures give estimated hazard functions for two specifications where sales prices are included. (a) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. (b) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. In addition, spell-specific dummy variables are included to control for sales prices. The dotted lines give 95% confidence intervals.



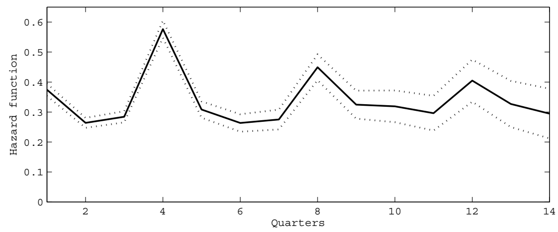
(a) Sales sample, $Sale^{eofs}$ dummy, incl. unobserved heterogeneity and TVC



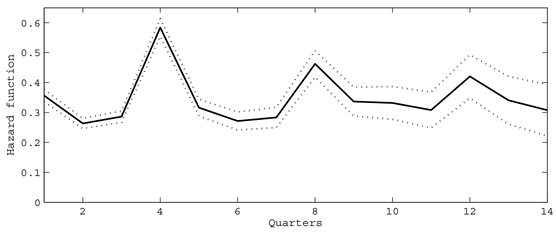
(b) Sales sample, $Sale^{other}$ dummy, incl. unobserved heterogeneity and TVC



(c) Sales sample, $Sale^{pre}$ dummy, incl. unobserved heterogeneity and TVC



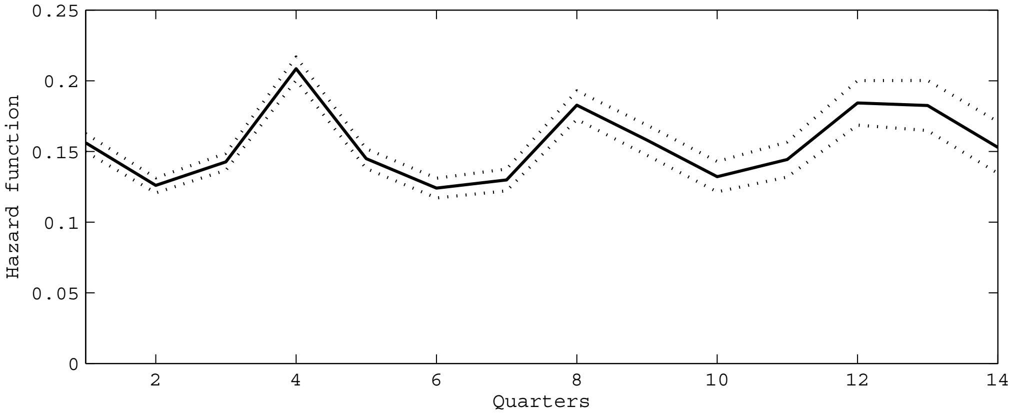
(d) Sales sample, $Sale^{FSOV}$ dummy, incl. unobserved heterogeneity and TVC



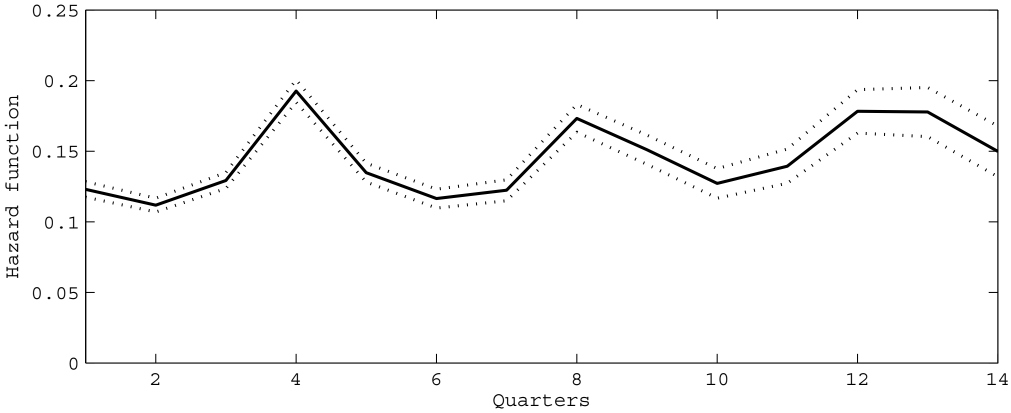
(e) Sales sample, $Sale^{V}$ dummy, incl. unobserved heterogeneity and TVC

Figure 13: Effect of various types of sales prices on the hazard function (unprocessed food)

Note: The figures give estimated hazard functions for five specifications where sales prices are included. (a) Only a dummy for sales spells assumed to be end-of-season sales ($Sales^{eofs}$) is included. (b) Only a dummy capturing the remaining cases of FSO sales prices is included. (c) Only a dummy for price spells which precede a sales price ($Sales^{pre}$) is included. (d) Only a dummy is included if it is a temporary price cut and the FSO denotes it as sales ($Sale^{FSOV}$). (e) Only a dummy for temporary price cuts ($Sales^{V}$) is included. In all specifications unobserved heterogeneity is controlled for, and the standard dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. The dotted lines give 95% confidence intervals.



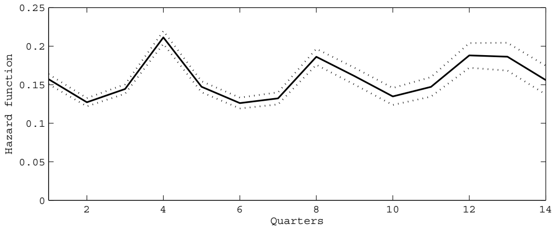
(a) Sales sample, no sales dummies, incl. unobserved heterogeneity and TVC



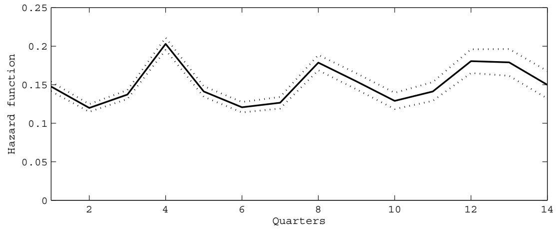
(b) Sales sample, sales dummies, incl. unobserved heterogeneity and TVC

Figure 14: Overall effect of sales prices (industrial products)

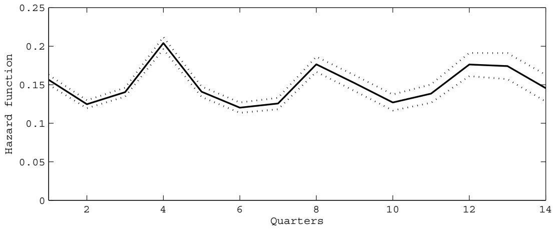
Note: The figures give estimated hazard functions for two specifications where sales prices are included. (a) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. (b) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. In addition, spell-specific dummy variables are included to control for sales prices. The dotted lines give 95% confidence intervals.



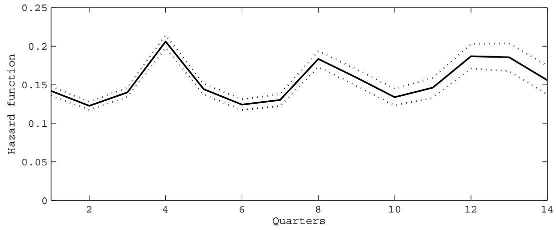
(a) Sales sample, $Sale^{eofs}$ dummy, incl. unobserved heterogeneity and TVC



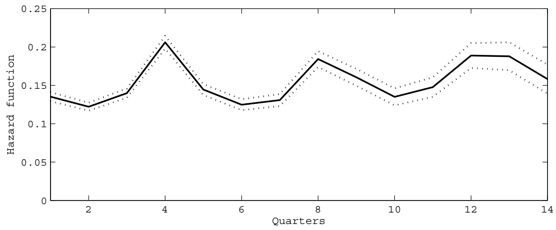
(b) Sales sample, $Sale^{other}$ dummy, incl. unobserved heterogeneity and TVC



(c) Sales sample, $Sale^{pre}$ dummy, incl. unobserved heterogeneity and TVC



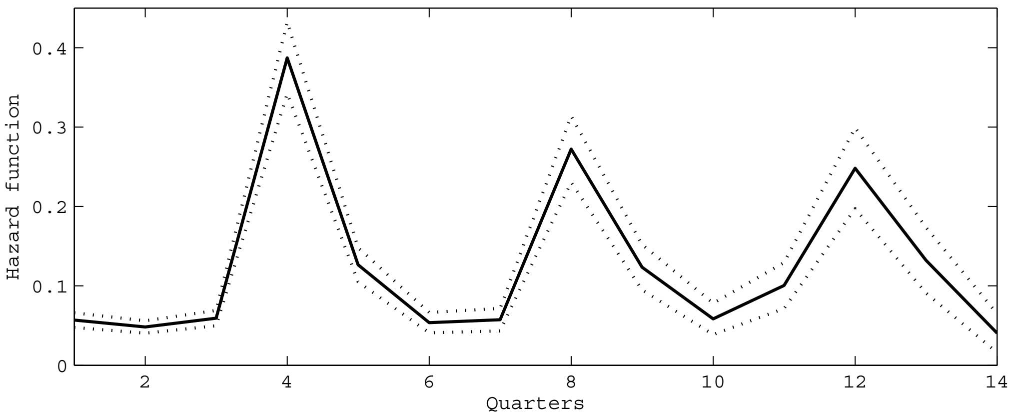
(d) Sales sample, $Sale^{FSOV}$ dummy, incl. unobserved heterogeneity and TVC



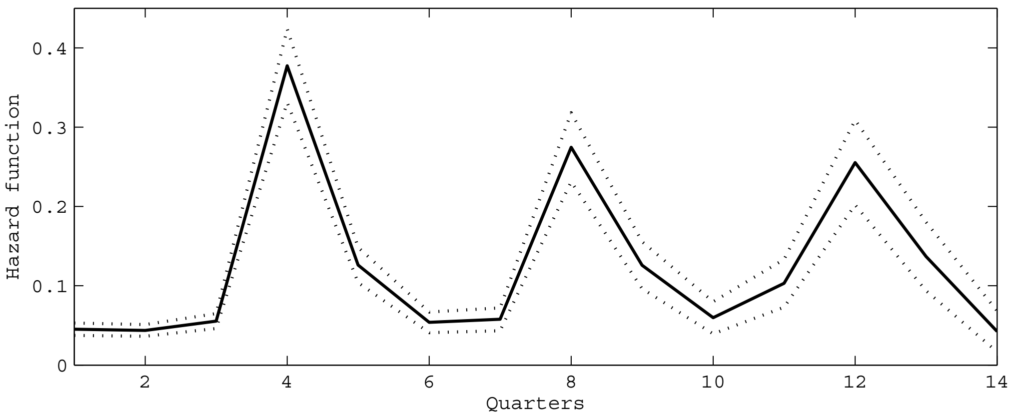
(e) Sales sample, $Sale^{V}$ dummy, incl. unobserved heterogeneity and TVC

Figure 15: Effect of various types of sales prices on the hazard function (industrial products)

Note: The figures give estimated hazard functions for five specifications where sales prices are included. (a) Only a dummy for sales spells assumed to be end-of-season sales ($Sales^{eofs}$) is included. (b) Only a dummy capturing the remaining cases of FSO sales prices is included. (c) Only a dummy for price spells which precede a sales price ($Sales^{pre}$) is included. (d) Only a dummy is included if it is a temporary price cut and the FSO denotes it as sales ($Sale^{FSOV}$). (e) Only a dummy for temporary price cuts ($Sales^{V}$) is included. In all specifications unobserved heterogeneity is controlled for, and the standard dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. The dotted lines give 95% confidence intervals.



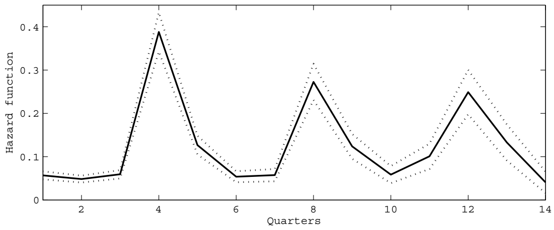
(a) Sales sample, no sales dummies, incl. unobserved heterogeneity and TVC



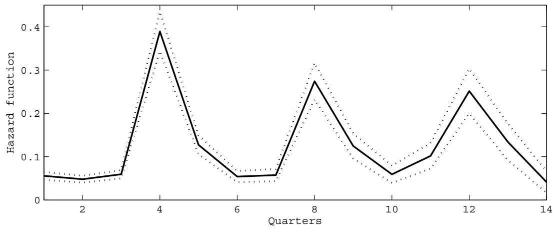
(b) Sales sample, sales dummies, incl. unobserved heterogeneity and TVC

Figure 16: Overall effect of sales prices (services)

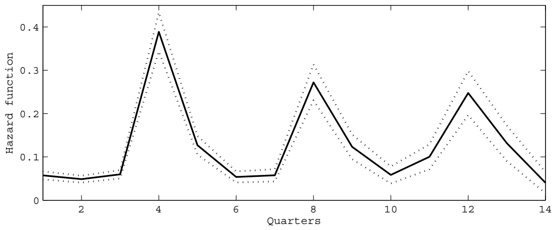
Note: The figures give estimated hazard functions for two specifications where sales prices are included. (a) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. (b) Unobserved heterogeneity is controlled for, dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. In addition, spell-specific dummy variables are included to control for sales prices. The dotted lines give 95% confidence intervals.



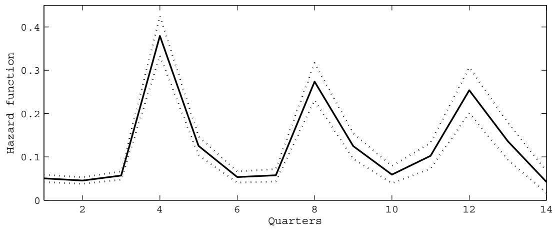
(a) Sales sample, $Sale^{eofs}$ dummy, incl. unobserved heterogeneity and TVC



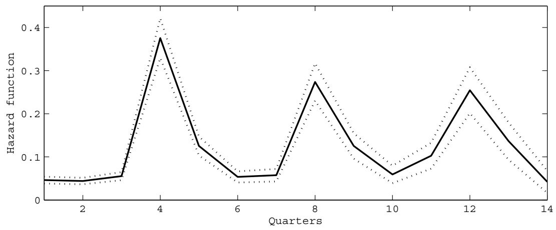
(b) Sales sample, $Sale^{other}$ dummy, incl. unobserved heterogeneity and TVC



(c) Sales sample, $Sale^{pre}$ dummy, incl. unobserved heterogeneity and TVC



(d) Sales sample, $Sale^{FSOV}$ dummy, incl. unobserved heterogeneity and TVC



(e) Sales sample, $Sale^{V}$ dummy, incl. unobserved heterogeneity and TVC

Figure 17: Effect of various types of sales prices on the hazard function (services)

Note: The figures give estimated hazard functions for five specifications where sales prices are included. (a) Only a dummy for sales spells assumed to be end-of-season sales ($Sales^{eofs}$) is included. (b) Only a dummy capturing the remaining cases of FSO sales prices is included. (c) Only a dummy for price spells which precede a sales price ($Sales^{pre}$) is included. (d) Only a dummy is included if it is a temporary price cut and the FSO denotes it as sales ($Sale^{FSOV}$). (e) Only a dummy for temporary price cuts ($Sales^{V}$) is included. In all specifications unobserved heterogeneity is controlled for, and the standard dummies and TVC are included. The latter are set to their mean values to evaluate the hazard. The dotted lines give 95% confidence intervals.

B Tables

Table 1: Data description (micro price data)

Variable	Source	Description
Q_q	author's calc.	Dummy = 1 in the qth quarter
Y_y :	author's calc.	Dummy = 1 in the y^{th} year
vat_{2001}	author's calc.	Dummy = 1 in the first quarter 2001
Foreign	FSO, author's calc.	Dummy = 1 if more than 75% of the elementary index item is imported according to the FSO (cf. *Foreign share* in Tables 3 to 6)
Small outlet	FSO	Dummy = 1 for single product, single family stores
Medium outlet	FSO	Dummy = 1 for regional stores with few branches
Large outlet	FSO	Dummy = 1 for firms operating nation-wide
$Sale^{FSO}$	FSO	Dummy = 1 for prices tagged as sales by the FSO. Includes end-of-season sales and temporary price cuts
$Sale^{eofs}$	FSO, author's calc.	Dummy = 1 for prices tagged as sales by the FSO and if the price spell is right-censored
$Sale^{FSOV}$	FSO, author's calc.	Dummy = 1 for prices tagged as sales by the FSO and $Sale^{V}$=1
$Sale^{other}$	FSO, author's calc.	Dummy = 1 if not an end-of-season sale or temporary price cut according to the FSO
$Sale^{V}$	author's calc.	Dummy = 1 for temporary price cuts defined as prices which drop for one period and return to their original level
$Sale^{pre}$	author's calc.	Dummy = 1 if the next price spell is either tagged as $Sale^{FSO}$ or $Sale^{V}$

Table 2: Data description (aggregate data)

Variable	Source	Seas. adj.	Description
$\Sigma\pi_t$	FSO	X12-D11	Accumulated q/q growth rates of the total CPI (in %)
$\Sigma\pi_t^{sub}$	FSO, author's calc.	X12-D11	Accumulated q/q growth rates at the CPI subsectors level (in %), (cf. also Tables 3 to 6)
$\Sigma\pi_t^{eii}$	FSO	X12-D11	Accumulated q/q growth rates at the CPI elementary index item level (COICOP 5-digit level) (in %), (cf. also Tables 3 to 6)
$\Sigma\Delta\tilde{p}_t$	FSO	X12-D11	Accumulated q/q growth rates of the wholesale price index (FSO: price index of total supply), subcomponent consumer goods (in %)
$\Sigma\Delta\tilde{w}_t$	SECO[1]	X12-D11	Accumulated q/q growth rates of wages, national accounts definition (in %)

[1] State secretariat for economic affairs.

Table 3: Definition of elementary index items and subsectors (processed food)

Elementary index item	Subsectors	Foreign share
Beer	Alcohol	.15
Foreign red wine	Alcohol	1
Foreign white wine	Alcohol	1
Liqueurs and aperitifs	Alcohol	.9
Sparkling wine	Alcohol	.8
Spirits/brandies	Alcohol	.8
Swiss red wine	Alcohol	0
Swiss white wine	Alcohol	0
Cocoa and nutritional beverages	Beverages	.2
Coffee	Beverages	.8
Fruit or vegetable juices	Beverages	.05
Natural mineral water	Beverages	.3
Soft drinks	Beverages	.05
Tea	Beverages	.5
Tinned fish and smoked fish	Fish	.98
Chocolate	Other food	.2
Ice-cream	Other food	.1
Jam and honey	Other food	.2
Ready-made foods	Other food	.1
Soups, spices, sauces	Other food	.4
Sugar	Other food	.6
Sweets and chewing gum	Other food	.2
Dried, frozen and tinned fruit	Fruits	.8
Cooked and processed meat	Processed meat	.1
Sausages	Processed meat	.1
Butter	Dairy products	.1
Cream	Dairy products	0
Fresh, soft and melted cheese	Dairy products	.4
Hard and other cheese	Dairy products	.1
Margarine, fats, edible oils	Dairy products	.25
Other dairy products	Dairy products	.1
Other type of milk	Dairy products	0
Whole milk	Dairy products	0
Dried, frozen, tinned vegetables, etc.	Vegetables	.4
Potato products	Vegetables	.4
Biscuit/rusk products	Grain products	.55
Bread	Grain products	.05
Flour	Grain products	.15
Other cereal products	Grain products	.25
Pasta	Grain products	.25
Rice	Grain products	1
Small baked goods	Grain products	.05
Viennese pastries, pastry products	Grain products	.1

Table 4: Definition of elementary index items and subsectors (unprocessed food)

Elementary index item	Subsectors	Foreign share
Fresh fish	Fish	.98
Frozen fish	Fish	.98
Bananas	Fruits	1
Citrus fruit	Fruits	1
Other fruits	Fruits	.6
Pome fruit	Fruits	.1
Stone fruit	Fruits	.7
Beef	Meat	.1
Lamb	Meat	.55
Other meat	Meat	.7
Pork	Meat	.1
Poultry	Meat	.6
Veal	Meat	.1
Eggs	Dairy products	.25
Brassicas	Vegetables	.3
Fruiting vegetables	Vegetables	.65
Onions	Vegetables	.1
Other vegetables	Vegetables	.65
Potatoes	Vegetables	.05
Root vegetables	Vegetables	.05
Salad vegetables	Vegetables	.3

Table 5: Definition of elementary index items and subsectors (industrial products)

Elementary index item	Subsectors	Foreign share
Major household appliances	Appliances	.65
Smaller electric household appliances	Appliances	.85
Newspapers, by subscription	Books	.05
Newspapers, purchased singly	Books	.5
Other printed matter	Books	.5
Writing and drawing materials	Books	.5
Computer software	Consumer electronics	1
PC hardware	Consumer electronics	1
Photographic, cinematographic equipment and optical instruments	Consumer electronics	1
Recording media	Consumer electronics	1
Television sets, audio and video appliances	Consumer electronics	1
Baby clothes	Clothing (Children)	.9
Children's hosiery and underwear	Clothing (Children)	.75
Men's underwear	Clothing (Men)	.75
Sportswear	Clothing (Sport)	.9
Summer/year-round sports articles, camping equipment	Clothing (Sport)	.9
Winter sports equipment	Clothing (Sport)	.9
Women's jumpers	Clothing (Women)	.9
Women's underwear	Clothing (Women)	.75
Telephone equipment	Communication	.8
Bed linen and household linen	Furniture	.65
Bedroom	Furniture	.7
Curtains and curtain accessories	Furniture	.65
Floor coverings and carpets	Furniture	.7
Furnishings	Furniture	.7
Kitchen and garden	Furniture	.7
Kitchen utensils	Furniture	.65
Living room	Furniture	.7
Other household utensils	Furniture	.65
Tableware and cutlery	Furniture	.65
Games, toys and hobbies	Other goods	.92
Musical instruments	Other goods	.95
Pets and related products	Other goods	.95
Plants and flowers	Other goods	.65
First aid material	Health	.25
Therapeutic appliances	Health	.2
Cleaning articles	Maintenance goods	.6
Detergents and cleaning products	Maintenance goods	.6
Garment fabrics	Maintenance goods	.85
Haberdashery and knitting wool	Maintenance goods	.85
Other clothing accessories	Maintenance goods	.85
Other household articles	Maintenance goods	.6
Products for housing maintenance and repair	Maintenance goods	.5
Spare parts	Maintenance goods	1
Tyres and accessories	Maintenance goods	.9
Beauty products and cosmetics	Personal goods	.4
Dental-care products	Personal goods	.4
Hair-care products	Personal goods	.4
Paper articles for personal hygiene	Personal goods	.15
Personal care appliances	Personal goods	.25
Soaps and foam baths	Personal goods	.4
Other personal effects	Other personal goods	.8
Watches	Other personal goods	.25
Equipment and other accessories for house and garden	Tools	.65
Motorized tools for DIY and garden	Tools	.85
Tools for house and garden	Tools	.85
Bicycles	Vehicles	.7
Motorcycles	Vehicles	1
New cars	Vehicles	1
Second-hand cars	Vehicles	0

Table 6: Definition of elementary index items and subsectors (services)

Elementary index item	Subsectors	Foreign share
Beverages in canteens	Beverages (e.g. in restaurants)	0
Financial services	Financial services	0
Cinema	Leisure	0
Leisure-time courses	Leisure	0
Photographic services	Leisure	0
Radio and television licences	Leisure	0
Sporting events	Leisure	0
Sports and leisure activities	Leisure	0
Theatre and concerts	Leisure	0
Veterinary services for pets	Leisure	0
Garment alterations	Maintenance services	0
Household cleaning services	Maintenance services	0
Repair and installation	Maintenance services	0
Repair services and work	Maintenance services	0
Shoe repairs	Maintenance services	0
Upkeep of textiles	Maintenance services	0
Car insurance	Other services	0
Other services	Other services	0
Other services in respect of personal transport equipment	Administered transport	0
Public transport: direct service	Administered transport	0
Taxi	Administered transport	0
Air transport	Vacation	0
Alternative accommodation facilities	Vacation	0
Hotels	Vacation	0
Package holidays	Vacation	.6

Table 7: Descriptive statistics (excluding sales)

(a) Processed food

	mean	median	std.dev.
Foreign	15.82	0.00	36.49
Small outlet	34.89	0.00	47.66
Medium outlet	34.11	0.00	47.41
Large outlet	30.99	0.00	46.25
Q_1	23.76	0.00	42.56
Q_2	24.84	0.00	43.21
Q_3	25.71	0.00	43.70
Q_4	25.69	0.00	43.69
vat_{01}	1.91	0.00	13.70
Duration	5.23	4.00	4.48
$\Sigma\pi_t$	1.07	0.76	0.98
$\Sigma\pi_t^{sub}$	1.48	0.92	1.82
$\Sigma\pi_t^{eii}$	1.59	1.00	1.72
$\Sigma\Delta\tilde{p}_t$	0.59	0.45	0.50
$\Sigma\Delta w_t$	3.17	2.31	3.16

(b) Unprocessed food

	mean	median	std.dev.
Foreign	12.52	0.00	33.10
Small outlet	32.60	0.00	46.88
Medium outlet	17.50	0.00	38.00
Large outlet	49.90	0.00	50.00
Q_1	23.61	0.00	42.47
Q_2	24.28	0.00	42.88
Q_3	26.25	0.00	44.00
Q_4	25.87	0.00	43.79
vat_{2001}	2.71	0.00	16.23
Duration	3.39	2.00	3.57
$\Sigma\pi_t$	0.71	0.44	0.78
$\Sigma\pi_t^{sub}$	2.46	1.54	2.45
$\Sigma\pi_t^{eii}$	3.57	2.31	3.90
$\Sigma\Delta\tilde{p}_t$	0.49	0.39	0.43
$\Sigma\Delta w_t$	2.32	1.36	2.47

(c) Industrial products

	mean	median	std.dev.
Foreign	49.53	0.00	50.00
Small outlet	49.90	0.00	50.00
Medium outlet	23.68	0.00	42.51
Large outlet	26.42	0.00	44.09
Q_1	23.80	0.00	42.59
Q_2	24.94	0.00	43.27
Q_3	25.51	0.00	43.59
Q_4	25.75	0.00	43.72
vat_{01}	1.70	0.00	12.92
Duration	4.53	3.00	4.06
$\Sigma\pi_t$	0.93	0.66	0.88
$\Sigma\pi_t^{sub}$	1.74	0.68	3.13
$\Sigma\pi_t^{eii}$	2.06	1.03	3.15
$\Sigma\Delta\tilde{p}_t$	0.53	0.43	0.44
$\Sigma\Delta w_t$	2.80	1.94	2.72

(d) Services

	mean	median	std.dev.
Foreign	0.00	0.00	0.00
Small outlet	42.33	0.00	49.41
Medium outlet	12.99	0.00	33.62
Large outlet	44.68	0.00	49.72
Q_1	25.98	0.00	43.85
Q_2	24.65	0.00	43.10
Q_3	24.65	0.00	43.09
Q_4	24.73	0.00	43.14
vat_{01}	1.93	0.00	13.77
Duration	4.04	3.00	3.78
$\Sigma\pi_t$	0.84	0.56	0.84
$\Sigma\pi_t^{sub}$	1.84	1.27	1.89
$\Sigma\pi_t^{eii}$	1.95	1.09	2.38
$\Sigma\Delta\tilde{p}_t$	0.48	0.39	0.39
$\Sigma\Delta w_t$	2.75	1.94	2.53

Note: The table gives descriptive statistics for the micro price and aggregate data excluding sales prices. Dummy variables are multiplied by 100 and thus the mean values denote percentage shares. Statistics on time-varying covariates give average accumulated q/q rates (in %) of changes over a price spell. Average trend values can be obtained through dividing by the average duration.

Table 8: Descriptive statistics (including sales)

(a) Processed food

	mean	median	std.dev.
Foreign	16.08	0.00	36.74
Small outlet	34.25	0.00	47.46
Medium outlet	33.84	0.00	47.32
Large outlet	31.91	0.00	46.61
Q_1	23.82	0.00	42.60
Q_2	24.87	0.00	43.23
Q_3	25.70	0.00	43.70
Q_4	25.61	0.00	43.65
vat_{2001}	1.96	0.00	13.85
$Sale^{FSO}$	4.20	0.00	20.05
$Sale^{V}$	1.62	0.00	12.63
$Sale^{pre}$	11.53	0.00	31.93
Duration	5.11	4.00	4.46
$\Sigma\pi_t$	1.04	0.75	0.97
$\Sigma\pi_t^{sub}$	1.46	0.88	1.82
$\Sigma\pi_t^{eii}$	1.56	0.97	1.70
$\Sigma\Delta\tilde{p}_t$	0.58	0.45	0.50
$\Sigma\Delta w_t$	3.09	2.15	3.13

(b) Unprocessed food

	mean	median	std.dev.
Foreign	12.61	0.00	33.20
Small outlet	32.29	0.00	46.76
Medium outlet	17.62	0.00	38.10
Large outlet	50.09	0.00	50.00
Q_1	23.62	0.00	42.48
Q_2	24.27	0.00	42.87
Q_3	26.15	0.00	43.95
Q_4	25.95	0.00	43.84
vat_{2001}	2.71	0.00	16.22
$Sale^{FSO}$	5.14	0.00	22.07
$Sale^{V}$	2.02	0.00	14.06
$Sale^{pre}$	12.74	0.00	33.34
Duration	3.38	2.00	3.56
$\Sigma\pi_t$	0.71	0.43	0.77
$\Sigma\pi_t^{sub}$	2.46	1.54	2.46
$\Sigma\pi_t^{eii}$	3.56	2.29	3.92
$\Sigma\Delta\tilde{p}_t$	0.49	0.39	0.43
$\Sigma\Delta w_t$	2.30	1.35	2.45

(c) Industrial products

	mean	median	std.dev.
Foreign	49.39	0.00	50.00
Small outlet	49.49	0.00	50.00
Medium outlet	23.48	0.00	42.39
Large outlet	27.03	0.00	44.41
Q_1	23.79	0.00	42.58
Q_2	24.98	0.00	43.29
Q_3	25.58	0.00	43.63
Q_4	25.65	0.00	43.67
vat_{2001}	1.70	0.00	12.94
$Sale^{FSO}$	5.18	0.00	22.15
$Sale^{V}$	0.74	0.00	8.58
$Sale^{pre}$	5.57	0.00	22.94
Duration	4.45	3.00	4.02
$\Sigma\pi_t$	0.91	0.64	0.87
$\Sigma\pi_t^{sub}$	1.71	0.67	3.08
$\Sigma\pi_t^{eii}$	2.02	1.01	3.10
$\Sigma\Delta\tilde{p}_t$	0.52	0.43	0.44
$\Sigma\Delta w_t$	2.76	1.89	2.70

(d) Services

	mean	median	std.dev.
Foreign	0.00	0.00	0.00
Small outlet	42.40	0.00	49.42
Medium outlet	12.96	0.00	33.58
Large outlet	44.65	0.00	49.72
Q_1	26.00	0.00	43.87
Q_2	24.72	0.00	43.14
Q_3	24.61	0.00	43.07
Q_4	24.67	0.00	43.11
vat_{2001}	2.00	0.00	13.99
$Sale^{FSO}$	0.60	0.00	7.69
$Sale^{V}$	0.44	0.00	6.60
$Sale^{pre}$	1.39	0.00	11.71
Duration	4.04	3.00	3.80
$\Sigma\pi_t$	0.83	0.56	0.84
$\Sigma\pi_t^{sub}$	1.84	1.27	1.89
$\Sigma\pi_t^{eii}$	1.94	1.07	2.39
$\Sigma\Delta\tilde{p}_t$	0.48	0.39	0.39
$\Sigma\Delta w_t$	2.75	1.94	2.54

Note: The table gives descriptive statistics for the micro price and aggregate data including sales prices. Dummy variables are multiplied by 100 and thus the mean values denote percentage shares. Statistics on time-varying covariates give average accumulated q/q rates (in %) of changes over a price spell. Average trend values can be obtained through dividing by the average duration.

Table 9: Hazard model ignoring unobserved and observed heterogeneity

	(1) Processed food	(2) Unprocessed food	(3) Industrial products	(4) Services
λ_1	-1.709***	-0.438***	-1.411***	-1.604***
	[0.0135]	[0.00875]	[0.00815]	[0.0177]
λ_2	-1.640***	-1.050***	-1.701***	-2.334***
	[0.0148]	[0.0158]	[0.0111]	[0.0292]
λ_3	-1.860***	-1.159***	-1.777***	-2.535***
	[0.0185]	[0.0203]	[0.0132]	[0.0340]
λ_4	-1.793***	-0.549***	-1.382***	-0.531***
	[0.0200]	[0.0194]	[0.0126]	[0.0149]
λ_5	-2.083***	-1.540***	-1.951***	-2.189***
	[0.0258]	[0.0401]	[0.0194]	[0.0533]
λ_6	-2.126***	-1.898***	-2.183***	-3.151***
	[0.0287]	[0.0542]	[0.0243]	[0.0995]
λ_7	-2.219***	-1.984***	-2.191***	-3.202***
	[0.0328]	[0.0627]	[0.0269]	[0.105]
λ_8	-2.015***	-1.476***	-1.847***	-0.956***
	[0.0324]	[0.0547]	[0.0252]	[0.0390]
λ_9	-2.237***	-1.959***	-2.142***	-2.461***
	[0.0400]	[0.0789]	[0.0328]	[0.0958]
λ_{10}	-2.246***	-2.230***	-2.408***	-3.312***
	[0.0437]	[0.101]	[0.0414]	[0.158]
λ_{11}	-2.164***	-2.337***	-2.350***	-2.816***
	[0.0460]	[0.115]	[0.0437]	[0.129]
λ_{12}	-2.208***	-1.945***	-2.103***	-1.267***
	[0.0515]	[0.104]	[0.0435]	[0.0664]
λ_{13}	-2.176***	-2.330***	-2.278***	-2.613***
	[0.0566]	[0.140]	[0.0531]	[0.153]
λ_{14}	-2.364***	-2.506***	-2.525***	-3.974***
	[0.0682]	[0.164]	[0.0661]	[0.316]
$\lambda_{>14}$	-1.962***	-2.058***	-2.243***	-2.453***
	[0.0300]	[0.0697]	[0.0310]	[0.0744]
Observations	169,419	73,328	286,332	69,823
Sample	excl. sales	excl. sales	excl. sales	excl. sales
Log-likelihood.	-68,193.3	-44,039.6	-125,316.1	-27,778.6

Note: The table gives estimation results for the hazard model. Robust standard errors (clustered by individual products) are given in brackets; *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$. λ_t : hazard dummies for every duration.

Table 10: Hazard model accounting for unobserved heterogeneity

	(1) Processed food	(2) Unprocessed food	(3) Industrial products	(4) Services
λ_1	-1.862***	-0.604***	-1.876***	-3.162***
	[0.0176]	[0.0139]	[0.0132]	[0.0439]
λ_2	-1.746***	-0.900***	-1.945***	-3.263***
	[0.0170]	[0.0191]	[0.0135]	[0.0452]
λ_3	-1.926***	-0.815***	-1.895***	-3.092***
	[0.0196]	[0.0241]	[0.0148]	[0.0464]
λ_4	-1.825***	-0.00600	-1.389***	-0.493***
	[0.0207]	[0.0253]	[0.0141]	[0.0321]
λ_5	-2.086***	-0.851***	-1.867***	-1.881***
	[0.0263]	[0.0445]	[0.0205]	[0.0610]
λ_6	-2.106***	-1.141***	-2.036***	-2.793***
	[0.0292]	[0.0581]	[0.0254]	[0.104]
λ_7	-2.177***	-1.174***	-1.994***	-2.774***
	[0.0334]	[0.0666]	[0.0280]	[0.110]
λ_8	-1.952***	-0.607***	-1.592***	-0.302***
	[0.0331]	[0.0599]	[0.0266]	[0.0514]
λ_9	-2.154***	-1.034***	-1.828***	-1.542***
	[0.0408]	[0.0832]	[0.0341]	[0.103]
λ_{10}	-2.143***	-1.267***	-2.051***	-2.304***
	[0.0446]	[0.104]	[0.0426]	[0.163]
λ_{11}	-2.042***	-1.346***	-1.953***	-1.730***
	[0.0471]	[0.119]	[0.0451]	[0.135]
λ_{12}	-2.067***	-0.917***	-1.656***	-0.0366
	[0.0528]	[0.109]	[0.0451]	[0.0800]
λ_{13}	-2.015***	-1.268***	-1.783***	-1.236***
	[0.0581]	[0.144]	[0.0548]	[0.161]
λ_{14}	-2.187***	-1.422***	-1.989***	-2.541***
	[0.0697]	[0.168]	[0.0677]	[0.321]
$\lambda_{>14}$	-1.722***	-0.875***	-1.583***	-0.811***
	[0.0354]	[0.0821]	[0.0359]	[0.0963]
$\ln(\sigma^2)$	-1.516***	-0.220***	-0.243***	1.286***
	[0.0768]	[0.0388]	[0.0245]	[0.0338]
Observations	169,419	73,328	286332	69,823
Individual products	16,106	10,711	31,976	6,204
Sample	excl. sales	excl. sales	excl. sales	excl. sales
LR: $\sigma^2 = 0$	229.3	2,051.4	3,756.4	6,491.5
p-value: $\sigma^2 = 0$	0.000	0.000	0.000	0.000
Log-likelihood	-68,078.7	-43,013.9	-123,437.9	-24,532.9

Note: The table gives estimation results for the hazard model. Robust standard errors (clustered by individual products) are given in brackets; *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$. The random effect controls for unobserved heterogeneity at the level of individual products. Its distribution is assumed to be log-normal. σ^2 denotes its estimated variance. For the distribution of the likelihood-ratio test statistic (LR) of H_0: $\sigma^2 = 0$ cf. Gutierrez et al. (2001). λ_t : hazard dummies for every duration.

Table 11: Hazard model accounting for unobserved heterogeneity and dummy variables

	(1) Processed food	(2) Unprocessed food	(3) Industrial products	(4) Services
Q_2	-0.0753***	0.151***	-0.184***	-0.172***
	[0.0192]	[0.0210]	[0.0135]	[0.0325]
Q_3	-0.112***	0.248***	-0.174***	-0.381***
	[0.0195]	[0.0209]	[0.0136]	[0.0330]
Q_4	0.0451**	0.0802***	-0.224***	-0.121***
	[0.0194]	[0.0217]	[0.0140]	[0.0304]
Y_{2000}	0.201***	0.0338	0.351***	0.372***
	[0.0497]	[0.0452]	[0.0421]	[0.122]
Y_{2001}	0.155***	0.202***	0.000820	-0.785***
	[0.0285]	[0.0323]	[0.0237]	[0.0619]
Y_{2002}	0.00798	0.0574**	-0.0571***	-0.616***
	[0.0250]	[0.0291]	[0.0194]	[0.0457]
Y_{2003}	-0.0515**	0.0674**	0.0289	-0.401***
	[0.0241]	[0.0275]	[0.0176]	[0.0399]
Y_{2004}	-0.0248	0.0427	-0.0654***	-0.159***
	[0.0233]	[0.0260]	[0.0170]	[0.0353]
Y_{2006}	0.504***	0.324***	0.361***	0.615***
	[0.0268]	[0.0319]	[0.0191]	[0.0368]
Y_{2007}	1.361***	0.980***	1.112***	1.118***
	[0.0258]	[0.0344]	[0.0198]	[0.0489]
vat_{2001}	0.477***	0.140***	0.376***	0.398***
	[0.0449]	[0.0483]	[0.0382]	[0.116]
Foreign	0.0452**	-0.121***	0.309***	
	[0.0197]	[0.0338]	[0.0141]	
Large outlet	0.186***	0.182***	0.378***	0.640***
	[0.0181]	[0.0312]	[0.0193]	[0.0803]
Small outlet	-0.181***	-0.396***	-0.111***	1.626***
	[0.0180]	[0.0334]	[0.0175]	[0.0805]
$\ln(\sigma^2)$	-2.089***	-0.332***	-0.493***	0.915***
	[0.125]	[0.0403]	[0.0267]	[0.0359]
Observations	169,419	73,328	286,332	69,823
Individual products	16,106	10,711	31,976	6,204
Sample	excl. sales	excl. sales	excl. sales	excl. sales
LR: $\sigma^2 = 0$	75.02	1,785.4	2,823.4	4,501.3
p-value: $\sigma^2 = 0$	0.000	0.000	0.000	0.000
Log-likelihood	-65,925.4	-42,151.4	-119,900.3	-23,504.1

Note: The table gives estimation results for the hazard model. Robust standard errors (clustered by individual products) are given in brackets; *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$. The random effect controls for unobserved heterogeneity at the level of individual products. Its distribution is assumed to be log-normal. σ^2 denotes its estimated variance. For the distribution of the likelihood-ratio test statistic (LR) of H_0: $\sigma^2 = 0$ cf. Gutierrez et al. (2001). Hazard dummies are not reported for reasons of brevity. Y_y : Dummies equal 1 in the y^{th} year; Q_q : Dummies equal 1 in the qth quarter; vat_{2001} : Dummy for VAT change equals 1 in the first quarter 2001; *Foreign* : Dummy equals 1 if the good is mostly imported; *Large outlet* : Dummy equals 1 if the firm operates nation-wide; *Small outlet* : Dummy equals 1 if the firm operates only locally.

Table 12: Hazard model accounting for unobserved heterogeneity, dummy variables and TVC

	(1) Processed food	(2) Unprocessed food	(3) Industrial products	(4) Services
$\Sigma\pi_t$	0.328***	0.242***	-0.0217	-0.0713
	[0.0269]	[0.0371]	[0.0203]	[0.0496]
$\Sigma\pi_t^{sec}$	0.0214***	0.0339***	-0.0254***	0.111***
	[0.00459]	[0.00454]	[0.00347]	[0.0126]
$\Sigma\pi_t^{eii}$	0.0165***	0.0248***	0.0198***	0.0255***
	[0.00506]	[0.00251]	[0.00312]	[0.00800]
$\Sigma\Delta\tilde{p}_t$	0.343***	0.264***	0.372***	0.343***
	[0.0207]	[0.0273]	[0.0167]	[0.0427]
$\Sigma\Delta w_t$	-0.0110**	0.0249***	0.0573***	0.0478***
	[0.00496]	[0.00737]	[0.00412]	[0.0118]
Q_2	-0.0740***	0.161***	-0.190***	-0.299***
	[0.0194]	[0.0212]	[0.0135]	[0.0324]
Q_3	-0.134***	0.272***	-0.173***	-0.404***
	[0.0197]	[0.0212]	[0.0138]	[0.0324]
Q_4	0.0322	0.114***	-0.201***	-0.453***
	[0.0197]	[0.0221]	[0.0143]	[0.0349]
vat_{2001}	0.435***	0.149***	0.269***	-0.00158
	[0.0463]	[0.0505]	[0.0390]	[0.115]
Foreign	0.0524**	-0.0637*	0.322***	
	[0.0204]	[0.0335]	[0.0149]	
Large outlet	0.202***	0.186***	0.370***	0.543***
	[0.0188]	[0.0308]	[0.0195]	[0.0808]
Small outlet	-0.179***	-0.392***	-0.121***	1.257***
	[0.0187]	[0.0330]	[0.0177]	[0.0782]
$\ln(\sigma^2)$	-1.786***	-0.379***	-0.464***	0.647***
	[0.0950]	[0.0409]	[0.0264]	[0.0439]
Observations	169,419	73,328	286,318	52,413
Individual products	16,106	10,711	31,974	5,330
Sample	excl. sales	excl. sales	excl. sales	excl. sales
LR: $\sigma^2 = 0$	139.7	1,706.1	2,995.1	2,555.4
p: $\sigma^2 = 0$	0.000	0.000	0.000	0.000
Log-likelihood	-65,546.6	-41,893.0	-119,383.3	-19,743.3

Note: The table gives estimation results for the hazard model. Robust standard errors (clustered by individual products) are given in brackets; *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$. The random effect controls for unobserved heterogeneity at the level of individual products. Its distribution is assumed to be log-normal. σ^2 denotes its estimated variance. For the distribution of the likelihood-ratio test statistic (LR) of H_0: $\sigma^2 = 0$ cf. Gutierrez et al. (2001). Hazard and yearly dummies are not reported for reasons of. $\Sigma\pi_t$: accumulated q/q growth rate (total, subsectors, elementary index item level) CPI inflation; $\Sigma\Delta\tilde{p}_t$: accumulated q/q growth rate consumer goods inflation at the wholesale stage; $\Sigma\Delta w_t$: accumulated q/q growth rate wage inflation; Q_q: Dummies equal 1 in the qth quarter; vat_{2001}: Dummy for VAT change equals 1 in the first quarter 2001; *Foreign*: Dummy equals 1 if the good is mostly imported; *Large outlet*: Dummy equals 1 if the firm operates nation-wide; *Small outlet*: Dummy equals 1 if the firm operates only locally.

Table 13: Hazard model accounting for unobserved heterogeneity, dummy variables and TVC, incl. sales prices, excl. sales dummies

	(1) Processed food	(2) Unprocessed food	(3) Industrial products	(4) Services
$\Sigma\pi_t$	0.283***	0.253***	-0.00137	-0.0818*
	[0.0255]	[0.0356]	[0.0186]	[0.0487]
$\Sigma\pi_t^{sub}$	0.0120***	0.0307***	-0.0184***	0.0971***
	[0.00455]	[0.00446]	[0.00316]	[0.0123]
$\Sigma\pi_t^{eii}$	0.0118**	0.0206***	0.0184***	0.0291***
	[0.00498]	[0.00242]	[0.00285]	[0.00760]
$\Sigma\Delta\tilde{p}_t$	0.296***	0.246***	0.359***	0.327***
	[0.0194]	[0.0266]	[0.0154]	[0.0419]
$\Sigma\Delta w_t$	0.00854*	0.0202***	0.0544***	0.0420***
	[0.00470]	[0.00712]	[0.00378]	[0.0116]
Q_2	-0.0608***	0.175***	-0.189***	-0.254***
	[0.0172]	[0.0205]	[0.0125]	[0.0314]
Q_3	-0.0620***	0.259***	-0.121***	-0.351***
	[0.0175]	[0.0207]	[0.0126]	[0.0316]
Q_4	0.118***	0.157***	-0.150***	-0.443***
	[0.0175]	[0.0214]	[0.0130]	[0.0343]
vat_{2001}	0.334***	0.263***	0.211***	0.123
	[0.0420]	[0.0487]	[0.0361]	[0.106]
Foreign	0.0599***	-0.0643**	0.225***	
	[0.0198]	[0.0309]	[0.0130]	
Large outlet	0.192***	0.182***	0.376***	0.577***
	[0.0181]	[0.0285]	[0.0171]	[0.0774]
Small outlet	-0.253***	-0.350***	-0.0914***	1.237***
	[0.0184]	[0.0304]	[0.0157]	[0.0751]
$\ln(\sigma^2)$	-1.248***	-0.576***	-0.743***	0.558***
	[0.0517]	[0.0431]	[0.0276]	[0.0434]
Observations	182,696	75,400	310,399	52,883
Individual products	16,948	10,937	33,281	5,359
Sample	incl. sales	incl. sales	incl. sales	incl. sales
LR: $\sigma^2 = 0$	588.3	1,421.5	2,521.4	2,516.6
p-value: $\sigma^2 = 0$	0.000	0.000	0.000	0.000
Log-likelihood.	-77,983.9	-43,254.2	-136,643.2	-20,373.9

Note: The table gives estimation results for the hazard model. Robust standard errors (clustered by individual products) are given in brackets; *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$. The random effect controls for unobserved heterogeneity at the level of individual products. Its distribution is assumed to be log-normal. σ^2 denotes its estimated variance. For the distribution of the likelihood-ratio test statistic (LR) of H_0: $\sigma^2 = 0$ cf. Gutierrez et al. (2001). Hazard and yearly dummies are not reported for reasons of. $\Sigma\pi_t$: accumulated q/q growth rate (total, subsectors, elementary index item level) CPI inflation; $\Sigma\Delta\tilde{p}_t$: accumulated q/q growth rate consumer goods inflation at the wholesale stage; $\Sigma\Delta w_t$: accumulated q/q growth rate wage inflation; Q_q: Dummies equal 1 in the qth quarter; vat_{2001}: Dummy for VAT change equals 1 in the first quarter 2001; *Foreign*: Dummy equals 1 if the good is mostly imported; *Large outlet*: Dummy equals 1 if the firm operates nation-wide; *Small outlet*: Dummy equals 1 if the firm operates only locally.

Table 14: Hazard model accounting for unobserved heterogeneity, dummy variables and TVC, incl. sales prices, incl. sales dummies

	(1) Processed food	(2) Unprocessed food	(3) Industrial products	(4) Services
$\Sigma\pi_t$	0.159***	0.287***	0.0102	-0.0763
	[0.0228]	[0.0365]	[0.0190]	[0.0496]
$\Sigma\pi_t^{sub}$	-0.0035	0.0333***	-0.0225***	0.104***
	[0.00466]	[0.00458]	[0.00325]	[0.0126]
$\Sigma\pi_t^{eii}$	-0.0031	0.0230***	0.0189***	0.0203**
	[0.00504]	[0.00249]	[0.00293]	[0.00789]
$\Sigma\Delta\tilde{p}_t$	0.450***	0.244***	0.364***	0.328***
	[0.0162]	[0.0272]	[0.0157]	[0.0428]
$\Sigma\Delta w_t$	0.0845***	0.0156**	0.0529***	0.0399***
	[0.00374]	[0.00731]	[0.00386]	[0.0118]
Q_2	-0.126***	0.183***	-0.196***	-0.255***
	[0.01776]	[0.0212]	[0.0126]	[0.0322]
Q_3	-0.187***	0.278***	-0.158***	-0.374***
	[0.01790]	[0.0213]	[0.0128]	[0.0325]
Q_4	-0.027	0.150***	-0.171***	-0.450***
	[0.01737]	[0.0221]	[0.0133]	[0.0351]
vat_{2001}	0.047	0.295***	0.224***	0.153
	[0.03957]	[0.0503]	[0.0370]	[0.111]
Foreign	0.059***	-0.0687**	0.288***	
	[0.02033]	[0.0329]	[0.0137]	
Large outlet	0.191***	0.167***	0.310***	0.536***
	[0.01871]	[0.0302]	[0.0179]	[0.0817]
Small outlet	-0.149***	-0.345***	-0.0969***	1.260***
	[0.01890]	[0.0323]	[0.0163]	[0.0792]
$Sale^{FSO}$	1.387***	0.492***	0.691***	2.015***
	[0.02794]	[0.0363]	[0.0208]	[0.163]
$Sale^{V}$	3.717***	3.594***	3.731***	5.249***
	[0.10020]	[0.225]	[0.0851]	[0.489]
$Sale^{pre}$	0.773***	0.286***	0.659***	0.681***
	[0.01798]	[0.0234]	[0.0196]	[0.0918]
$\ln(\sigma^2)$	-1.285***	-0.423***	-0.616***	0.686***
	[0.0526]	[0.0421]	[0.0266]	[0.0433]
Observations	182,696	75,400	310,399	52,883
Individual products	16,948	10,937	33,281	5,359
Sample	incl. sales	incl. sales	incl. sales	incl. sales
LR: $\sigma^2 = 0$	421.0	1,547.6	2,818.5	2,683.9
p: $\sigma^2 = 0$	0.000	0.000	0.000	0.000
Log-likelihood	-72,086.2	-41,943.5	-132,412.6	-19,781.2

Note: The table gives estimation results for the hazard model. Robust standard errors (clustered by individual products) are given in brackets; *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$. The random effect controls for unobserved heterogeneity at the level of individual products. Its distribution is assumed to be log-normal. σ^2 denotes its estimated variance. For the distribution of the likelihood-ratio test statistic (LR) of H_0: $\sigma^2 = 0$ cf. Gutierrez et al. (2001). Hazard and yearly dummies are not reported for reasons of. $\Sigma\pi_t$: accumulated q/q growth rate (total, subsectors, elementary index item level) CPI inflation; $\Sigma\Delta\tilde{p}_t$: accumulated q/q growth rate consumer goods inflation at the wholesale stage; $\Sigma\Delta w_t$: accumulated q/q growth rate wage inflation; Q_q: Dummies equal 1 in the qth quarter; vat_{2001}: Dummy for VAT change equals 1 in the first quarter 2001; *Foreign*: Dummy equals 1 if the good is mostly imported; *Large outlet*: Dummy equals 1 if the firm operates nation-wide; *Small outlet*: Dummy equals 1 if the firm operates only locally.

Table 15: Effect of wholesale price inflation on mean price durations

(a) Processed food

$\Delta\tilde{p}_t$	D	$D^l_{95\%}$	$D^u_{95\%}$	z-stat
0.1	7.0	6.8	7.3	
0.2	5.9	5.7	6.2	-31.7
0.3	5.1	4.9	5.4	-36.8
0.5	4.6	4.4	4.8	-41.5

(b) Unprocessed food

$\Delta\tilde{p}_t$	D	$D^l_{95\%}$	$D^u_{95\%}$	z-stat
0.1	3.1	3.0	3.2	
0.3	2.9	2.7	3.0	-10.7
0.4	2.7	2.6	2.8	-11.9
0.6	2.6	2.4	2.7	-13.1

(c) Industrial products

$\Delta\tilde{p}_t$	D	$D^l_{95\%}$	$D^u_{95\%}$	z-stat
0.1	6.6	6.4	6.8	
0.2	5.8	5.6	6.0	-25.4
0.4	5.1	4.9	5.3	-30.3
0.5	4.6	4.4	4.8	-35.9

(d) Services

$\Delta\tilde{p}_t$	D	$D^l_{95\%}$	$D^u_{95\%}$	z-stat
0.1	7.2	6.4	8.0	
0.2	6.4	5.6	7.1	-8.0
0.4	5.7	4.9	6.4	-9.3
0.5	5.1	4.4	5.9	-11.0

Note: The table presents mean price durations (in quarters) implied by the hazard model (cf. Table 14) for different trend paths of the time-varying covariates. The first column gives the assumed q/q trend growth rates over a price spell. The first row corresponds to the case where all covariates are assumed to follow their mean growth rate in the sample. The preceding rows give the results for higher growth rates of the corresponding covariate. The second and third columns give 95% upper ($D^u_{95\%}$) and lower ($D^l_{95\%}$) confidence bounds. In addition, the last column presents a test statistic, which is asymptotically normal, where the null hypothesis is that the corresponding mean duration is equal to the baseline mean duration in the first row. The confidence bounds and the test statistic are calculated with standard errors based on the delta-method.

Table 16: Effect of wage inflation on mean price durations

(a) Processed food

Δw_t	D	$D^l_{95\%}$	$D^u_{95\%}$	z-stat
0.6	7.0	6.8	7.3	
1.2	5.9	5.7	6.1	-22.4
1.8	5.1	4.9	5.3	-26.6
2.4	4.5	4.3	4.7	-30.5

(b) Unprocessed food

Δw_t	D	$D^l_{95\%}$	$D^u_{95\%}$	z-stat
0.7	3.1	3.0	3.2	
1.4	3.0	2.9	3.1	-2.2
2.0	2.9	2.8	3.1	-2.3
2.7	2.9	2.7	3.1	-2.4

(c) Industrial products

Δw_t	D	$D^l_{95\%}$	$D^u_{95\%}$	z-stat
0.6	6.6	6.4	6.8	
1.2	5.9	5.8	6.1	-14.3
1.9	5.3	5.1	5.6	-16.2
2.5	4.9	4.6	5.1	-18.9

(d) Services

Δw_t	D	$D^l_{95\%}$	$D^u_{95\%}$	z-stat
0.7	7.2	6.4	8.0	
1.4	6.6	5.8	7.4	-3.5
2.0	6.0	5.1	6.9	-3.9
2.7	5.5	4.6	6.5	-4.5

Note: The table presents mean price durations (in quarters) implied by the hazard model (cf. Table 14) for different trend paths of the time-varying covariates. The first column gives the assumed q/q trend growth rates over a price spell. The first row corresponds to the case where all covariates are assumed to follow their mean growth rate in the sample. The preceding rows give the results for higher growth rates of the corresponding covariate. The second and third columns give 95% upper ($D^u_{95\%}$) and lower ($D^l_{95\%}$) confidence bounds. In addition, the last column presents a test statistic, which is asymptotically normal, where the null hypothesis is that the corresponding mean duration is equal to the baseline mean duration in the first row. The confidence bounds and the test statistic are calculated with standard errors based on the delta-method.

Table 17: Effect of elementary index item level inflation on mean price durations

(a) Processed food

π_t^{eii}	D	$D_{95\%}^l$	$D_{95\%}^u$	z-stat
0.3	7.0	6.8	7.3	
0.6	7.0	6.8	7.3	0.6
0.9	7.0	6.7	7.3	0.6
1.2	7.1	6.7	7.4	0.6

(b) Unprocessed food

π_t^{eii}	D	$D_{95\%}^l$	$D_{95\%}^u$	z-stat
1.1	3.1	3.0	3.2	
2.1	2.9	2.8	3.0	-9.8
3.2	2.8	2.7	2.9	-10.7
4.2	2.7	2.5	2.8	-11.6

(c) Industrial products

π_t^{eii}	D	$D_{95\%}^l$	$D_{95\%}^u$	z-stat
0.5	6.6	6.4	6.8	
0.9	6.4	6.2	6.6	-6.5
1.4	6.3	6.0	6.5	-6.6
1.8	6.1	5.8	6.3	-6.8

(d) Services

π_t^{eii}	D	$D_{95\%}^l$	$D_{95\%}^u$	z-stat
0.5	7.2	6.4	8.0	
1.0	7.0	6.2	7.8	-2.6
1.4	6.8	5.9	7.6	-2.7
1.9	6.5	5.6	7.4	-2.7

Note: The table presents mean price durations (in quarters) implied by the hazard model (cf. Table 14) for different trend paths of the time-varying covariates. The first column gives the assumed q/q trend growth rates over a price spell. The first row corresponds to the case where all covariates are assumed to follow their mean growth rate in the sample. The preceding rows give the results for higher growth rates of the corresponding covariate. The second and third columns give 95% upper ($D_{95\%}^u$) and lower ($D_{95\%}^l$) confidence bounds. In addition, the last column presents a test statistic, which is asymptotically normal, where the null hypothesis is that the corresponding mean duration is equal to the baseline mean duration in the first row. The confidence bounds and the test statistic are calculated with standard errors based on the delta-method.

Table 18: Effect of subsector level inflation on mean price durations

(a) Processed food

π_t^{sub}	D	$D_{95\%}^l$	$D_{95\%}^u$	z-stat
0.3	7.0	6.8	7.3	
0.6	7.0	6.8	7.3	0.7
0.9	7.0	6.8	7.3	0.7
1.1	7.1	6.7	7.4	0.7

(b) Unprocessed food

π_t^{sub}	D	$D_{95\%}^l$	$D_{95\%}^u$	z-stat
0.7	3.1	3.0	3.2	
1.5	2.9	2.8	3.0	-8.1
2.2	2.8	2.6	2.9	-8.9
2.9	2.7	2.5	2.8	-9.6

(c) Industrial products

π_t^{sub}	D	$D_{95\%}^l$	$D_{95\%}^u$	z-stat
0.4	6.6	6.4	6.8	
0.8	6.8	6.6	7.0	6.8
1.2	7.0	6.8	7.2	6.8
1.5	7.2	6.9	7.5	6.8

(d) Services

π_t^{sub}	D	$D_{95\%}^l$	$D_{95\%}^u$	z-stat
0.5	7.2	6.4	8.0	
0.9	6.2	5.5	6.9	-8.3
1.4	5.4	4.7	6.1	-10.1
1.8	4.8	4.2	5.5	-12.0

Note: The table presents mean price durations (in quarters) implied by the hazard model (cf. Table 14) for different trend paths of the time-varying covariates. The first column gives the assumed q/q trend growth rates over a price spell. The first row corresponds to the case where all covariates are assumed to follow their mean growth rate in the sample. The preceding rows give the results for higher growth rates of the corresponding covariate. The second and third columns give 95% upper ($D_{95\%}^u$) and lower ($D_{95\%}^l$) confidence bounds. In addition, the last column presents a test statistic, which is asymptotically normal, where the null hypothesis is that the corresponding mean duration is equal to the baseline mean duration in the first row. The confidence bounds and the test statistic are calculated with standard errors based on the delta-method.

Table 19: Effect of CPI inflation on mean price durations

(a) Processed food

π_t	D	$D^l_{95\%}$	$D^u_{95\%}$	z-stat
0.2	7.0	6.8	7.3	
0.4	6.3	6.0	6.6	-7.4
0.6	5.7	5.3	6.1	-8.2
0.8	5.2	4.8	5.7	-9.3

(b) Unprocessed food

π_t	D	$D^l_{95\%}$	$D^u_{95\%}$	z-stat
0.2	3.1	3.0	3.2	
0.4	2.7	2.6	2.9	-9.4
0.6	2.5	2.3	2.7	-11.0
0.8	2.3	2.2	2.5	-12.5

(c) Industrial products

π_t	D	$D^l_{95\%}$	$D^u_{95\%}$	z-stat
0.2	6.6	6.4	6.8	
0.4	6.6	6.3	6.8	-0.5
0.6	6.5	6.1	6.9	-0.5
0.8	6.5	5.9	7.0	-0.5

(d) Services

π_t	D	$D^l_{95\%}$	$D^u_{95\%}$	z-stat
0.2	7.2	6.4	8.0	
0.4	7.6	6.5	8.6	1.5
0.6	7.9	6.5	9.3	1.5
0.8	8.3	6.5	10.1	1.5

Note: The table presents mean price durations (in quarters) implied by the hazard model (cf. Table 14) for different trend paths of the time-varying covariates. The first column gives the assumed q/q trend growth rates over a price spell. The first row corresponds to the case where all covariates are assumed to follow their mean growth rate in the sample. The preceding rows give the results for higher growth rates of the corresponding covariate. The second and third columns give 95% upper ($D^u_{95\%}$) and lower ($D^l_{95\%}$) confidence bounds. In addition, the last column presents a test statistic, which is asymptotically normal, where the null hypothesis is that the corresponding mean duration is equal to the baseline mean duration in the first row. The confidence bounds and the test statistic are calculated with standard errors based on the delta-method.

Table 20: Explanatory power of the hazard models for aggregate price stickiness

Sector	Specification	α	β	R^2
Processed food	Hazard only	-0.570	5.366	0.039
		[0.6817]	[4.9360]	
	Time dependent	0.043	1.069	0.017
		[0.1810]	[1.4963]	
	State dependent	-0.221**	3.100***	0.438
		[0.0846]	[0.6521]	
Unprocessed food	Hazard only	-0.966	3.392*	0.107
		[0.7149]	[1.8195]	
	Time dependent	-0.234	1.763**	0.200
		[0.2241]	[0.6554]	
	State dependent	-0.2410**	1.688***	0.563
		[0.1005]	[0.2764]	
Industrial products	Hazard only	-0.133	2.109	0.008
		[0.6421]	[4.3220]	
	Time dependent	-0.131	2.382**	0.206
		[0.1146]	[0.8688]	
	State dependent	-0.176***	2.389***	0.716
		[0.0427]	[0.2792]	
Services	Hazard only	0.093*	0.748**	0.137
		[0.0525]	[0.3489]	
	Time dependent	0.086	0.751*	0.115
		[0.0608]	[0.3872]	
	State dependent	0.049	0.788**	0.160
		[0.0661]	[0.3355]	

Note: The table gives estimation results of linear regressions of the estimated frequency of price changes as implied by the hazard model and the actual frequency of price changes (calculated as the quarterly share of price changes in total observations). This gives an idea of the explanatory power of duration dependence (hazard only), time-dependent pricing (seasonal and other dummy variables), and state-dependent pricing (time-varying covariates). Standard errors are given in brackets; *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$. α denotes the constant in the regression and β the slope coefficient on the predicted frequency of price changes. The predicted frequency of price changes is calculated at the level of the individual product, conditional on the observed covariates. It is then aggregated by taking unweighted quarterly averages. Note that the corresponding hazard models control for unobserved heterogeneity, but the yearly time dummies are ignored since they automatically explain a very large share of the aggregate frequency of price changes.

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