Price stickiness: Microeconometric evidence using hazard models with high-dimensional fixed effects

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3. Examine the importance of idiosyncratic and sectoral characteristics in explaining the probability of a price change
4. Estimate competing-risks duration models, which deal with price increases and price decreases as separate events - "state heterogeneity"

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- Time-dependent models assume that prices are adjusted at an exogeneously set timing [e.g. Taylor's staggered contracts model; Calvo's model]
- State-dependent models feature the timing of a price change as endogeneous to the firm [e.g. Menu cost models; Imperfect information models]

Related literature

Increased availability of detailed price data spurred the research on the dynamics of price setting at the micro level e.g. Bils and Klenow, 2004; Klenow and Krytsov, 2008; Nakamura and Steinsson, 2008; Fougère et al., 2007; Alvarez et al., 2021

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- favors state-dependent models
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- shows that the size of a price change is independent of price duration
- shows that prices are ajusted so that the mark-up is not distant from a given reference value - menu-cost models e.g. Eichenbaum et al., 2011

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Industrial Production Prices Index (IPPI) dataset collected by the Portuguese Statistics Institute (INE)

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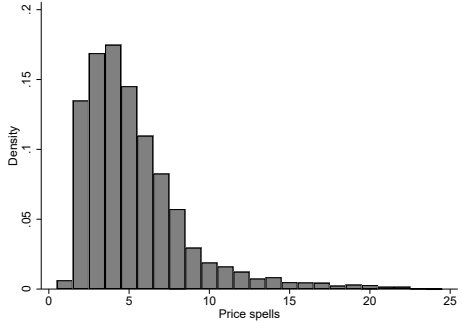
- Our data goes from jan 1995 - dec 2001
- Manufacturing firms
- 722 classes of products, 14,590 items, 2,279 firms
- On average, firms are asked about the price of 5 products
- Multiple completed spells for the same product and firm, which allows to account for product- and firm-specific frailties

Frequency of monthly price changes



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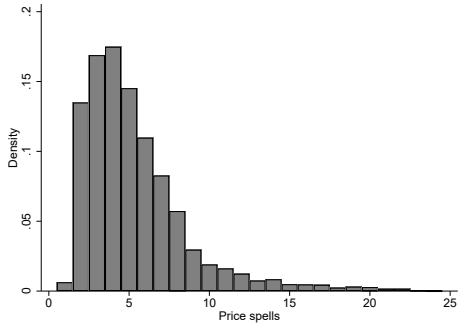

Median price spell equals 5 months and very few products register more than 9 price spells over the sampling period

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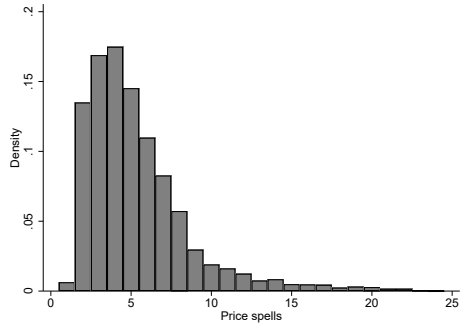

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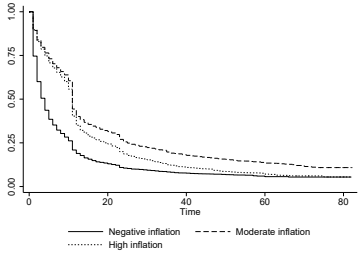
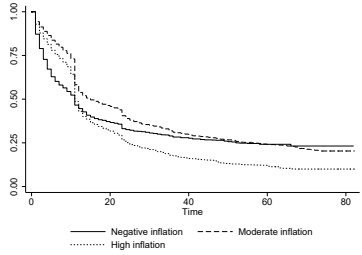
Prima facie evidence of some nominal rigidity in price changes

Unconditional Survival Function

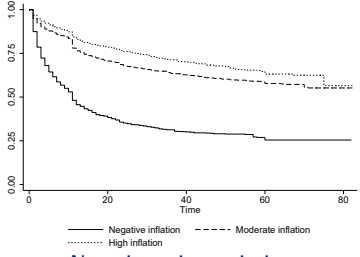
Survival function for price changes by inflation regime



Price variation



Positive price variation



Negative price variation

Hazard function for price changes

1. Hazard function for price changes: no fixed effects

$$\text{cloglog}[p(t, \mathbf{x}_i|\beta)] = D(t) + \mathbf{x}_i'\beta$$

	Δ	Δ^+	Δ^-
log number of competitors	-0.0228***	0.0165***	-0.0917***
	(0.0048)	(0.0057)	(0.0087)
Last change price decrease	0.3393***	0.0980***	0.7524***
	(0.0124)	(0.0157)	(0.0212)
log magnitude last price change	-0.0040***	-0.0027***	-0.0126***
	(0.0005)	(0.0005)	(0.0015)
Product inflation$_{t-1}$	0.0027	0.0903***	-0.0907***
	(0.0052)	(0.0057)	(0.0061)
Sectoral inflation$_{t-1}$	-0.0236	0.1262**	-0.4851***
	(0.0484)	(0.0573)	(0.0906)
log duration	-0.3481***	-0.2266***	-0.5818***
	(0.0053)	(0.0064)	(0.0099)
Time	-0.0002	0.0003	-0.0019***
	(0.0003)	(0.0003)	(0.0005)
constant	-0.9088***	-1.5180***	-1.9459***
	(0.0247)	(0.0296)	(0.0462)
Observations	495,789	495,789	495,789

2. Hazard function for price changes: random intercepts model

$$\text{cloglog}[p(t, \mathbf{x}_i|\beta, \nu_i)] = D(t) + \mathbf{x}_i'\beta + u_i$$

	Δ	Δ^+	Δ^-
log number of competitors	-0.0218**	0.0271***	-0.1587***
	(0.0110)	(0.0099)	(0.0164)
Last change price decrease	0.1234***	0.2204***	0.1112***
	(0.0156)	(0.0190)	(0.0256)
log magnitude last price change	-0.0040***	-0.0032***	-0.0092***
	(0.0006)	(0.0006)	(0.0016)
Product inflation$_{t-1}$	0.0229***	0.0891***	-0.0632***
	(0.0043)	(0.0055)	(0.0063)
Sectoral inflation$_{t-1}$	0.1035**	0.2356***	-0.4204***
	(0.0496)	(0.0581)	(0.0927)
log duration	0.1126***	0.1041***	-0.2283***
	(0.0077)	(0.0093)	(0.0128)
Time	-0.0053***	-0.0035***	-0.0051***
	(0.0003)	(0.0004)	(0.0005)
constant	-1.8608***	-2.3339***	-2.7798***
	(0.0451)	(0.0451)	(0.0701)
Observations	495,789	495,789	495,789

Duration dependence is key

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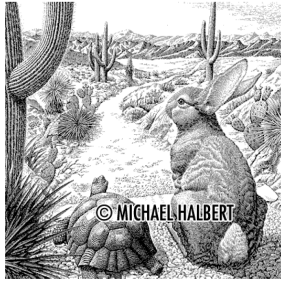
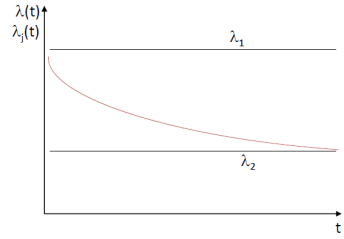
- In the words of Salant (1977), "In the cooling process by evaporation, hot molecules (and thus faster) exit the liquid, while the cold ones (and thus slower) stay."





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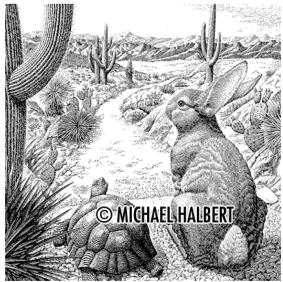

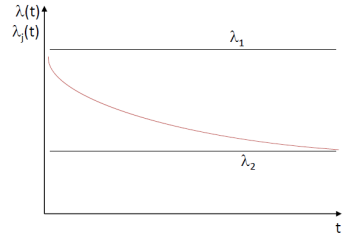

- A useful strategy is to take advantage of repeated spells to extract true duration dependence

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- This means that a *cloglog* model with HDFE can be obtained by recursively estimating a linear regression model with HDFE. More specifically:

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$$\beta^{(r)} = (\mathbf{X}'\mathbf{W}^{(r-1)}\mathbf{X})^{-1}\mathbf{X}'\mathbf{W}^{(r-1)}\mathbf{z}^{(r-1)} \tag{1}$$

- For the *cloglog* model $\mathbf{W}$ is a diagonal matrix with generic element given by

$$w_i = [(1-\mu_i)\log(1-\mu_i)]^2\,[\mu_i(1-\mu_i)]^{-1}$$

and $\mu_i = 1 - \exp(-\exp(\mathbf{x}_i'\beta))$. The elements of the vector $\mathbf{z}$ are obtained as:

$$z_i = \mathbf{x}_i'\beta - (y_i - \mu_i)\,[(1-\mu_i)\log(1-\mu_i)]^{-1}$$

3. Hazard function for price changes: product and firm fixed effects

$$\text{cloglog}[p(t, \mathbf{x}_i|\beta, \nu_i)] = \alpha_i + \gamma_j + D(t) + \mathbf{x}_i'\beta$$

	Δ	Δ^+	Δ^-
log number of competitors	0.3546***	0.5798***	-0.1698*
	(0.0557)	(0.0690)	(0.0917)
Last change price decrease	0.0442***	0.2080***	-0.1108***
	(0.0165)	(0.0217)	(0.0242)
log magnitude last price change	-0.0021***	-0.0022***	-0.0004
	(0.0008)	(0.0007)	(0.0013)
Product inflation$_{t-1}$	0.0156***	0.0705***	-0.0500***
	(0.0049)	(0.0062)	(0.0059)
Sectoral inflation$_{t-1}$	0.0726	0.2388***	-0.4885***
	(0.0512)	(0.0590)	(0.0951)
log duration	0.1246***	0.2901***	-0.1145***
	(0.0077)	(0.0096)	(0.0133)
Time	-0.0047***	-0.0052***	-0.0044***
	(0.0003)	(0.0004)	(0.0006)
Observations	469,365	399,648	353,481
Product fixed effects	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes

4. Hazard function for price changes: product×firm fixed effects

$$\text{cloglog}[p(t, \mathbf{x}_i|\beta)] = \alpha_{ij} + D(t) + \mathbf{x}_i'\beta$$

	Δ	Δ^+	Δ^-
log number of competitors	0.4529***	0.6684***	-0.1636
	(0.0620)	(0.0759)	(0.1038)
Last change price decrease	0.0030	0.2945***	-0.3484***
	(0.0195)	(0.0264)	(0.0268)
log magnitude last price change	-0.0037***	-0.0043***	0.0008
	(0.0010)	(0.0012)	(0.0020)
Product inflation$_{t-1}$	0.0258***	0.0914***	-0.0660***
	(0.0050)	(0.0067)	(0.0065)
Sectoral inflation$_{t-1}$	0.0950*	0.2424***	-0.4889***
	(0.0521)	(0.0599)	(0.0964)
log duration	0.3911***	0.5094***	0.1217***
	(0.0091)	(0.0112)	(0.0153)
Time	-0.0083***	-0.0077***	-0.0078***
	(0.0004)	(0.0004)	(0.0006)
Observations	425,751	399,650	208,793
Product×Firm fixed effects	Yes	Yes	Yes

5. Non-monotonic hazard functions

The probability of observing a price change in the baseline duration model that accounts for time dependence with time dummies can be calculated as:

$$\Pr(y_{it} = 1) = 1 - \exp\big(-\exp(x_{it}'\beta + \gamma_t)\big).$$

- We include 34 time dummies in the model estimation, which means that we assume a constant baseline hazard from 35 months onward.

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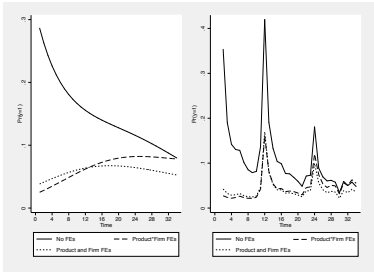
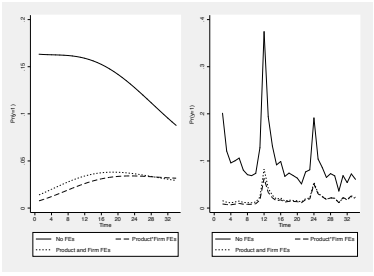
The probability of an event occurring in the baseline duration model with a fourth-order polynomial can be written as:

$$\Pr(y_{it} = 1) = 1 - \exp(-\exp(x_{it}'\beta + \delta_1 t + \delta_2 t^2 + \delta_3 t^3 + \delta_4 t^4)). \tag{2}$$

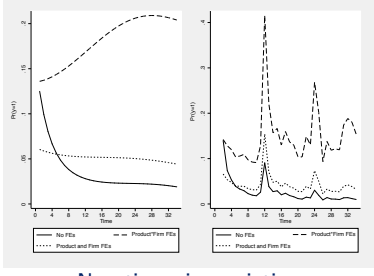
Non-monotonic hazard functions



Price variation



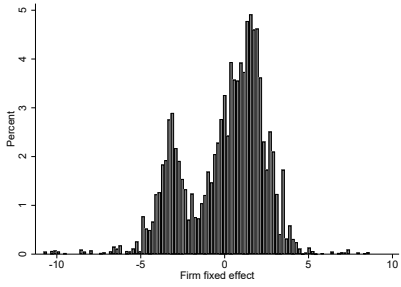
Positive price variation

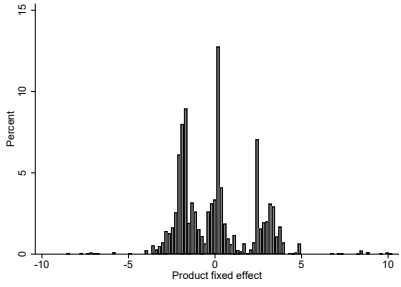


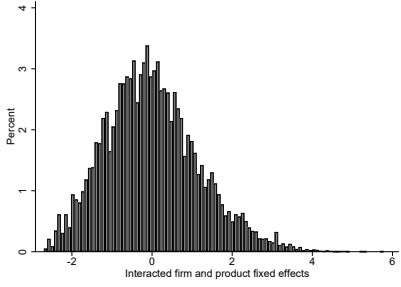
Negative price variation

Product and Firm Heterogeneity

Firm, product, and interaction between firm and product fixed effects







Incidental parameters problem

cloglog model with HDFEs: a simulation exercise

		Corr(x,fe)=0
dgp	y=f(x)	0.000
No unobserved heterogeneity	y=f(x,fe1)	-0.350
Product fixed effects	y=f(x,fe1)	0.210
Bias corrected estimates	y=f(x,fe1)	-0.036
No unobserved heterogeneity	y=f(x,fe1,fe2)	-0.556
Product and firm fixed effects	y=f(x,fe1,fe2)	0.196
Bias corrected estimates	y=f(x,fe1,fe2)	-0.018

The split-panel Jackknife estimator proposed by Dhaene and Jockmans, 2015 is:

$$\widehat{\rho}^{k}_{jk_{1/2}} = 2\widehat{\rho}^{k} - 1/2(\widehat{\rho}^{k}_{1} + \widehat{\rho}^{k}_{2})$$

- where $\widehat{\rho}^{k}$ denotes the least-squares estimate of ρ from the full panel with a fixed effect and $\widehat{\rho}^{k}_{1}$ and $\widehat{\rho}^{k}_{2}$ correspond to the estimates from the first half-panel, $t = 1, ..., T/2$, and the second half-panel, $t = T/2 + 1, ..., T$, respectively

Incidental Parameter Bias Correction

Duration dependence coefficients

	Δ	Δ^+	Δ^-
No unobserved heterogeneity	-0.348	-0.227	-0.582
Product and firm fixed effects	0.123	0.290	-0.115
Bias corrected estimates	0.060	0.173	-0.169
Product$\times$firm fixed effects	0.391	0.509	0.122
Bias corrected estimates	-0.004	0.100	-0.186

Conclusion

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Use very detailed product data at the firm level and show that:

- Competitive pressure increases the likelihood of a price increase and decreases the likelihood of a price decrease
- The probability of a price change is estimated to comove with inflation, at both the product and sector level
- When we extensively account for time-invariant heterogeneity, duration dependence is estimated to be positive
- Price changes depend on both idiosyncratic and sectoral conditions - evidence in favour of state-dependent models
- Price adjustment is considerably heterogeneous across products and firms

Thanks!