Les 8èmes

« TOULOUSE LECTURES IN ECONOMICS »

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A New Monetarist Sticky Price Model

Previously titled "Really, Really Rational Inattention – or, How I Learned to Stop Worrying and Love Sticky Prices"

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PRINCETON

The most difficult question in macroeconomics:

> Why do sellers set p in nominal terms that do not respond to changes in aggregate P?

At least some p must respond, or aggregate P does not change, but individual p is *sticky* in the short run.

In many popular models, including those used by most policy makers, this is an **assumption**.

We derive it as a **result**.

Does this finally provide microfoundations for the critical – the *defining* – ingredient in Keynesian economics?

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Does this finally provide microfoundations for the critical – the *defining* – ingredient in Keynesian economics?

No. In our economy money is neutral.

Ball and Mankiw (1994) 'A Sticky Price Manifesto'

"We believe that sticky prices provide the most natural explanation of monetary nonneutrality since so many prices are, in fact, sticky... [B]ased on microeconomic evidence, we believe that sluggish price adjustment is the best explanation for monetary nonneutrality... As a matter of logic, nominal stickiness requires a cost of nominal adjustment."

Golosov and Lucas (2003) 'Menu Costs and Phillips Curves'

"Finally, and not least, menu costs are really *there*: The fact that many individual goods prices remain fixed for weeks or months in the face of continuously changing demand and supply conditions testifies conclusively to the existence of a fixed cost of repricing."

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One might draw several conclusions from of the above assertions:

1. Empirical: Prices in the data are sticky, defined to mean that some individual nominal prices do not change when economic conditions change.

2. Theoretical: “As a matter of logic” we need menu costs in our models.

3. Policy: Money is nonneutral and hence Keynesian policy recommendations are valid.

We concede 1. We prove that 2 and 3 are wrong.

We prove this by building a simple model that:

1. delivers nominal price setting and stickiness as an equilbrium and matches the data quite well;

2. does this with neither Mankiw costs nor Calvo fairies;

3. and implies money is exactly neutral – the Fed cannot print us out of a recession.

Clarification:The NME position is *not* that money is neutral – there are many reasons why money matters.

It is that sticky prices in the data imply neither that menu costs are important nor that Keynesian policies will work.

THE LOGIC: 1

Consider a model that has two features:

- money, so that p is posted in dollars (Kiyotaki)
- a nondegenerate p distribution (Campbell)

Such a model can deliver this:

- equilibrium $\Rightarrow F(p)$ with support $\mathcal{F} = [\underline{p}, \overline{p}]$
- low p sellers earn less per unit but make it up on the volume: $\Pi(p) = \bar{\Pi}\ \forall p \in \mathcal{F}$
- $\triangle M > 0 \Rightarrow \triangle P > 0 \Rightarrow F(p)$ shifts but $F(p/P)$ is invariant
- any seller with $p_{t-1} \notin \mathcal{F}_t$ must adjust
- but sellers with $p_{t-1} \in \mathcal{F}_t$ may not!

THE LOGIC: 2

Consider a model that has two features:

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THE LOGIC: 4

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THE LOGIC: 5

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Related literature – data:

Checchetti (1986)	Klenow-Kryvtsov (2008)
Carlson (1986)	Nakamura-Steinsson (2008)
Blinder (1991)	Eichenbaum et al. (2009)
Bils-Klenow (2004)	Gagnon (2009)
Campbell-Eden (2007)	Matsuoka (2009)

Related literature – theory:

Caplin-Spulber (87) Eden (94) Golosov-Lucas (07) Midrigan (08)
and 30 years of Search Theory some people seem to have missed.

Related literature – big picture:

New Keynesian economics (Ball-Mankiw, Woodford)
New Monetarist economics (Williamson-Wright, Wallace)

Some Facts to Match

1. Median frequency of $\triangle p$: 4-7 or 8-10 months
2. Frequency of $\triangle p$ varies a lot across goods
3. Size of $\triangle p$ varies a lot across goods
4. When they change, firms do not all pick same p
5. About $1/3$ of p changes are reductions
6. Hazard rates flat or declining with eventual spike
7. Many $\triangle p$ are small
8. Frequency of $\triangle p$ positively related to π

Other models cannot easily match all these.

Example: Fact 7 (many small $\triangle\ p$) "is hard to reconcile with the large menu costs needed to rationalize large average price changes" (KK)

GL has less than 10% of p changes small (below 5%)

KK try very hard, still cannot get it.

Midrigan can get it but loses approximate neutrality.

We can get it with exact neutrality

$\lvert\Delta p\rvert$	$< 5\%$	$< 2.5\%$	$< 1\%$
Data - Posted prices	39.8%	23.4%	11.3%
Data - Regular prices	44.3%	25.4%	12.1%
Model	43.9%	34.9%	14.0%

Model

Recall that we want a model with two features:

- money, so that p is posted in dollars
- a nondegenerate distribution $F(p)$

Naturally, we use search theory:

- money plays same role as Lagos-Wright
- distribution from the logic of Burdett-Judd

Note:

- we want M in the model to discuss neutrality issues, but a special case is our pure credit version
- we still use LW to make BJ dynamic general equil

Each period $t = 1, 2, \ldots$ has two subperiods.

A frictionless AD market and decentralized market with these frictions:

- Burdett-Judd search $\Rightarrow$ price dispersion
- double coincidence problem $\Rightarrow$ barter impossible
- limited commitment $+$ record keeping $\Rightarrow$ credit difficult

Model 1: credit is available with prob γ

Model 2: credit is always availability at cost η

- $\gamma = 1$ or $\eta = 0 \Rightarrow$ nonmonetary model
- $\gamma = 0$ or $\eta = \infty \Rightarrow$ pure money model

Household Problem: AD Market

$$W_t(m) = \max_{x,\ell,\hat{m}} \{U(x) - A\ell + \beta V_{t+1}(\hat{m})\}$$

$$\text{st } x = w_t\ell + \phi_t(m - \hat{m}) - T_t + D_t$$

Simplifying (but not otherwise important) results:

- linearity: $W_t'(m) = \phi_t$
- history independence: $\hat{m}_t \perp m_t$.

Known extensions:

- heterogeneity, shocks, many goods, other assets
- general technologies, capital, growth
- nonconvexities, unemployment, taxation

Household Problem: BJ Market

For exposition, suppose for now that:

- goods are indivisible
- no credit – i.e. $\gamma = 0$ or $\eta = \infty$

Let $\alpha_n = pr\left(n \text{ contacts}\right)$ and $J_t^n(p)$ be the dist'n of the lowest p given n draws from $F_t(p)$.

$$V_t(m) = W_t(m) + \sum_{n=1}^{\infty} \alpha_n \int_{\underline{p}_t}^{m} \max\{u - \phi_t p, 0\} dJ_t^n(p)$$

Known extensions:

- divisible/multiple goods, more complicated pricing
- endogenous entry and/or search intensity

Particularly Useful Extensions:

1. Number of contacts: BJ show how to get $\alpha_1 > 0$, $\alpha_2 > 0$ and $\alpha_n = 0 \; \forall n > 2$ endogenously

2. Matching: Assume measure $b \in [0, 1]$ houseolds in BJ market and write

$$\alpha_0 = [1 - \lambda(b)]^2$$
$$\alpha_1 = 2\lambda(b)[1 - \lambda(b)]$$
$$\alpha_2 = \lambda(b)^2$$

where $\lambda(b)$ comes from a standard matching technology.

3. Entry: b adjusts to equate expected BJ surplus to cost k.

Firms

Each f can produce any amount of BJ goods at constant marginal cost $c \in (0, u)$.

They max Π and pay out dividends in AD market.

As BJ exchange requires money, naturally firms post p in "dollars per unit."

$$\Pi(p) = (\phi p - c)b\{\alpha_1(b) + 2\alpha_2(b)[1 - F(p)]\}.$$

Profit mazimiaztion:

$$\Pi(p) = \Pi^* \forall p \in \mathcal{F} \text{ and } \Pi(p) \le \Pi^* \forall p \notin \mathcal{F}.$$

Burdett-Judd 101

Lemma: F has no mass points and $\mathcal{F} = [\underline{p}, \overline{p}]$.

Proposition:

$$F(p) = 1 - \frac{\alpha_1(b)}{2\alpha_2(b)} \frac{\phi\overline{p} - \phi p}{\phi p - c}$$

Proof: Recall

$$\Pi(p) = (\phi p - c)b\{\alpha_1(b) + 2\alpha_2(b)[1 - F(p)]\}$$

At highest price

$$\Pi(\overline{p}) = (\phi\overline{p} - c)b\alpha_1(b)$$

Equate and solve for $F(p)$. ■

Still need to find $\overline{p}$ and $\underline{p}$ (easy enough).

Closed form solution F can be taken to the data – just like the Burdett-Mortensen wage dist'n $F(w)$.

As in that model, extensions may be needed to fit well.

An advantage here: we can also take the dist'n of prices paid (as opposed to posted) to the data.

Model nests monopoly and perfect competition as special cases when $\alpha_2 \to 0$ and $\alpha_1 \to 0$ (Diamond & Betrand).

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Question: How can one make BJ dynamic GE?

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Question: How can one make BJ GE?

Answer: LW.

As usual we tranform m into real balances $z = \phi m$ and look for stationary equil.

Def'n 1. A SME is a price dist'n F^* and a level of real balances $z^* > 0$ satisfying:

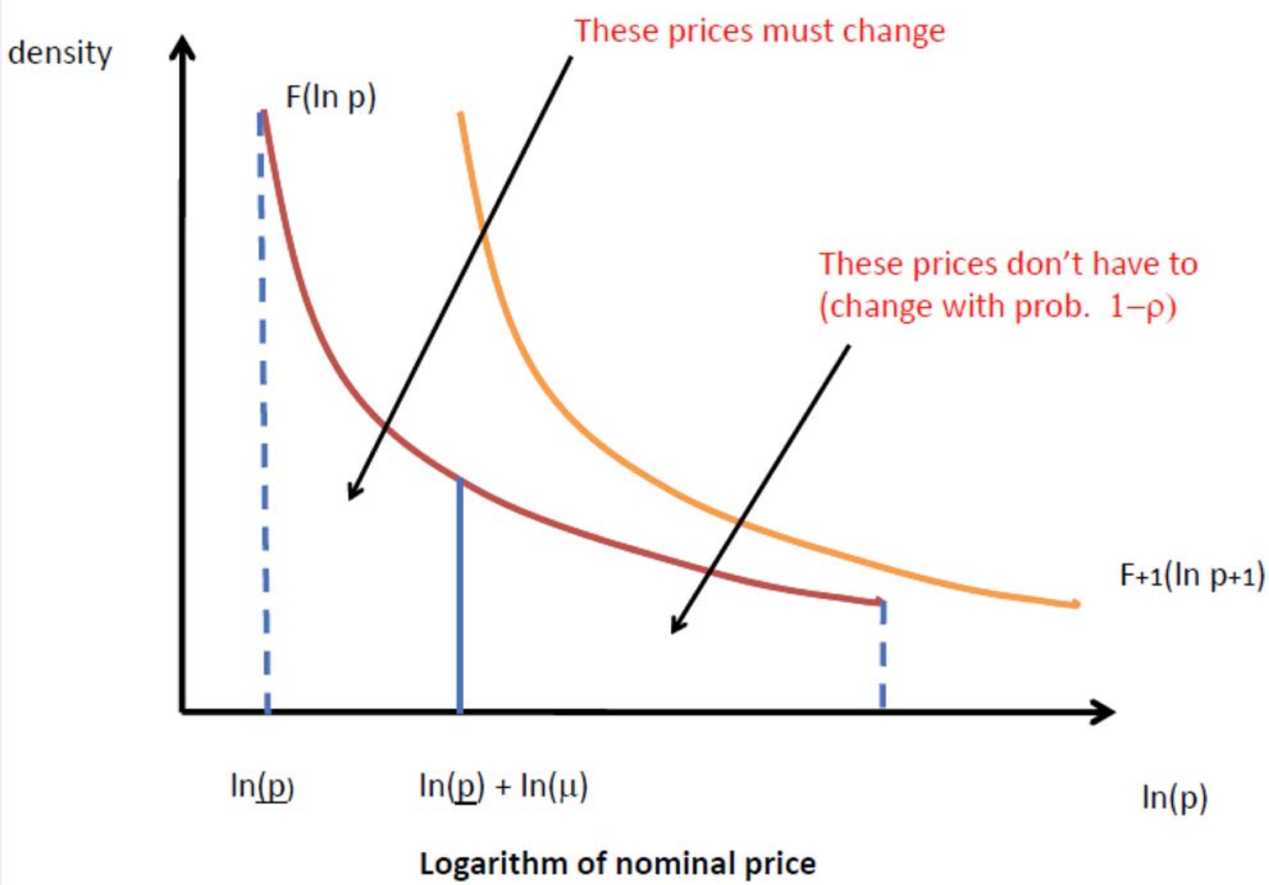
(i) given $\phi = z^*/M$, the dist'ns F^* is constructed as above;

(ii) given F^*, z^* solves the AD problem

$$\max_z \left\{ -iz + \alpha_1 \int_{\underline{z}}^{z} (u - \tilde{z}) dJ^1(\tilde{z}) + \alpha_2 \int_{\underline{z}}^{z} (u - \tilde{z}) dJ^2(\tilde{z}) \right\}$$

where $i = (1 + \pi)/\beta - 1$ and J^n is the dist'n of the lowest z given n draws from the dist'n F constructed above.

Infrequent Price Adjustments



Def'n 2. A SME with entry is F^*, $z^* > 0$ and $b^* > 0$ satisfying (i) and (ii) above, plus

(iii) $\mathrm{E}\big($surplus in BJ$\big) \leq k$, $=$ if $b^* > 0$.

Entry shows clearly how model is distinctly *non-Keynesian*.

Consider a Calvo-pricing version:

$\vartriangle M > 0 \Rightarrow \vartriangle 1/\phi > 0$

In SR $F(p)$ cannot change, so all real prices $p\phi$ fall

$\Rightarrow$ shopping spree $\Leftrightarrow$ production boom

By contrast, in our model $F(\phi p)$ is invariant to M – money is neutral, but of course not superneutral.

Recall our claim that we build a model with:

1. prices that are set in nominal terms, and are sticky, as in the data;

2. neither Mankiw costs nor Calvo fairies;

3. monetary neutrality.

So far we have shown how to get sticky nominal prices w/o menu costs.

The model does not rationalize Keynesian policies – in fact, the policy recommendations are very New Monetarist.

Left to do: check if the model can match the data.

Technical Detail

The above model has many equilibria.

The sticky price implications hold in all equilibria, but this is still problematic.

Problem due to a coordination effect in any model with money, price posting and indivisible goods (Green-Zhou).

Solutions:

1. use the refinement in JRW – not so nice.
2. introduce costly credit – very nice!
3. move to divisble goods – even nicer?

Divisible Goods

Consider the divisible goods version – mainly because calibration of the other model is still a work in progress.

The notion of equil is the same, except that when buyers contact a seller posting p they purchase

$$q(p,m) = \arg\max_q \{u(q) - \phi pq\} \text{ st } pq \leq m.$$

Constraint may or may not bind in any particular match.

If $u(q) = \dfrac{q^{1-\gamma}}{1-\gamma}$ with $\gamma < 1$ then:

$$pq = m \Leftrightarrow p \leq \hat{p}(m) = \phi^{\frac{1}{\gamma-1}} m^{\frac{\gamma}{\gamma-1}}$$

Also, on the firm side

$$\Pi(p) = b\{\alpha_1 + 2\alpha_2[1 - F(p)]\}R(p,m)$$

where

$$R(p,m) = q(p,m)(p\phi - c).$$

Result:

$$F_t(p) = 1 - \frac{\alpha_1(b)}{2\alpha_2(b)} \frac{R_t(\overline{p}_t) - R_t(p)}{R_t(p)}$$

Same as previous model except there $q(p,m) \equiv 1$.

Proposition: There exists a unique SME.

Proof: Do some algebra. Apply Tarski Thm.

Then do some more algebra. ■

Quantitative Work

In equilibrium many firms are indifferent between changing and not changing their price each period.

Consider the following *tie-breaking rule*:

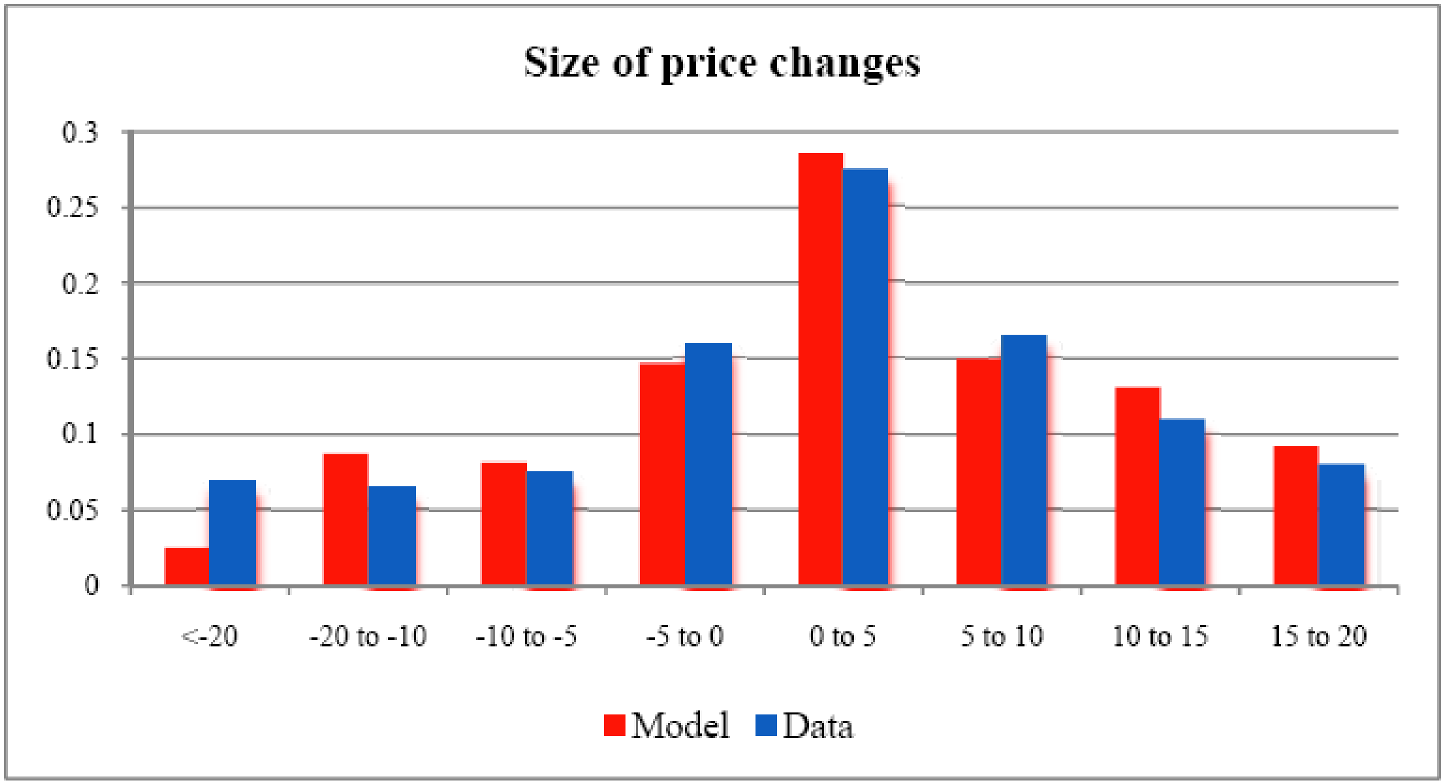
$$p_{t+1} = \begin{cases} \tilde{p} \quad \text{with prob. } 1 & \text{if } p_t < \underline{p}_{t+1} \\ p_t \quad \text{with prob. } \sigma \in [0,1] & \\ \tilde{p} \quad \text{with prob. } 1-\sigma & \text{if } p_t \geq \underline{p}_{t+1} \end{cases}$$

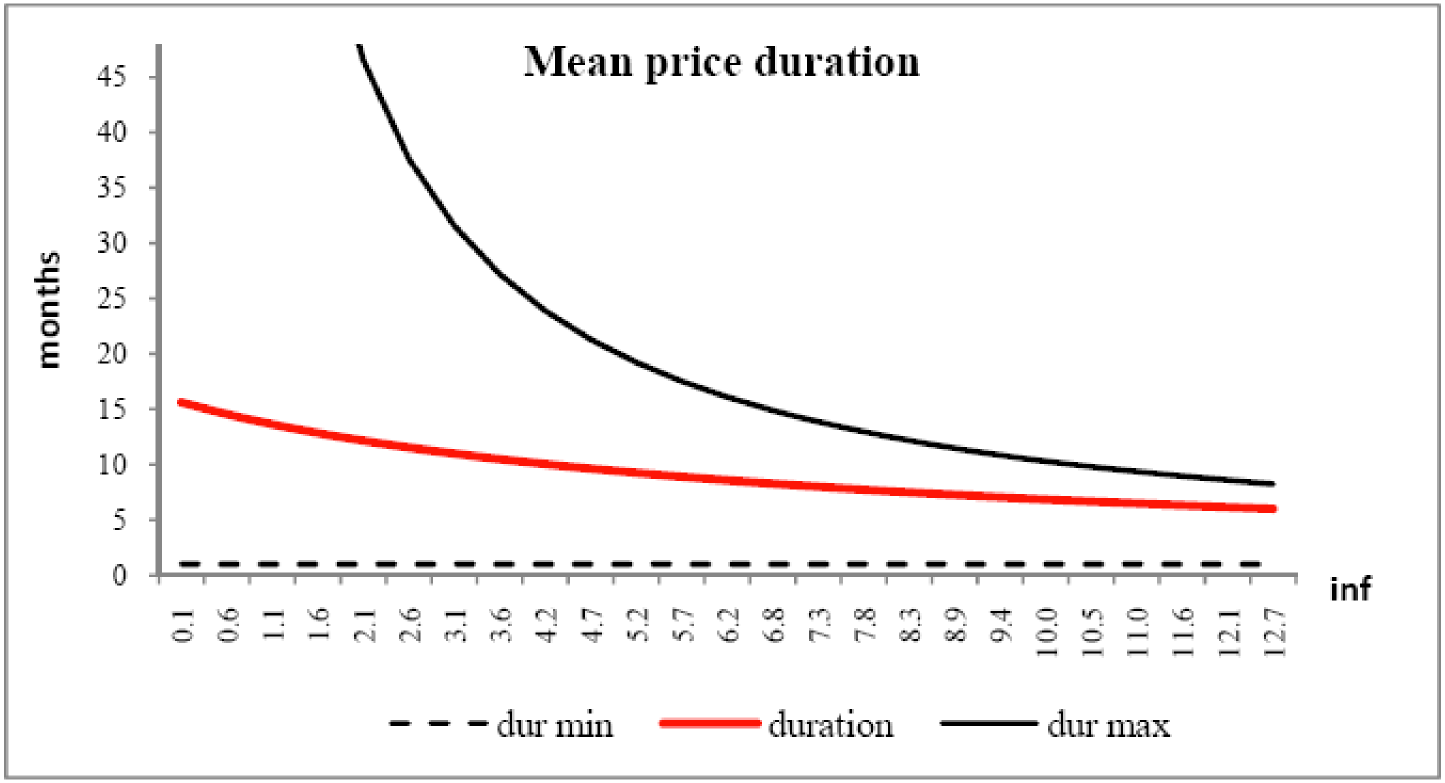
where $\tilde{p} \sim G_{t+1}(\tilde{p})$, and G_{t+1} is constructed to generate the equilibrium F_{t+1}.

Question: *Can this model simultaneously account for the empirical features of pricing behavior?*

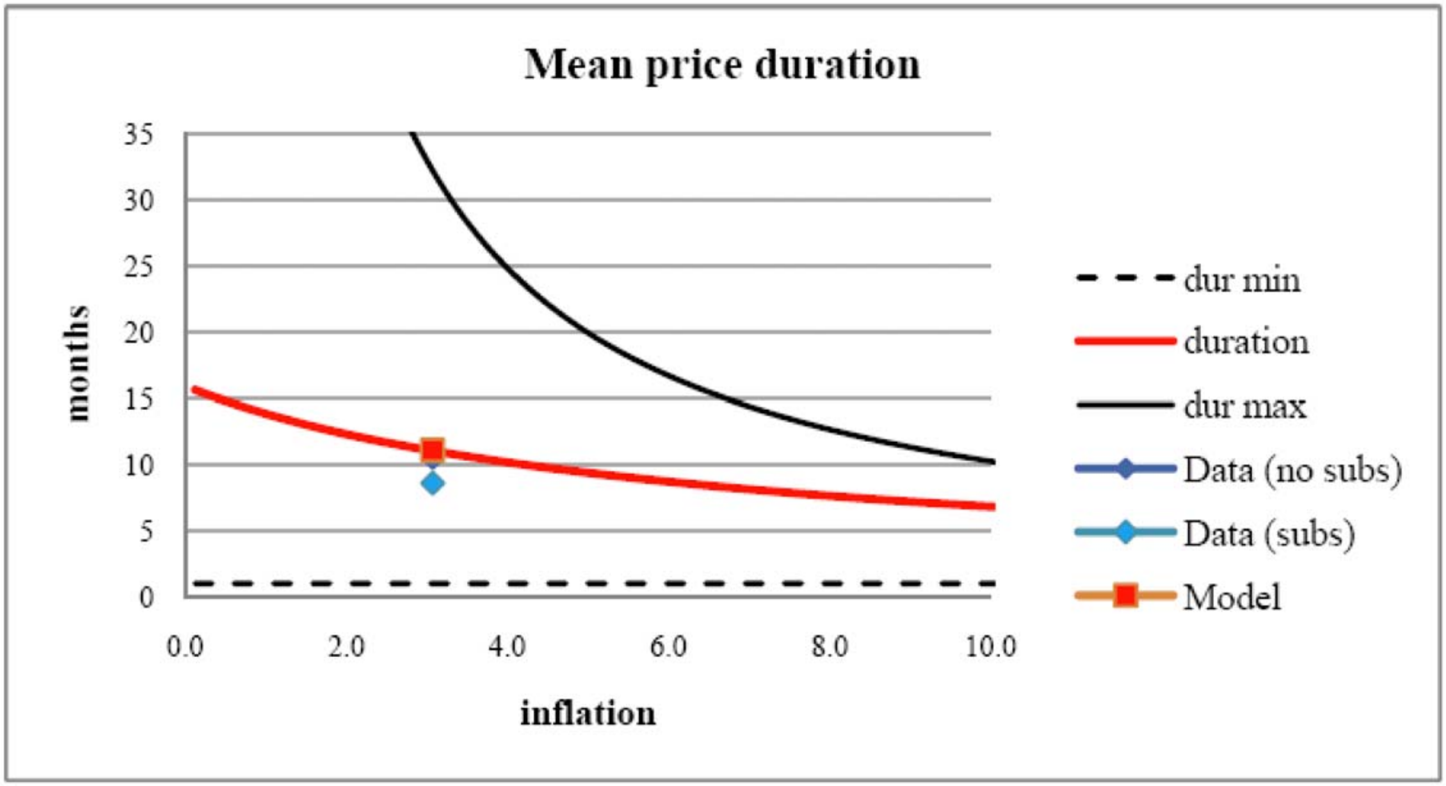
Calibration

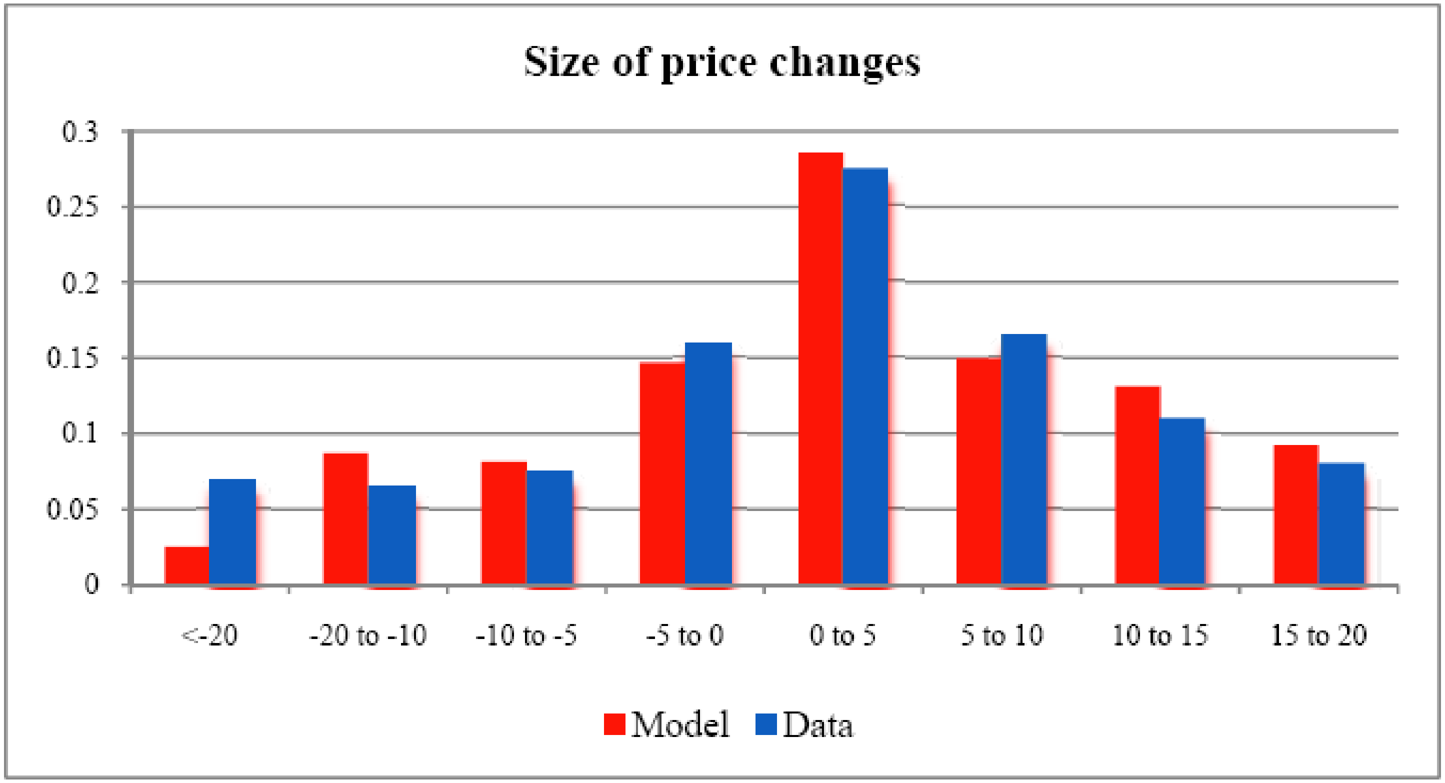
Parameter	Target
μ money growth	annual inflation rate 3%
β discount factor	annual interest rate 7.5%
λ search frictions	average markup 30%
γ elasticity of demand	price change distribution
σ tie breaking rule	price change distribution


Size of price changes
0.3
0.25
0.2
0.15
0.1
0.05
0
<-20
-20 to -10
-10 to -5
-5 to 0
0 to 5
5 to 10
10 to 15
15 to 20
Model
Data

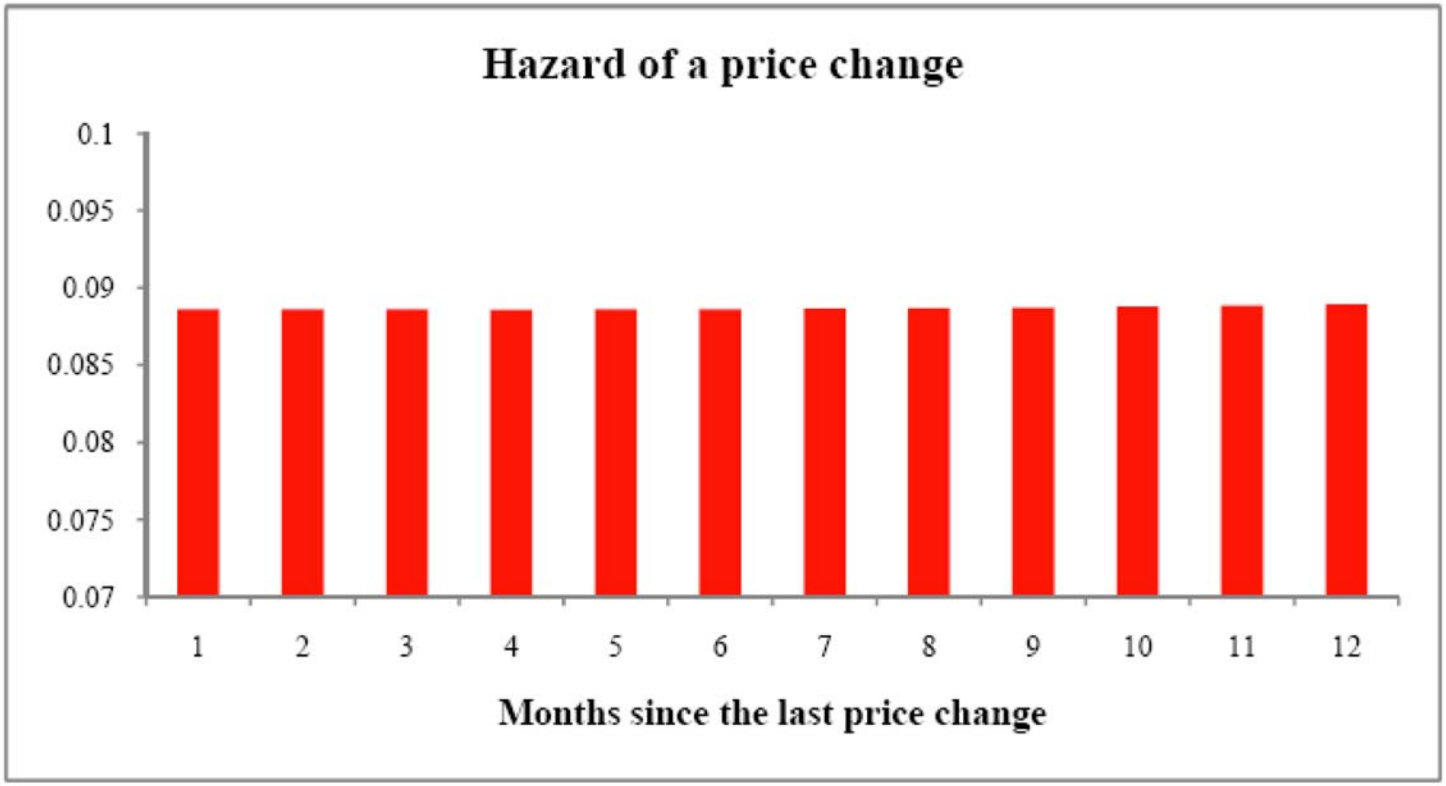

Mean price duration
months
45
40
35
30
25
20
15
10
5
0
0.1
0.6
1.1
1.6
2.1
2.6
3.1
3.6
4.2
4.7
5.2
5.7
6.2
6.8
7.3
7.8
8.3
8.9
9.4
10.0
10.5
11.0
11.6
12.1
12.7
inf
dur min
duration
dur max

	Model	Data
Mean inflation rate	0.03	0.03
Mean price duration	11.6	8.6–10.4


Mean price duration
months
35
30
25
20
15
10
5
0
0.0
2.0
4.0
6.0
8.0
10.0
inflation
dur min
duration
dur max
Data (no subs)
Data (subs)
Model


Size of price changes
0.3
0.25
0.2
0.15
0.1
0.05
0
<-20
-20 to -10
-10 to -5
-5 to 0
0 to 5
5 to 10
10 to 15
15 to 20
Model
Data

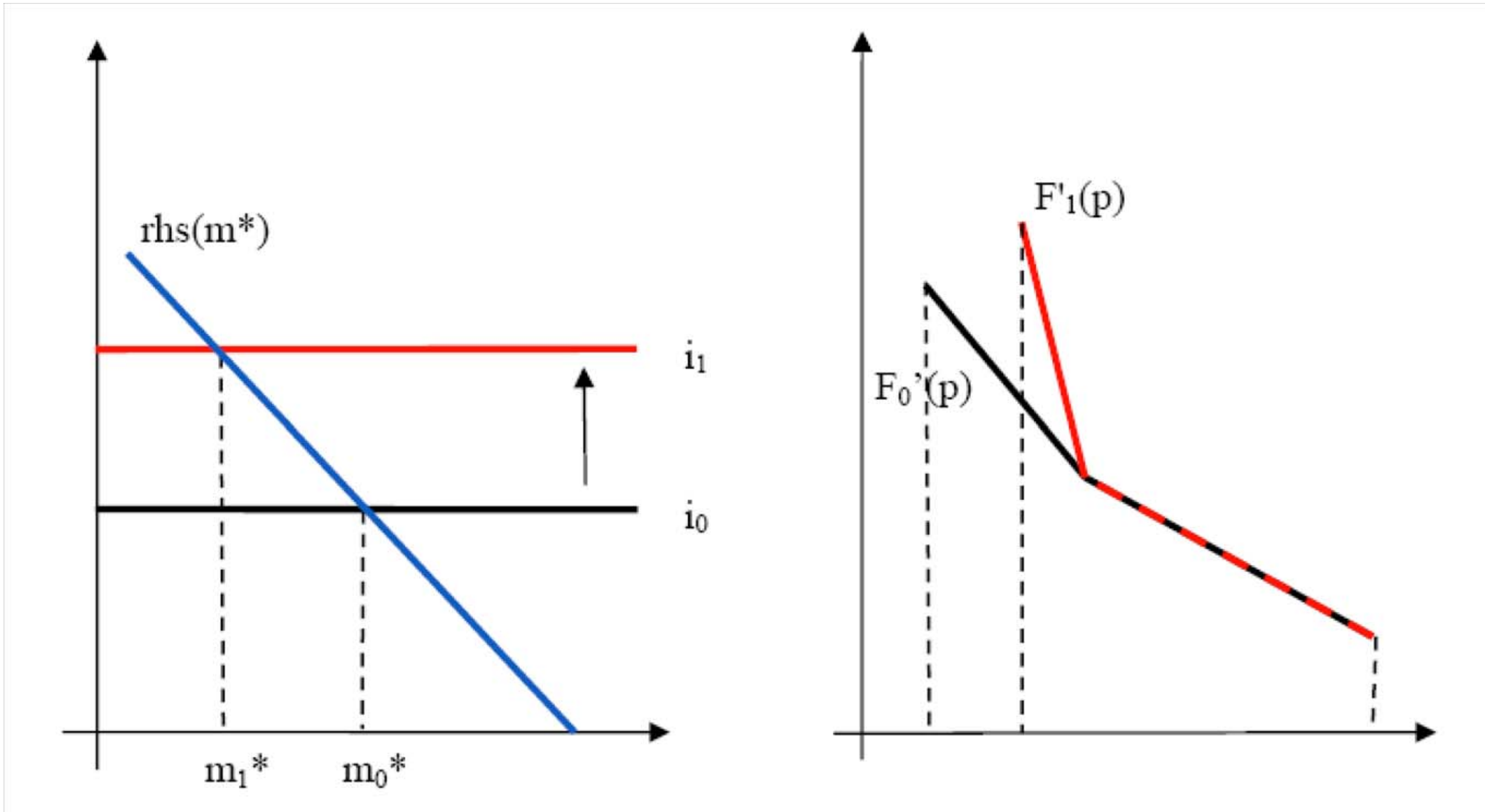
	Model	Data
Average size of a price change	0.09	0.11
Fraction of price changes $< 5\%$	0.43	0.44
Fraction of negative price changes	0.35	0.37

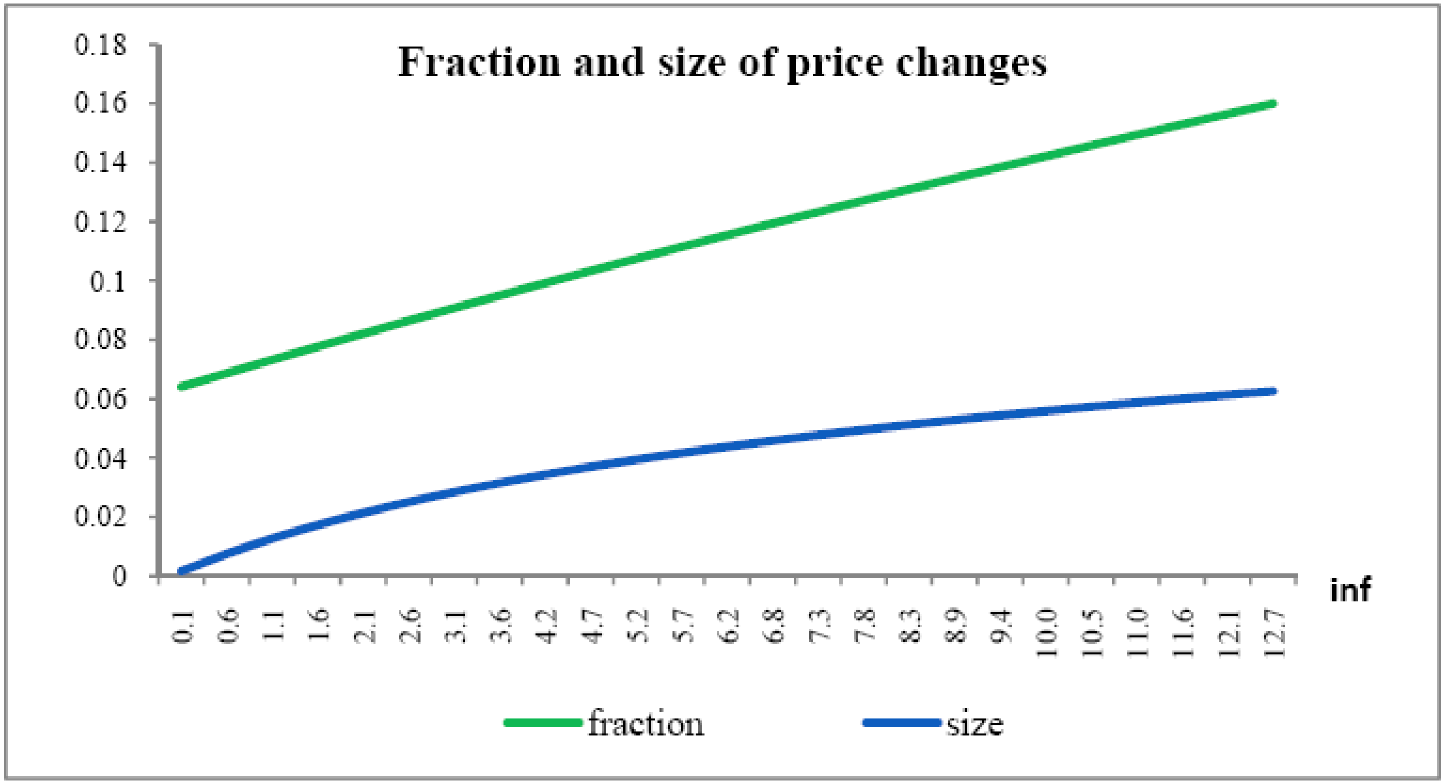


Klenow and Kryvtsov (2008) estimate a flat hazard rate

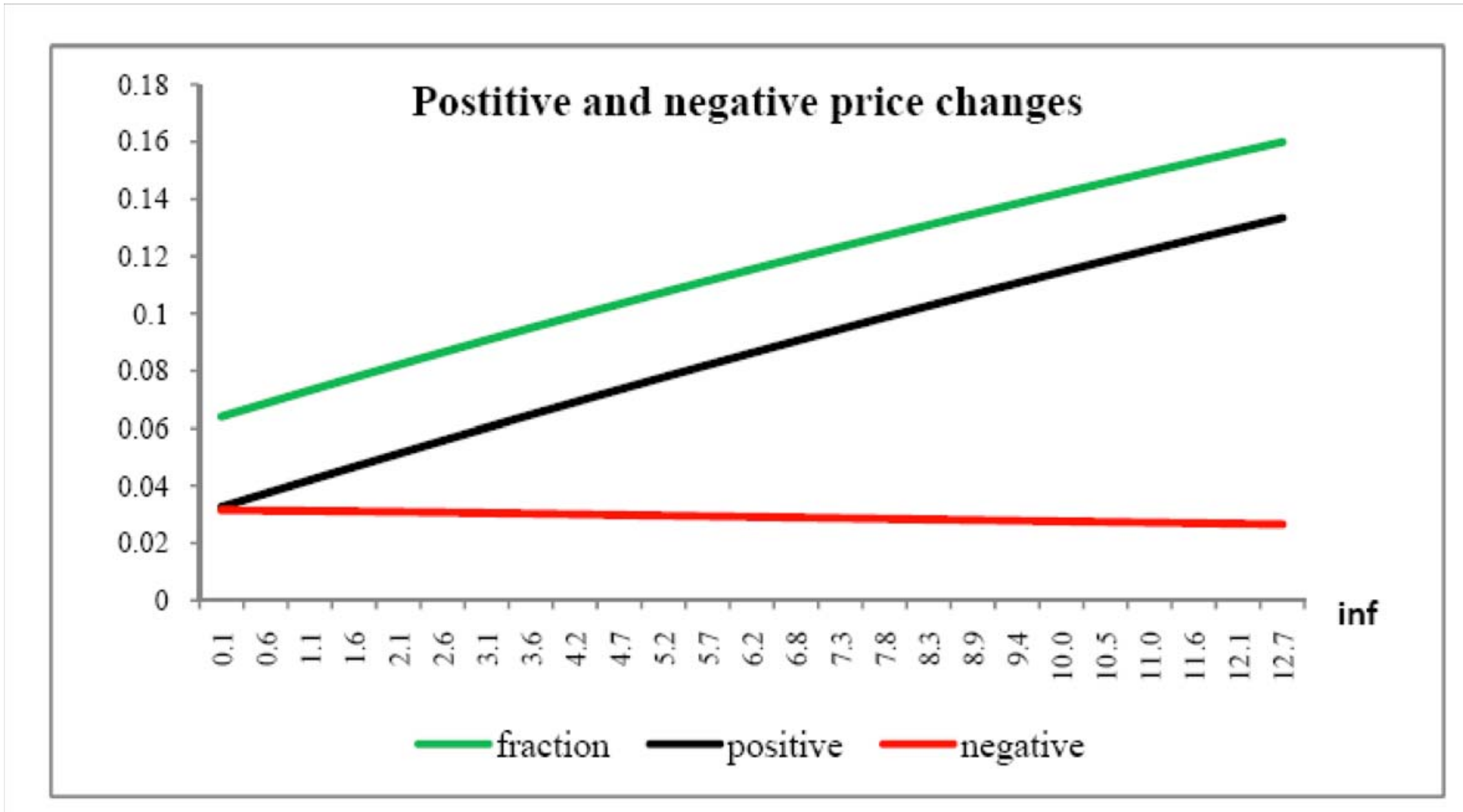
Steinsonn and Nakamura (2009) estimate a decreasing hazard rate

Equilibrium effects of inflation




Fraction and size of price changes
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.1 0.6 1.1 1.6 2.1 2.6 3.1 3.6 4.2 4.7 5.2 5.7 6.2 6.8 7.3 7.8 8.3 8.9 9.4 10.0 10.5 11.0 11.6 12.1 12.7
inf
fraction
size

	fraction	size
coeff in regression of π (model)	9.66	5.71
coeff in regression of π (data)	2.38	3.55


Postitive and negative price changes
0.18
0.16
0.14
0.12
0.1
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0.06
0.04
0.02
0
inf
0.1 0.6 1.1 1.6 2.1 2.6 3.1 3.6 4.2 4.7 5.2 5.7 6.2 6.8 7.3 7.8 8.3 8.9 9.4 10.0 10.5 11.0 11.6 12.1 12.7
fraction
positive
negative

	fraction	positive	negative
coeff in regression of π (model)	9.66	10.18	-0.51
coeff in regression of π (data)	2.38	5.48	-3.10

Finding: Our theory can simultaneously account for all of the important empirical features of pricing behavior discussed by Klenow - Kryvtsov and Steinsson - Nakamura:

1. Mean duration of a price is between 8 and11 months.

2. Features of the price change distribution: on average, price changes are large, many price changes are small, many price changes are negative.

3. Correlation between inflation and pricing behavior: inflation is positively correlated with the frequency and size of price changes, and it is negatively correlated with the frequency of negative price changes.

Neither Mankiw-Menu cost nor Calvo-Taylor models can simultaneously account for all of these facts. And we used a no-frills version of our model.

Conclusion

We constuct a model of sticky prices with these properties:

Many sellers do not change p, even though p/P falls and they earn less per unit in real terms, because they make it up on the volume so that profits are unaffected.

The methodolgy and the policy implications are distinctly New Monetarist, not Keynesian: the Fed cannot exploit price stickiness to increase Y by printing money.

The model can account for the key facts concerning pricing in the micro data.