Calvo vs Menu Costs

- Last week, some of you seemed unconvinced by the use of the ***Calvo fairy*** to deal with price stickiness
- Perhaps you prefer the ***Calvo devil*** who keeps pouring beer to workers until λ% of them are incapable of asking for a pay raise
- I claimed that either form of Calvo was certainly fanciful, but ***empirically useful***
- The following slides present more evidence on ***price stickiness***
- There is no doubt that it is an important empirical phenomenon, rendering the standard RBC quite useless

QJE 2010 Nakamura and Steinsson

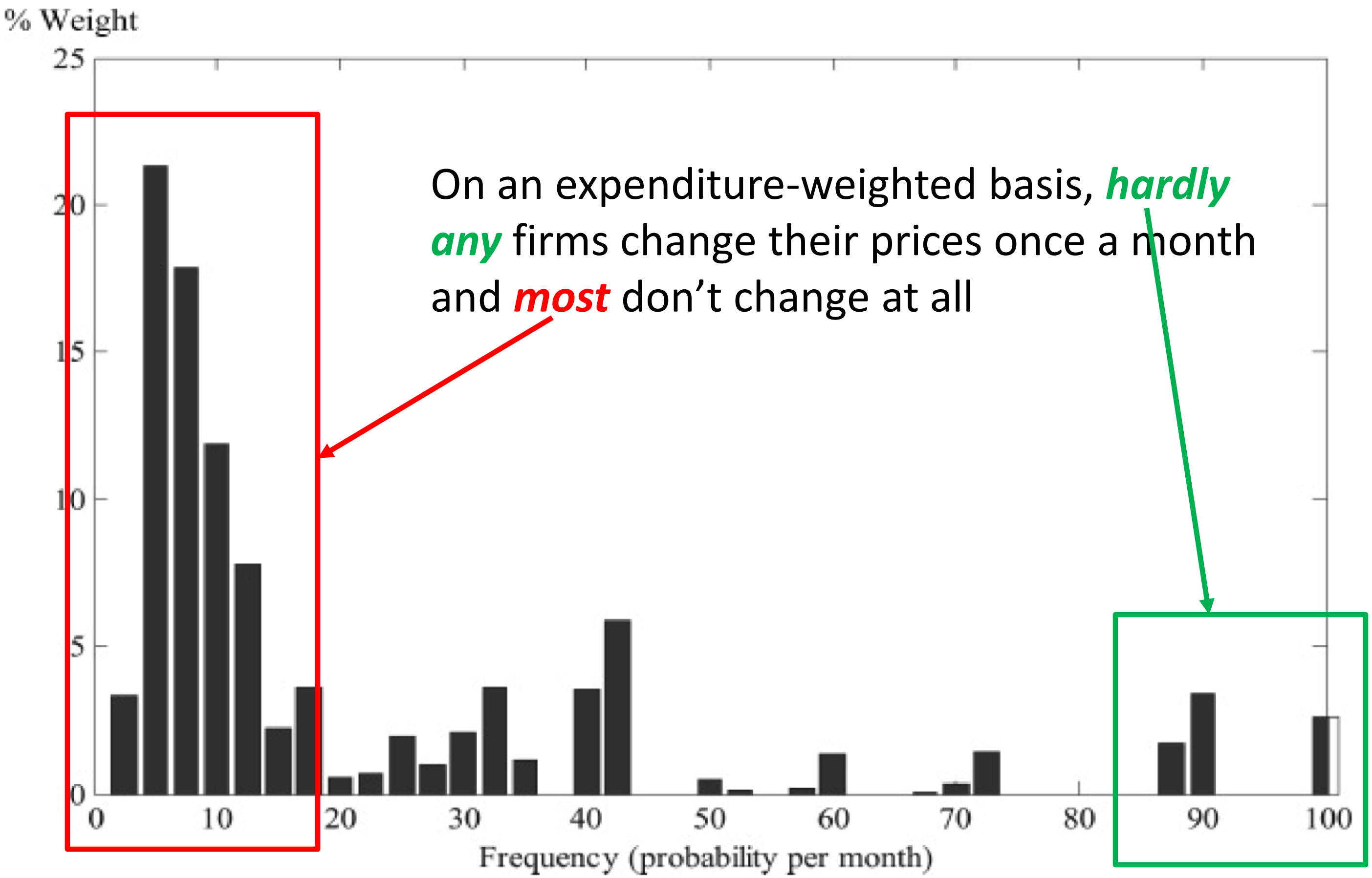

FIGURE I

The Distribution of the Frequency of Price Change for U.S. Consumer Prices

This figure presents a histogram of the cross-sectional distribution of the frequency of nonsale price changes in U.S. consumer prices for the period 1998–2005 (percent per month). The figure is based on the statistics in Nakamura and Steinsson (2008). It is based on the individual price quotes underlying the U.S. CPI. The figure shows the expenditure weighted distribution of the frequency of price changes across entry-level items (ELIs) in the CPI.

TABLE 1—FREQUENCY OF PRICE ADJUSTMENT BY INDUSTRY

	Total	Agriculture	Manufacturing	Utilities	Trade	Finance	Service
Panel A. Frequency of price adjustment (percent) Per month							
Mean	14.17	26.96	11.57	19.12	19.70	13.14	8.47
Standard deviation	(13.08)	(17.91)	(11.19)	(13.93)	(13.50)	(11.63)	(8.85)
Average duration (months)	6.54	3.18	8.13	4.71	4.56	7.1	11.3
Panel B. Synchronization of price adjustment (percent) Share of price quotes of a given firm in a given month which change							
Mean	14.45	26.33	11.60	20.46	16.99	14.03	9.77
Standard deviation	(10.81)	(17.34)	(8.54)	(11.04)	(9.24)	(9.42)	(7.42)
Panel C. Number of products							
Mean	110.59	93.67	113.64	199.34	82.99	72.50	69.25
Median	64.18	40.54	73.64	181.51	42.17	44.96	31.99
Standard deviation	(124.54)	(112.81)	(119.56)	(177.70)	(96.78)	(74.72)	(82.10)
Firms	760	52	342	109	45	138	74

QJE 2010 Nakamura and Steinsson

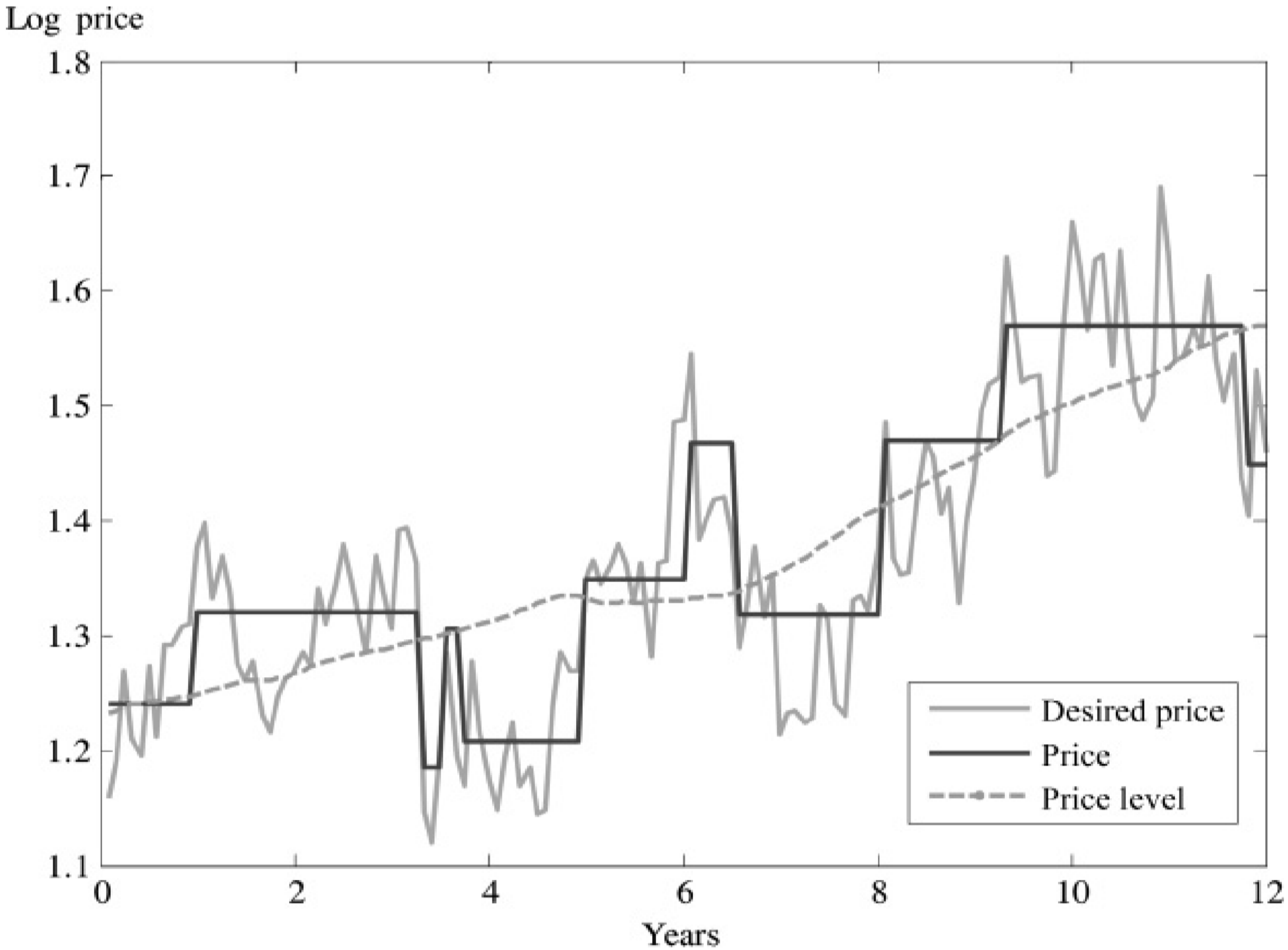

FIGURE IV

A Sample Path from the Price of a Typical Product

This figure plots a sample path of the price for a single firm in the model with intermediate inputs. The menu cost and variance of idiosyncratic shocks for the firm are set to match the median frequency and size of price changes. It also plots the price level and the firm's static desired price.

- Gautier and Le Bihan

- In a recent paper at the Banque de France, Gautier and Le Bihan present a model which generalises that which I showed you last week and should convince you to love Calvo!

- *Shocks vs Menu Costs: Patterns of Price Rigidity in an Estimated Multi-Sector Menu-Cost Model*
- May 2018, Banque de France WP #682

- The model allows for ***differentiated wholesale firms*** using ***differentiated intermediate goods*** to produce their ***differentiated outputs*** (which are then Dixit-Stiglitz aggregated into a single final "consumption bundle")
- The model also ***nests*** both the ***Calvo*** (time-dependent) approach and the older ***menu cost*** (state-dependent) approach to price stickiness
- Last week, I did not mention the menu cost approach
- This was the original way to introduce the empirically-observed price stickiness

- Recent empirical work suggests that small price changes (1-5%) are relatively common
- This evidence has been used to criticize classic menu-cost models because they do not generate such small price changes
- The basic idea is that a firm has to pay a “menu cost” if it wants to reset its price
- This menu cost should be interpreted broadly as the cost of
  - reprinting price stickers/bar codes with new prices
  - collecting and processing information
  - bargaining with suppliers and customers
  - management time spent in monitoring prices and deciding whether to effect a price adjustment

- A firm resets its price from P_i to P* only if the gains from doing so exceed the menu cost ➔ ***"state dependent"*** pricing decision
- ***state dependency*** because if a price is far enough away from its optimal value, it may be worthwhile to pay the cost to change it since the benefit of changing the price would be even larger than the cost
- ***vs*** Calvo ***"time dependent"*** since firm can only wait to see if the Calvo fairy allows it to change price to P*
- Below is a brief description of the model

- <u>Household Behaviour</u>
- The representative household maximizes an intertemporal utility function given by:

$$E_t \sum_{\tau=0}^{\infty} \beta^{\tau} \left[\frac{1}{1-\gamma} C_{t+\tau}^{1-\gamma} - \omega L_{t+\tau} \right]$$

- where the disutility of labour is additively separable and linear, L_t is Labour, C_t is a consumption aggregate
- Households discount future utility by a factor β per period

- Households have ***constant relative risk aversion*** equal to γ (aka intertemporal elasticity of substitution)
- The level and convexity of their ***disutility of labour*** is determined by the parameter ω
- Households consume ***differentiated products***
- They must decide each period ***how much*** to consume of each of the differentiated products

- For any given level of spending in time t, the households choose the ***consumption bundle*** that yields the highest level of a consumption ***index C_t*** given by a ***discrete*** Dixit-Stiglitz index of the ***differentiated goods*** produced by the ***K different sectors*** of the economy

$$C_t = \left[\sum_{k=1}^{K} \omega_k^{\frac{1}{\theta}} C_{k,t}^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}$$

- Aggregate household demand for ***differentiated good k*** is given by

$$C_{k,t} = \omega_k \left[\int_0^1 C_{i,k,t}^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}}$$

- where θ is the ***elasticity of substitution*** between the different goods (which is assumed to be ***identical*** within a sector and across sectors)
- and ω_k is a ***sectoral weight*** equal to the CPI weight of product k in the CPI

- <u>Production function</u>
- There is a continuum of firms in the economy indexed by k
- Each firm belongs to one of ***K sectors*** and specializes in the production of a ***differentiated product***
- The production function of ***firm i in sector k at time t*** is given by
- $Y_{i,k,t} = A_{i,k,t} L_{i,k,t}^{(1-sm)} M_{i,k,t}^{sm}$
- s_m is the share of ***intermediate inputs*** $\boldsymbol{M_{i,k,t}}$

- Index of intermediate input

$$M_{i,k,t} = \left[\int_0^1 m_{i,k,t}(j)^{\frac{1-\theta}{\theta}} dj \right]^{\frac{\theta}{1-\theta}}$$

- where $m_{i,k,t}$ (j) is intermediate input produced by firm j and used by firm i in sector k at time t
- ***All products serve both as final output and as inputs into the production of other products***
- This ***"roundabout" production model*** reflects the complex input–output structure of a modern economy

- <u>Price stickiness and Menu costs</u>
- Price stickiness is implemented by assuming that firms in sector k must ***hire additional units of labour*** if they decide to change their prices in period t; this fixed cost of price adjustment is the "menu cost"
- The (***state-dependent***) menu cost $\boldsymbol{c_{i,k,t}W_t}$ is here allowed to be ***time-varying*** because models with ***fixed*** menu costs ($c_{i,k,t} = c_{i,k}$) are typically ***not able*** to fit empirically the small price changes observed in most price data sets

- With probability λ_k , the price change is ***costless***: $c_{i,k,t} = 0$
- With probability $1 - \lambda_k$, the price change carries the ***menu cost*** $c_{i,k,t} = \mu_k$
- Thus μ_k is the cost paid by the firm ***conditional*** on drawing a ***non-zero*** menu cost
- This formulation ***encompasses*** both the pure ***menu cost*** model (corresponding to $\lambda_k = 0$) and the ***Calvo*** model corresponding to $\mu_k = \infty$), in which price changes are triggered only by the (costless) adjustment opportunities offered to the firm by the Calvo fairy

- <u>Model Solution</u>
- Solving this type of model is ***much more complex*** than is solving the NK model with only Calvo …
- For a firm i belonging to sector k, denote the vector of ***state variables***

$$\mathcal{S}_{i,t} = \{P_{i,t-1}/P_t, A_{i,t}\}$$

- Then the present value of profits is

$$V(\mathcal{S}_{i,t}) = \max[V^{nc}(\mathcal{S}_{i,t}), V^{c}(\mathcal{S}_{i,t})]$$

$$V(\mathcal{S}_{i,t}) = \max[V^{nc}(\mathcal{S}_{i,t}), V^{c}(\mathcal{S}_{i,t})]$$

- where V^c is the value when price adjusts:

Discount factor

Menu costs

$$V^{c}(\mathcal{S}_{i,t}) = \max_{P_{i,t}}[\Pi(P_{i,t}/P_t, A_{i,t}) + E_t Q_{t+1} V(\mathcal{S}_{i,t+1})] - c_{i,t}\frac{W_t}{P_t}$$

- and V^nc is value when price does ***not*** adjust:

$$V^{nc}(\mathcal{S}_t) = \Pi(P_{i,t-1}/P_t, A_{i,t}) + E_t Q_{t+1} V(\mathcal{S}_{i,t+1})$$

No menu costs!

- The model is solved by numerical methods and value function iteration
- As is common in the menu cost set-up, the solution produces a ***"range of inaction"***, rationalising infrequent price changes

- Having set up the model Gautier and Le Bihan estimate the value of
  - the menu cost
  - the Calvo component (the probability of drawing a ***costless*** opportunity to change prices)
  - at the product level
- They estimate this model for more than ***200 different products*** of the French CPI
- Empirical moments are obtained using a large microeconomic data set of more than ***25 million*** individual consumer ***price quotes***

- Their main results are the following:
  - There is a substantial degree of ***heterogeneity*** across sectors in all structural parameters
  - The ***Calvo*** component plays a ***crucial*** role to fit the data and is the ***main source*** of price rigidity (estimated to generate about 70% of all price changes in their baseline model)
  - The genuine "***menu cost***" component contributes ***only a small proportion of*** the overall degree of price rigidity
  - Across sectors, the heterogeneity in the ***Calvo*** component ***explains most*** of the heterogeneity in the frequency of price changes across products

Table 4: Estimates of Price Rigidity Model - Aggregate models

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	Menu cost			
	λ	μ	average	$\frac{\lambda}{Freq}$
$s_m = 0$ Share of intermediate goods				
			Single sector	
Median moments	0.049	0.024	0.079	58.9
Mean moments	0.075	0.011	0.061	56.2
			4-sector model	
Food	0.101	0.047	0.139	77.0
Manuf. goods	0.048	0.045	0.126	62.5
Energy	0.724	0.061	0.000	100
Services	0.041	0.062	0.052	82.5

fraction of price changes performed under ***Calvo***

Gautier and Le Bihan. Banque de France WP682 2018

	Menu cost			
	λ	μ	average	$\frac{\lambda}{Freq}$
$s_m = 0.7$ Share of intermediate goods				fraction of price changes performed under ***Calvo***
			Single sector	
Median moments	0.068	0.027	0.045	79.5
Mean moments	0.099	0.009	0.032	72.1
			4-sector model	
Food	0.125	0.049	0.057	91.3
Manuf. goods	0.064	0.053	0.075	81.1
Energy	0.758	0.071	0.000	100
Services	0.054	0.068	0.011	97.0

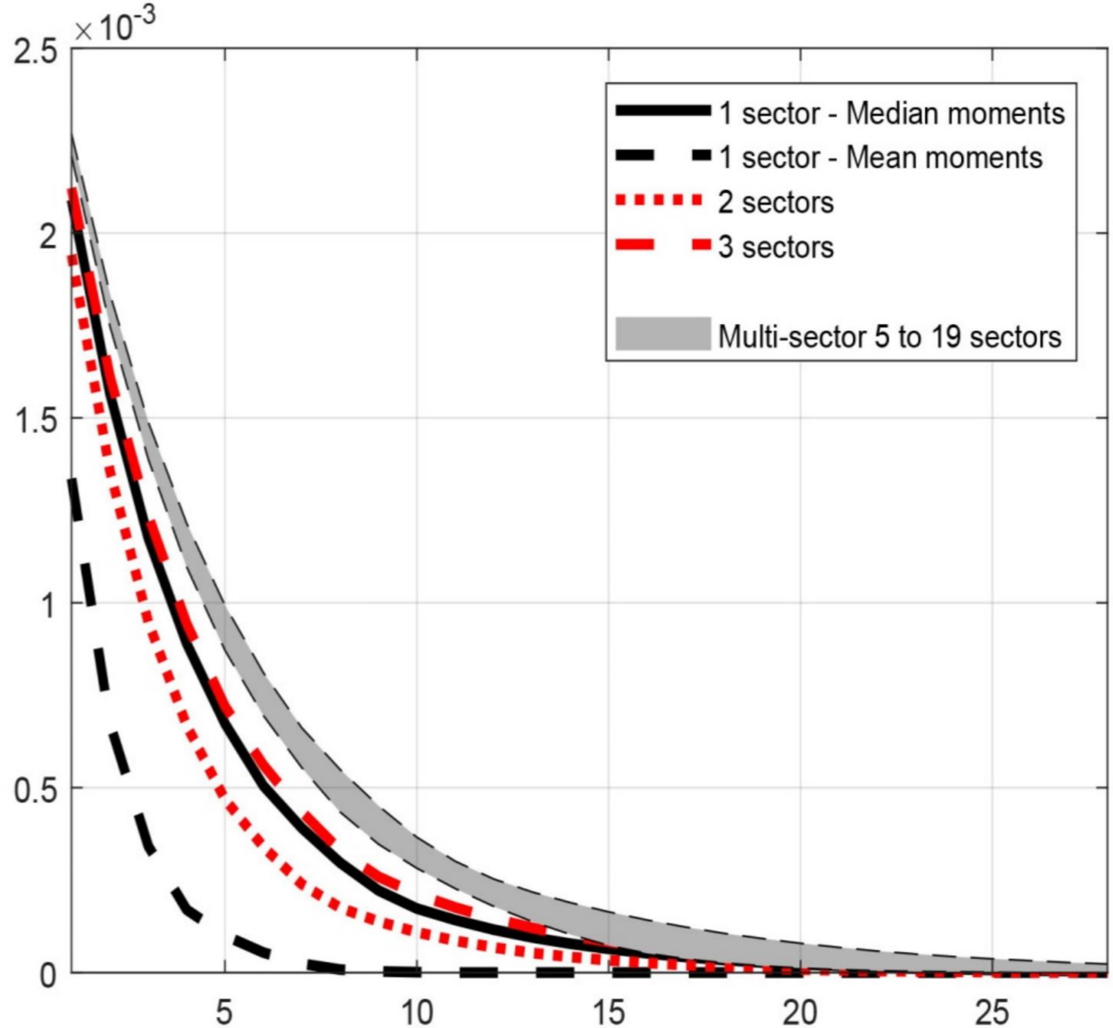
- What about ***monetary non-neutrality*** in this context
- Nakamura and Steinsson measure the degree of monetary non-neutrality as the ***variance of real value-added output*** when the model is simulated with purely nominal aggregate shocks
- Others use the ***cumulative impulse response of real value-added output*** to a permanent shock to nominal aggregate demand
- If money were ***neutral***, these measures would be ***approximately zero***

- It turns out that under normal assumptions the results using the two alternative measures are ***practically identical***
- N-S find that the degree of monetary non-neutrality is ***sharply increasing*** in the number of sectors
- Gautier and Le Bihan ***also find*** that product heterogeneity matters for monetary policy

- They find that the degree of ***monetary non-neutrality*** is ***much larger*** in a ***multi-sector*** model than in a one-sector model calibrated on the same average moments
- Specifically, the degree of monetary non-neutrality is about ***4 times larger*** in a model with 3 or more different sectors than in a single sector model calibrated on the same average moments
- The ***Calvo*** component also matters: the real effect of monetary policy with Calvo is around ***twice as large*** as that obtained using a fixed ***menu–cost*** model

Impulse Response of Output to a Nominal Shock – Single-Sector Models vs Multi-Sector Models

Gautier and Le Bihan. Banque de France WP682 2018



Note: Aggregate responses of output to a monetary policy shock of one standard deviation of inflation (0.3%) obtained from different models. One sector model fitting average moments (dark dashed line), one sector model fitting the median moments of the data (dark solid line), two--sector model (energy and core sectors) (red dotted line), three-sector model (non-energy goods, energy, services) (red dashed line), multi-sector models where sectors group products according to the value of the Calvo component (grey shaded area – 5 to 19 sectors).