Flattening of the Phillips curve with state-dependent prices and wages

James Costain, Anton Nakov, Borja Petit

Banco de España, ECB & CEPR, CUNEF

18 February 2021

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Motivation: old and new

Old questions in economics:

- How fast do monetary shocks transmit to the price level?
- How large are their short-term real effects?

New question

- What can explain the flattening of the US Phillips curve since 2000?

The answers depend on details of price-setting at the micro level

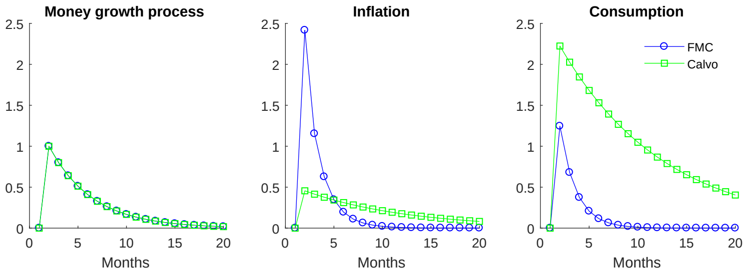
Motivation

What we know:

- With exogenous timing of price changes (Calvo, 1983): large real effects
- With fixed menu costs (Golosov-Lucas, 2007): near neutrality of money
  - **Selection effect**:
  - the most misaligned prices are reoptimized
  - individual price changes are large and the aggregate price level is flexible

Money supply shock: Calvo vs. Fixed Menu Cost

(both models are calibrated to the same average frequency of adjustment)



Related literature

- New SDP models: Midrigan (2011), Alvarez et al. (2011), Matejka (2011), Costain and Nakov (2011, 2015): **attenuate the selection effect**
- The new SDP models match much better retail price microdata than Golosov-Lucas
- And respond better to changes in the inflation environment than Calvo
- Survey evidence by Zbaracki et al (2004) suggests **decision-making costs** are an important fraction of overall price changing costs

Related literature

- For simplicity SDP models ignore all other frictions: **sticky prices only**
- Except Takahashi (2017): combines SD sticky prices and SD sticky wages

  But Takahashi has no idiosyncratic shocks, so cannot match price or wage change histograms, the usual targets of the newer SDP models

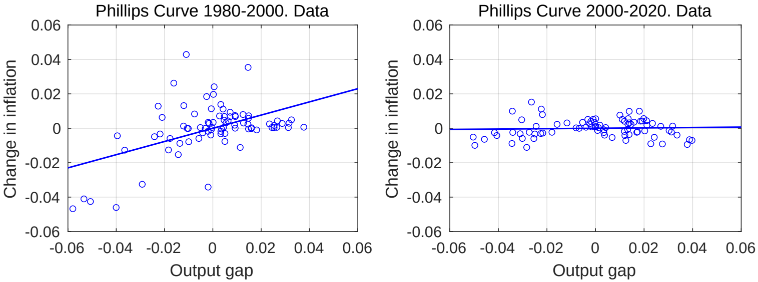
This paper: theory

1. Studies simultaneously SD prices and SD wages
2. Nominal rigidities following "Logit Price Dynamics" (Costain-Nakov, 2019)
   - Main assumption: **precise decisions are costly**
3. We adopt the "control costs" approach of Mattson and Weibull (2002)
   - Has rational inattention microfoundations (Steiner-Stuart-Matejka, 2017)
   - Consists of imposing a cost function for the precision of actions
   - In equilibrium actions are not fully precise (trembling hand)
   - If precision is measured by relative entropy, then choices distributed as logit
4. Market structure following Erceg, Henderson, and Levin (2000)
   - Firms are monopolistic suppliers of goods
   - Workers are monopolistic suppliers of labor

This paper: application

- We apply our model to the changing slope of the Phillips curve

Figure: Phillips curves in US data before and after 2000



Literature: Phillips curve flattening

- Several papers have explored the apparent flattening of the Phillips curve: Barnichon and Mesters (2021), Ball and Mazumder (2011), Coibion and Gorodnichenko (2015), among others
- A variety of explanations have been offered, including:
  - Asymmetric rigidities (Benigno and Ricci, 2011; Linde and Trabandt, 2018)
  - Better anchoring of expectations (Barnichon and Mesters, 2021)
  - And improved monetary policy (Roberts, 2006; McLeay and Tenreyro, 2020)
- We emphasize a new mechanism due to **state dependence and lower** π^*
- Our explanation is complementary to existing ones

This paper: findings

- Stickiness of wages is more important than stickiness of prices for monetary non-neutrality
  - This is because wages are an important component of marginal costs and because wage adjustment is less frequent than price adjustment.
- The decline in long run inflation, coupled with state-dependence, can account for about half of the flattening of the Phillips curve since 2000
  - Lower long-run inflation decreases the frequencies of price and wage adjustment making short-run inflation less responsive to nominal shocks.
- Limits to monetary stimulus
  - Large money shocks induce more frequent price and wage adjustment and have smaller real effects

Model: monopolistic firms

- **Profits**:
  - Firm i's demand: $Y_{it} \;=\; (P_{it}/P_t)^{-\epsilon} Y_t$
  - Firm i's output: $Y_{it} \;=\; A_{it} N_{it}$, where $\log A_{it}$ is AR(1)
  - Profits: $U_t(P_{it}, A_{it}) \;\equiv\; P_{it} Y_{it} - W_t N_{it}$
- **Control variable**:
  - Firm adjusts its nominal price P_{it}
  - Current P_{it} remains in effect until firm sets a new nominal price
  - Output and hours worked are demand determined
- **Frictions**:
  - Changing prices itself is costless (zero menu costs)
  - But greater precision requires more decision time, so decisions are costly

Costs of decision-making: price choice

- Think of decisions as probability distributions over alternatives
- Assume precision is costly
- Let $\pi(p)$ be a firm's chosen distribution over its log real price p

A1: The time cost τ of decision π is:

$$\kappa_\pi \mathcal{D}(\pi||\eta) \equiv \kappa_\pi \int \pi(p) \ln \left(\frac{\pi(p)}{\eta(p)} \right) dp$$

where $\eta(p)$ is an exogenous "default" distribution.

Costs of decision-making: timing choice

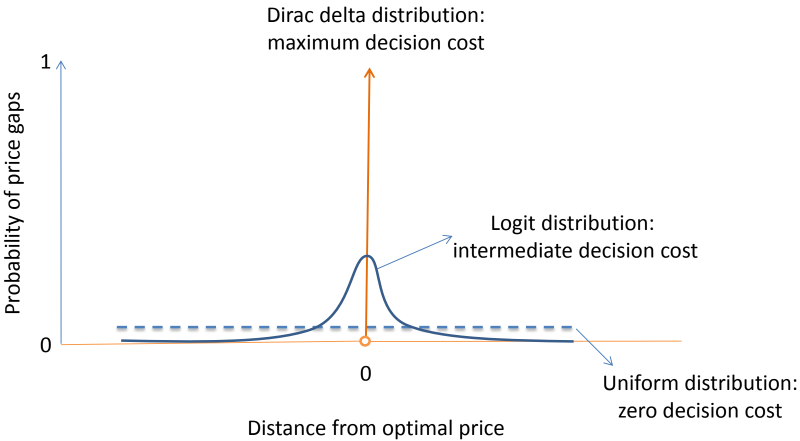
- Let λ be the (endogenous) probability of making a decision today

A2: The time cost μ of choosing whether or not to make a decision is:

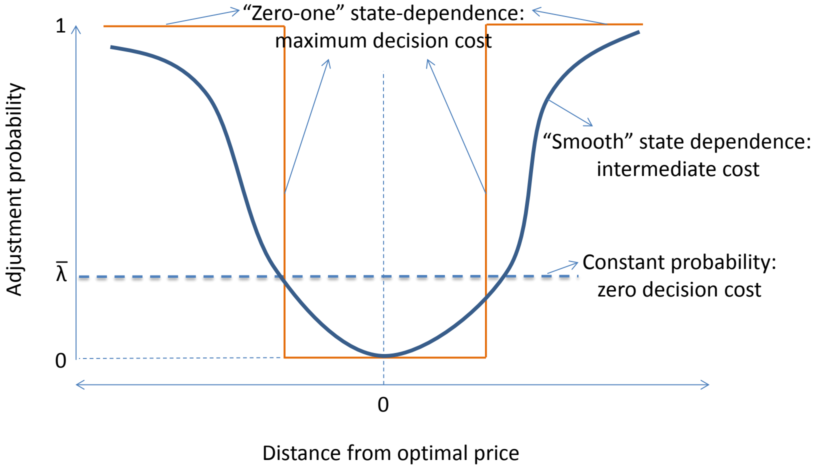
$$\kappa_\lambda \mathcal{D}\left(\lambda || \bar{\lambda}\right) \equiv \kappa_\lambda \left(\lambda \log \frac{\lambda}{\bar{\lambda}} + (1-\lambda) \log \frac{1-\lambda}{1-\bar{\lambda}}\right)$$

where $\bar{\lambda}$ is an exogenous "default" probability.

Adjustment behavior: pricing choice



Adjustment behavior: timing choice



Distribution of actions

- Both price distribution and probability of decision are weighted logits:
- Distribution of prices, conditional on decision:

$$\pi_t(p|a) = \frac{\eta(p)\exp\left(\frac{v_t^e(p,a)}{\kappa_\pi w_t}\right)}{\int \eta(\tilde{p})\exp\left(\frac{v_t^e(\tilde{p},a)}{\kappa_\pi w_t}\right) d\tilde{p}}$$

- Probability of making a decision:

$$\lambda_t(p,a) = \frac{\bar{\lambda}\exp\left(\frac{\tilde{v}_t(a)}{\kappa_\lambda w_t}\right)}{\bar{\lambda}\exp\left(\frac{\tilde{v}_t(a)}{\kappa_\lambda w_t}\right) + (1-\bar{\lambda})\exp\left(\frac{v_t^e(p,a)}{\kappa_\lambda w_t}\right)},$$

Adding wage stickiness in an analogous way

- Next, do **wage stickiness too**
- Model wages and prices analogously, as in **Erceg-Henderson-Levin (2000)**
- We assume each worker sells a distinct type of labor in a monopolistically competitive fashion to many firms
- We are not yet addressing any other labor market frictions: no search and matching or unemployment

Costs of decision-making: wage choice

- Let $\pi^{w}(w)$ be a worker's chosen distribution over his log real wage w.

A3: The time cost τ^{w} of decision π^{w} is:

$$\kappa_{w}\mathcal{D}(\pi^{w}||\eta^{w}) \equiv \kappa_{w}\int \pi^{w}(w)\ln\left(\frac{\pi^{w}(w)}{\eta^{w}(w)}\right)dw$$

where $\eta^{w}(w)$ is an exogenous "default" decision.

Costs of decision-making: wage timing

- Let ρ be the (endogenous) probability of making a decision today

A4: The time cost μ^w of choosing whether to make a decision is:

$$\kappa_w \mathcal{D}\left(\rho || \bar{\rho}\right) \equiv \kappa_w \left(\rho \log \frac{\rho}{\bar{\rho}} + (1-\rho) \log \frac{1-\rho}{1-\bar{\rho}} \right)$$

where $\bar{\rho}$ is an exogenous "default" probability.

Distribution of actions

- Both wage distribution and probability of decision are weighted logits:
- Distribution of wages, conditional on decision:

$$\pi_t^w(w|z) = \frac{\eta^w(w)\exp\left(\frac{I_t^e(w,z)}{\kappa_w \xi_t}\right)}{\int \eta^w(w')\exp\left(\frac{I_t^e(w',z)}{\kappa_w \xi_t}\right) dw'}$$

- Probability of making a decision:

$$\rho_t(w,z) = \frac{\bar{\rho}\exp\left(\frac{\tilde{I}_t(w,z)}{\kappa_\rho \xi_t}\right)}{\bar{\rho}\exp\left(\frac{\tilde{I}_t(z)}{\kappa_\rho \xi_t}\right) + (1-\bar{\rho})\exp\left(\frac{I_t^e(w,z)}{\kappa_\rho \xi_t}\right)}$$

Parameters

Table: Exogenous parameters

Parameter	Description	Value	Source
β	Discount factor (monthly)	0.9967	Annual real rate of 4%
β_S	Survival probability (monthly)	0.9979	Economic life span of 40 years
ζ	Inverse Frisch elasticity	0.5	Standard value
γ	Intertemporal elasticity of subs.	2	Golosov-Lucas (2007)
χ	Coefficient on disutility of labor	6	Golosov-Lucas (2007)
ϵ, ϵ_n	Elasticities of subs. across varieties	7	Golosov-Lucas (2007)
μ^*	Long-run gross money growth	1.0017	Annual inflation of 2% (Dominicks')

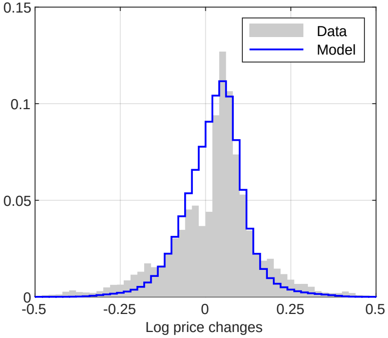
Parameters

Table: Calibrated parameters

Firms	Default hazard (monthly)	$\bar{\lambda}$	0.2707
	Adjustment cost	κ_f	0.0177
	Productivity persistence	ρ_a	0.6441
	Standard deviation productivity shocks	σ_a	0.0703
Workers	Default hazard (monthly)	$\bar{\rho}$	0.2317
	Adjustment cost	κ_w	0.0275
	Productivity persistence	ρ_z	0.9700
	Standard deviation productivity shocks	σ_z	0.0574

Price and wage change distributions

Figure: Distribution of nonzero price and wage changes



Varying decision cost

Table: Adjustment parameters for counterfactual exercises

	Baseline	FP	FW	FPFW
Firms (κ_f)	$\kappa_f = 0.0177$	$\kappa_f/100$	κ_f	$\kappa_f/100$
Workers (κ_w)	$\kappa_w = 0.0275$	κ_w	$\kappa_w/100$	$\kappa_w/100$

Price setting stats for different κ_f and κ_w

Table: Evaluating the model with different values of κ_f and κ_w

	Data	Base.	FP	FW	FPFW
Frequency of price change (%)	10.20	10.21	59.51	10.21	59.65
Mean absolute price change (%)	9.90	6.94	4.53	6.92	4.52
Kurtosis of price changes	4.81	4.60	2.01	4.60	2.01
% of price changes > 0	65.10	56.47	52.37	56.49	52.37
% of abs price changes < 0.025	12.00	27.26	25.69	27.27	25.84
Output losses due to price stickiness (%)[a]	–	2.78	1.16	2.77	1.16

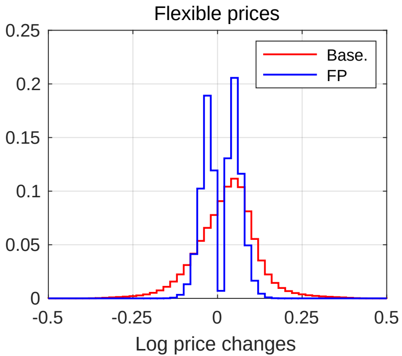
Wage setting stats for different κ_f and κ_w

Table: Evaluating the model with different values of κ_f and κ_w

	Data	Base.	FP	FW	FPFW
Frequency of wage change (%)	8.30	8.34	8.33	30.81	30.68
Mean absolute wage change (%)	6.47	5.50	5.50	1.95	1.96
Kurtosis of wage changes	4.39	11.94	11.70	2.00	2.00
% of wage changes > 0	86.50	70.62	70.60	66.75	66.77
% of abs wage changes < 0.025	11.80	25.17	25.17	80.21	80.02
Output losses due to wage stickiness (%)[a]	–	1.98	2.00	0.08	0.08

Price and wage changes histograms: varying decision cost

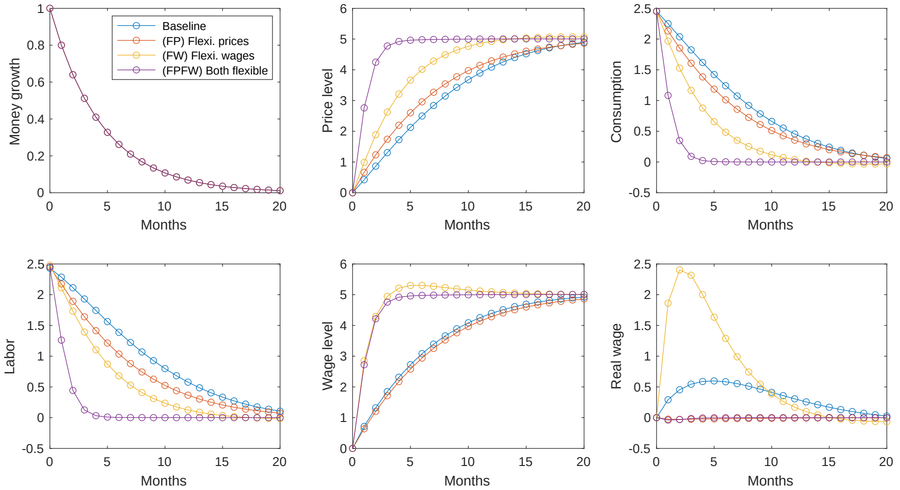
Figure: Distribution of nonzero price and wage changes: varying κ_f and κ_w



Notes: left panel shows the effect of decreasing price stickiness on the distribution of nonzero price adjustments keeping wages sticky. Right panel shows the effects of decreasing wage stickiness on the distribution of nonzero wage adjustments keeping prices sticky.

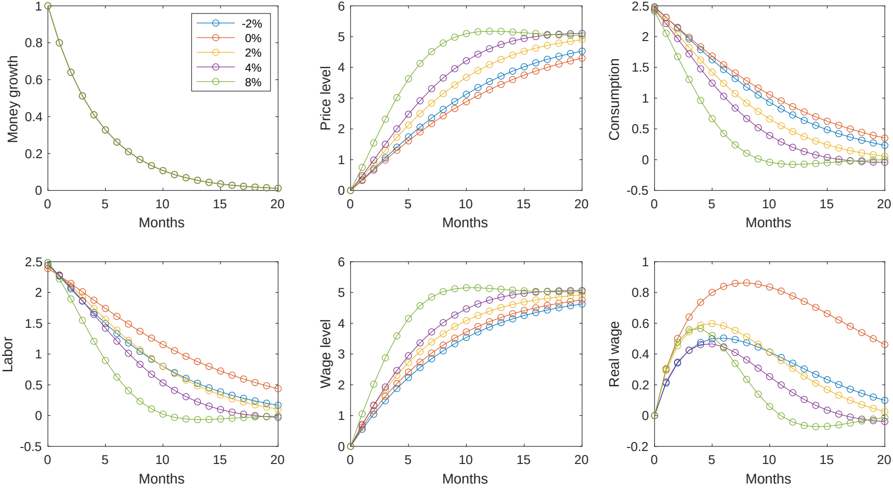
Money supply shock: effects of price and wage stickiness

Figure: Money growth shock: effects of nominal rigidity



Money supply shock: effects of trend inflation

Figure: Impulse responses at different trend inflation rates in the baseline model



Phillips multipliers: Barnichon and Mesters

Definition: area under inflation response / area under output response

Table: Phillips multipliers at different trend inflation rates and noise parameters

Trend inflation	Baseline	Flexible Prices	Flexible Wages	Flexible Prices and Wages
-2%	0.229	0.225	0.572	1.071
0%	0.167	0.212	0.267	1.080
2%	0.239	0.295	0.414	1.156
4%	0.297	0.404	0.502	1.230
8%	0.446	0.665	0.614	1.335

Trend inflation decline and PC regressions

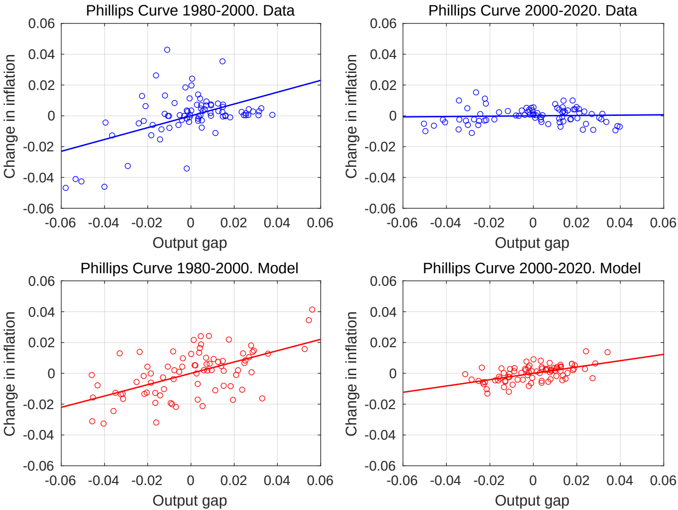
- We take a traditional approach to evaluating the flattening, by estimating reduced-form Phillips curves both in the data and in our model
- We follow Jorgensen and Lansing (2021) splitting the sample in 2000

Period	Aver. US inflation
1980-2000	4.6%
2000-2020	2.0%

- We then regress the change in inflation on the output gap

Flattening of the Phillips curve

Figure: Phillips curves in the data and the model



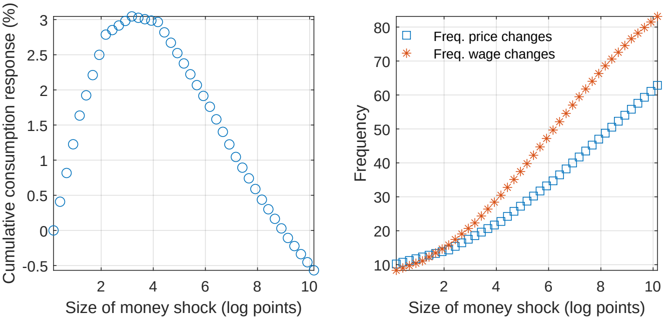
Flattening of the Phillips curve

Table: Slope of the Phillips curve. Data and Model

	1980-2000	2000-2020	Change	% Change
Data	0.3835	0.0114	0.3721	97.03
Model	0.3676	0.2051	0.1625	44.21

Limits to monetary stimulus

Figure: Comparing small and large money supply shocks



Left: cumulative responses of consumption to one-time increase in the money supply.
Right: change in adjustment frequency, on impact, for wages and prices.

Conclusions

We develop a DSGE model with **state dependence** in both prices and wages and **idiosyncratic shocks**, for comparison to microdata

Model combines monopolistic competition in goods and labor inputs, with nominal rigidity derived from **costly decision-making**

1. **Wage stickiness** is a stronger source of non-neutrality than price stickiness
2. Decreased trend inflation makes nominal adjustment and short-run inflation less reactive to monetary shocks, **lowering the slope of the Phillips curve**
3. The model is able to **explain roughly half** of the observed drop in the slope of the US Phillips curve since 2000