MONETARY NON-NEUTRALITY IN A MULTI-SECTOR MENU COST MODEL

NAKAMURA & STEINSSON (2010)

Discussion ECON 210C - Paula Donaldson

TIME *VS.* STATE-DEPENDENT PRICING MODELS

- Time-dependent pricing models assume the frequency of price changes is constant over time $\rightarrow$ Calvo pricing
- State-dependent pricing models assume the frequency of price changes is a function of the state of the economy $\rightarrow$ Menu cost models

Menu Cost Models

- In menu cost models firms face a fixed cost of changing prices
- Firms that change prices are not chosen randomly
- The decision to change prices is based on the expected benefits of doing so, which depend on the state of the economy
- This leads to a potentially more flexible response of prices to changes in economic conditions

MONETARY NON-NEUTRALITY: CALVO VS. MENU COST MODELS

- Calvo pricing can generate relatively large and persistent MNN
- Golosov & Lucas (07) argue that monetary non-neutrality with menu cost models is *small and transient*
- Nakamura & Steinsson (10):

  "...assess whether the implications of highly stylized menu cost models hold up in a richer, more realistic setting"

MONETARY NON-NEUTRALITY IN A MULTI-SECTOR MENU COST MODEL - NAKAMURA & STEINSSON (10)

- Central role of nominal rigidities as a source of monetary non-neutrality
- State-dependent pricing models appear more realistic than time-dependent pricing models
- but, if they generate too little monetary non-neutrality
- Should we still rely on nominal rigidities to explain the effects of monetary policy?
- NS (10) argue that a more realistic menu cost model is able to generate monetary non-neutrality in accordance with empirical evidence

MULTI-SECTOR MENU COST MODEL - KEY INGREDIENTS

Based on empirical evidence, they extend the benchmark menu cost model in the following ways:

1. Heterogeneity across sectors in the frequency and size of price changes
2. Intermediate inputs used in production (roundabout production)

The model introduces (1) heterogeneous nominal rigidities and a (2) “macro” real rigidity

KEY FINDINGS

- The model generates output fluctuations in response to nominal shocks in line with empirical evidence (Shapiro & Watson 1988):
  - Nominal shocks account for 23% of the US business cycle
  - In Golosov & Lucas (07) this share is 2%
- This different degree of monetary non-neutrality is explained by:
  - Heterogeneity in the frequency of price changes
  - The presence of intermediate inputs in production

HOW DO SECTORAL HETEROGENEITY AND INTERMEDIATE INPUTS AFFECT NON-NEUTRALITY?

Some intuition before we jump into the full model

1. Sectoral heterogeneity:
   - Amplification occurs if MNN is a convex function of the frequency of price changes
   - Jensen's inequality: the average of a convex function is greater than the function evaluated at the average, $f(E[x]) \leq E[f(x)]$
2. Intermediate inputs give raise to strategic complementarities in price setting
   - Strategic complementarities arise when the optimal price of one firm depends on the prices set by other firms
   - Firm changing price right after a shock, changes price by less because the prices of many of its inputs haven't changed yet
   - This leads to a more sluggish response of prices to shocks
   - Strategic complementarities are a source of real rigidities. Juan will real rigidities in detail tomorrow.

MODEL - HOUSEHOLDS AND CENTRAL BANK

- Households maximize discounted expected utility subject to a sequence of budget constraints
- They consume a continuum of differentiated products indexed by z.

$$c_t(z) = \left(\frac{p_t(z)}{P_t}\right)^{-\theta} C_t$$

- Optimamlity conditions for the household problem are:

$$D_{t,T} = \beta^{T-t}\left(\frac{C_T}{C_t}\right)^{-\gamma}\frac{P_t}{P_T}$$

$$\frac{W_t}{P_t} = \omega L_t^{\psi} C_t^{\gamma} \quad \rightarrow \quad W_t = \omega P_t C_t$$

- Monetary authority targets a path for the nominal value-added output

$$\log S_t = \mu + \log S_{t-1} + \eta_t, \quad \eta_t \sim \mathcal{N}(0, \sigma_\eta^2), \qquad S_t = P_t C_t$$

MODEL - FIRMS

- Continuum of firms indexed by z that belong to one of J sectors and produce a differentiated variety.

$$y_t(z) = A_t(z)L_t(z)^{1-s_m}M_t(z)^{s_m}$$

$A_t(z)$: productivity, $M_t(z)$: index of intermediate inputs, s_m: share of intermediates in production

- The index of intermediate products is given by:

$$M_t(z) = \left(\int_0^1 m_t(z,z')^{\frac{\theta-1}{\theta}}dz'\right)^{\frac{\theta}{\theta-1}}$$

- $m_t(z,z')$: quantity of intermediate input z' used in the production of good z
- Roundabout production: all products serve as inputs and final output
- Strategic complementarities: arises as a result of roundabout + price rigidity

MODEL - FIRMS - PROFIT MAXIMIZATION

$$\max \mathbb{E}_t \sum_{\tau=0}^{\infty} D_t t + \tau \Pi_{t+\tau}(z) \quad \text{s.t.}$$

$$y_t(z) = A_t(z) L_t(z)^{1-s_m} M_t(z)^{s_m}$$

$$y_t(z) = Y_t \left(\frac{p_t(z)}{P_t} \right)^{-\theta} \qquad \text{where} \quad Y_t = C_t + \int_0^1 M_t(z) dz$$

$$\Pi_{t+\tau}(z) = p_t(z) y_t(z) - W_t L_t(z) - P_t M_t(z) - \chi_j W_t l_t(z) - P_t U$$

- χ_j: units of labor a firm in sector j must pay to change price
- The law of motion of firm-level productivity is given by:

$$\log A_t(z) = \rho \log A_{t-1}(z) + \epsilon_t(z), \qquad \epsilon_t(z) \sim \mathcal{N}(0, \sigma^2_{\epsilon,j})$$

MODEL - FIRMS - RECURSIVE FORMULATION

- State-space of the firm's problem is infinite-dimensional
- Need to keep track of entire distribution of prices and productivity
- Assume firms form expectations about prices as a function of limited number of moments
- Firms perceive that

$$\frac{P_t}{P_{t-1}} = \Gamma\left(\frac{S_t}{P_{t-1}}\right)$$

- They use the function Γ to form expectations about the price level
- Bellman Equation

$$V\left(A_t(z), \frac{p_{t-1}(z)}{P_t}, \frac{S_t}{P_t}\right) = \max_{p-t(z)} \left\{\Pi_t^R(z) + \mathbb{E}_t\left[D_{t,t+1}^R V\left(A_{t+1}, \frac{p_t(z)}{P_{t+1}}, \frac{S_{t+1}}{P_{t+1}}\right)\right]\right\}$$

CALIBRATION OF MENU COSTS AND $\sigma_{e,j}$

- Calibrate menu cost and variance of idiosyncratic shocks to match frequency and size of price changes in the data

	Menu cost model			
	$s_m = 0$		$s_m = 0.7$	
	Δp cost $\times 10^{-2}$	σ_ε $\times 10^{-2}$	Δp cost $\times 10^{-2}$	σ_ε $\times 10^{-2}$
		Panel A: Six-sector model		
Vehicle fuel, used cars	0.004	5.00	0.001	5.10
Transp. goods, utilities, travel	0.309	6.90	0.087	6.85
Unprocessed food	0.667	9.10	0.194	9.20
Processed food, other goods	0.331	5.70	0.091	5.70
Services (excl. travel)	0.165	3.90	0.046	4.05
Hh. furn., apparel, rec. goods	0.271	5.46	0.070	5.40
		Panel B: Nine-sector model		
Vehicle fuel, used cars	0.004	5.30	0.002	5.40
Transp. goods, utilities, travel	0.307	6.90	0.091	7.00
Unprocessed food	0.667	9.00	0.185	9.00
Services (1)	0.059	2.40	0.019	2.65
Processed food, other goods	0.340	5.80	0.093	5.70
Services (2)	0.137	3.50	0.035	3.45
Services (3)	0.156	3.80	0.042	3.90
Hh. furn., apparel, rec. goods	0.306	5.80	0.076	5.40
Services (4)	0.340	6.50	0.083	6.39

Table III

- Why are calibrated menu costs smaller in the model with intermediates?

RESULTS - *w/o intermediates*

- Monetary non-neutrality is higher in the multi-sector models
- $Var(C_t)$ is the variance of real value-added output

TABLE VI

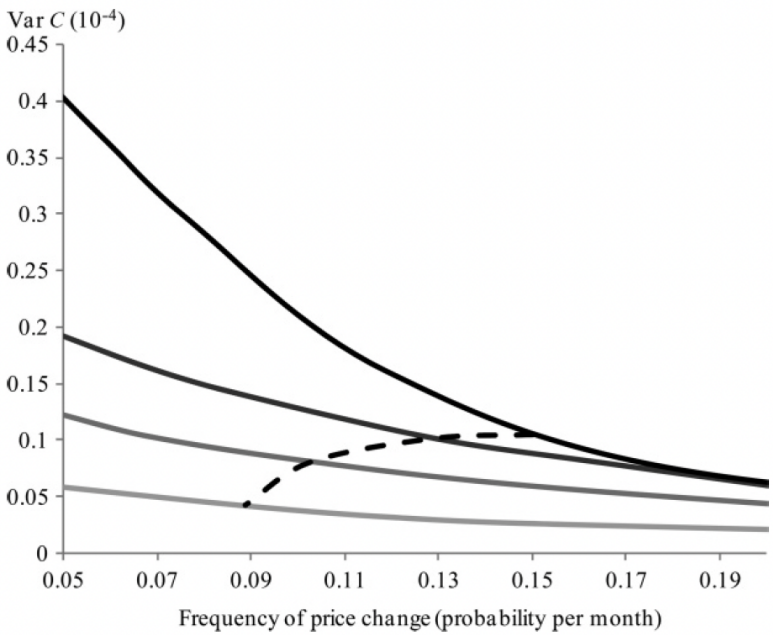
HETEROGENEITY AND MONETARY NON-NEUTRALITY

	Menu cost model		CalvoPlus model	
	$s_m = 0$	$s_m = 0.7$	$s_m = 0$	$s_m = 0.7$
Monetary non-neutrality: Var(C_t)				
One-sector model (mean)	0.055	0.182	0.173	0.461
Six-sector model	0.136	0.470	0.458	1.492
Nine-sector model	0.143	0.576	0.495	1.563
Fourteen-sector model	0.188	0.627	0.520	1.709
One-sector model (median)	0.261	0.658	0.625	1.480

Table VI

RESULTS - *w/o intermediates*

- Monetary non-neutrality depends on *both* size of menu costs and variance of idiosyncratic shocks
- *y – axis*: monetary non-neutrality
- *x – axis*: size of menu costs (higher menu costs as you move towards the origin)
- Each solid line corresponds to different values of the variance of idiosyncratic shocks (**darker line, higher** σ)



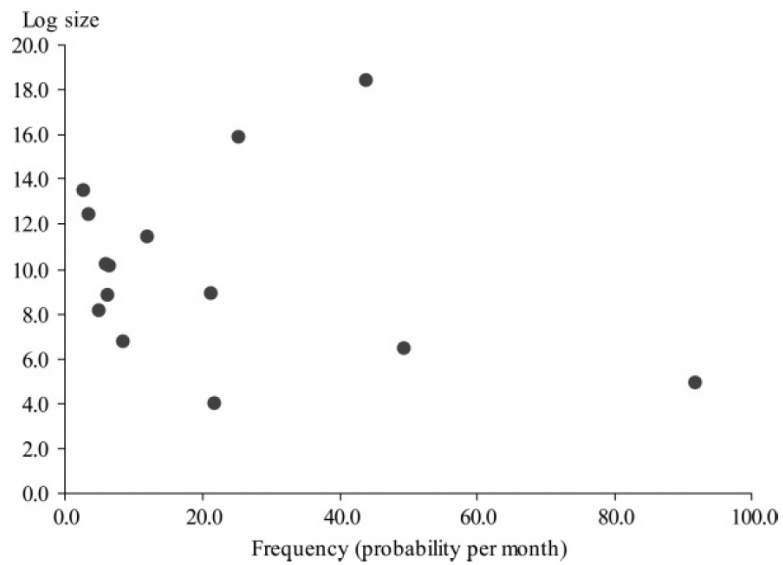


Table VII

RESULTS - *w/o intermediates*

- Amplification depends on:
  1. Heterogeneity in the frequency of price changes
  2. The overall level of the frequency of price changes

TABLE VII
AMPLIFICATION DUE TO HETEROGENEITY

	Two-sector models			One-sector models		Amp. factor
	Freq. 1	Freq. 2	Var(C_t)	Freq.	Var(C_t)	
(1)	0.10	0.20	0.1194	0.15	0.1050	1.137
(2)	0.20	0.30	0.0395	0.25	0.0360	1.098
(3)	0.30	0.40	0.0154	0.35	0.0152	1.014
(4)	0.40	0.50	0.0060	0.45	0.0059	1.010
(5)	0.10	0.30	0.0889	0.20	0.0620	1.433
(6)	0.10	0.40	0.0702	0.25	0.0360	1.949

Table VII

RESULTS - *with intermediates*

- Firms marginal costs directly depend on pricing decisions of other firms

$$MC_t(z) = \frac{\omega S_t^{1-s_m} P_t^{s_m}}{A_t(z)}$$

- Strategic complementarities are a source of real rigidities $\rightarrow$ *more later*
- A high frequency firm changes price less because low frequency firms haven't yet adjusted
- This leads to a more sluggish response of prices to shocks and greater non-neutrality
- This amplification channel is independent of the heterogeneity in frequency of price changes

RESULTS - *with intermediates*

- Monetary non-neutrality increases with the share of intermediate inputs in production

TABLE VIII

INTERMEDIATE INPUTS AND MONETARY NON-NEUTRALITY

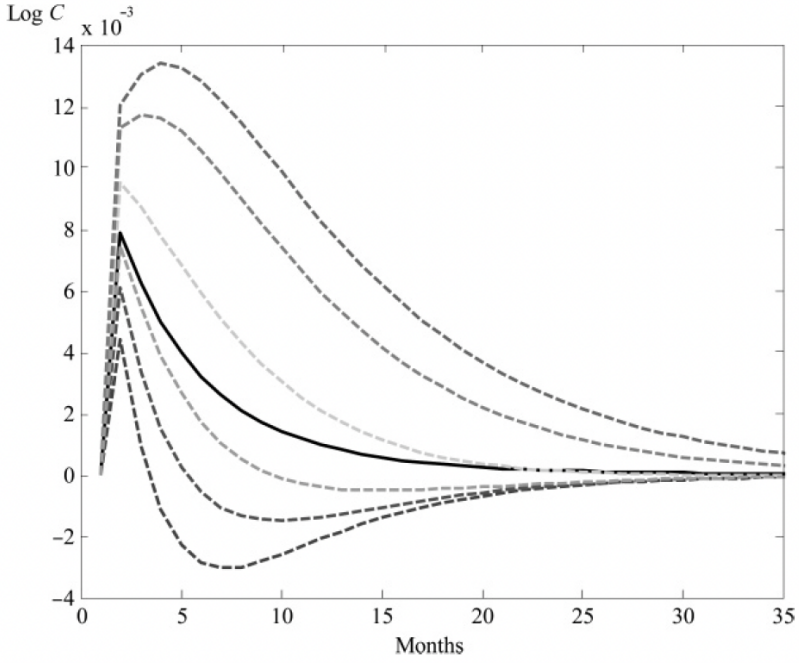
	Interm. input share	Frequency of price change	
		21.1%	8.7%
	Monetary non-neutrality: Var(C_t)		
(1)	0.00	0.055	0.261
(2)	0.50	0.109	0.443
(3)	0.60	0.133	0.518
(4)	0.70	0.182	0.658
(5)	0.80	0.276	0.844
(6)	0.90	0.471	1.346

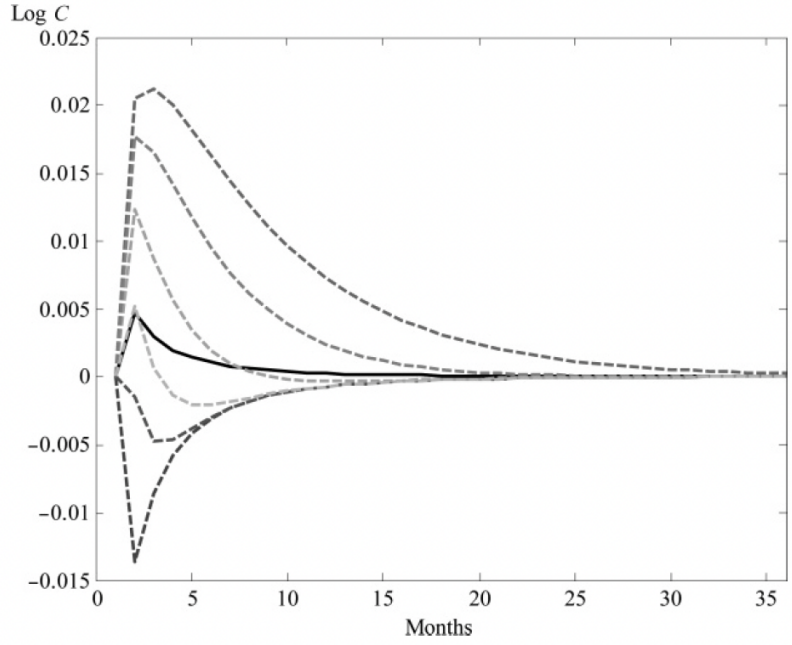
Table VI

- Roundabout production increases monetary non-neutrality even with $J = 1$. (*See Table VI*)

SECTORAL COMOVEMENT

- Intermediate inputs are crucial to generate positive sectoral comovement
- Without them, large differences in relative prices across low and high frequency sectors generates negative comovement
- Demand flows from the high frequency sector to the low frequency sector in response to a positive nominal shock
- Negative sectoral comovement is at odds with the empirical evidence





CONCLUSION: CAN MENU COSTS GENERATE SIZABLE MONETARY NON-NEUTRALITY?

TABLE X
NOMINAL RIGIDITIES AND THE BUSINESS CYCLE

	$\mathrm{Var}(C_t)$ (10^{-4})	Frac. tot. (%)
HP-filtered U.S. GDP 1947–2005	2.72	100
Multisector model with $s_m = 0.7$	0.63	23
Multisector model with $s_m = 0$	0.19	7
Single-sector model with $s_m = 0.7$	0.18	7
Single-sector model with $s_m = 0$	0.05	2

Notes. This table reports the variance of HP-filtered U.S. real GDP for 1947–2005 as well as estimates of the variance of real value-added output for the single-sector and fourteen-sector versions of our menu cost model for two values of the intermediate input share (s_m). It also reports the fraction of the variance of HP-filtered U.S. real GDP accounted for by each of these models.

Table VIII

- Combination of heterogeneous nominal rigidities and sticky intermediates (real rigidity) can generate sizable monetary non-neutrality