Imperfect Information and Aggregate Supply

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1. Foundations

General equilibrium base:

Representative consumer, continuum of firms, differentiated varieties of labor and goods, Dixit-Stiglitz and monopolistic competition, consumers have full information, individual firms do not.

Equilibrium conditions:

$$p_{it} = \hat{E}_{it}\left[p_t + \mu + \alpha(y_t - a_{it})\right],$$

$$n_t = p_t + y_t,$$

$$p_t = \int_0^1 p_{it}\,di.$$

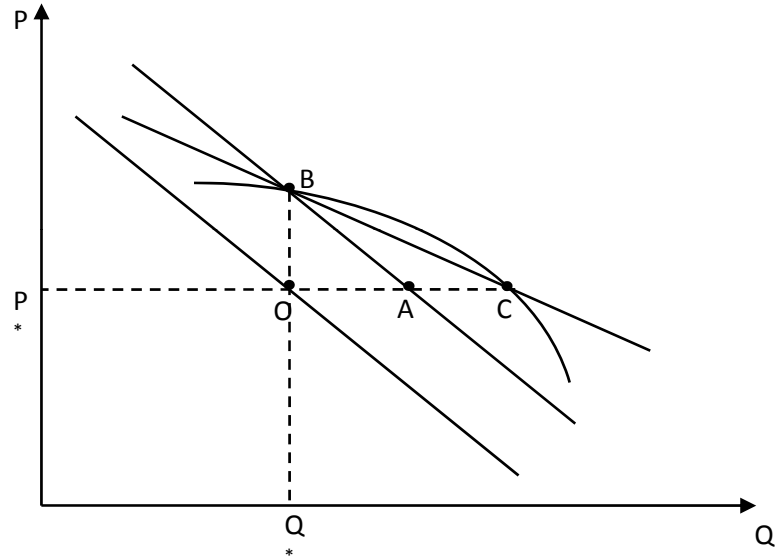
Key reduced-form parameter: $\alpha = \dfrac{\psi + 1}{\psi + \gamma} \in (0.12, 0.4)$

Full information:

$$y_t^F = a_t - \mu/\alpha, \quad p_t^F = n_t - a_t + \mu/\alpha.$$

What to plan and menu costs

What to plan? Choose plans for prices or output, ex ante to maximize expected profits *X(.)*. Reis (2006) prices if:



$$Q_s Q_{ps} + \left(-\frac{Q_s^2}{2Q_p} \right) Q_{pp} \leq 0$$

Menu costs. If everyone has full information, will a marginal firm facing information costs k wish to get information?

Akerlof Yellen (1985), Mankiw (1985)

Numerically: k ≥ 0.63%

$$X_{pp}(.)(p_{it}^{*} - p)^2 \leq k$$

Real rigidities, strategic complementarities

Real rigidities: If everyone doesn't have information on shocks, will marginal firm want to pay information cost k? Ball and Romer (1990)

$$-0.5X_{pp}(.)\alpha^2 n_t^2 \leq k$$

Strategic complementarities: If pricing decision strategic complements, better-informed firms keep their prices in line with less-informed firms. Cooper and John (1988) note that firm's best response function

$$p_{it} = \hat{E}_{it}\left[(1-\alpha)p_t + \alpha n_t - \alpha a_{it}\right]$$

Key condition $\alpha < 1$.

Same parameter, but different concepts!

2. Two paradigms in imperfect information

Delayed information model

- Only a share λ of firms have up-to-date information, others have 1-period old information

Partial information model

- Each firm observes only a private noisy signal with relative precision τ of current shocks

In both need to solve one equation:

$$p_t = \int_1^0 \hat{E}_{it}\left[\alpha n_t + (1-\alpha)\, p_t\right] di$$

Delayed: $p_t = \lambda\left[\alpha n_t + (1-\alpha)\, p_t\right] + (1-\lambda) E_{t-1}\left[\alpha n_t + (1-\alpha)\, p_t\right]$

Partial: $p_t = \alpha \sum_{j=1}^{\infty} (1-\alpha)^{j-1} \underbrace{\bar{E}_t \bar{E}_t \ldots \bar{E}_t}_{\text{j times}} (n_t), \text{ with } \bar{E}_t(.) = \int \hat{E}_{it}(.) di$

Common predictions: delayed information

Key tool: innovations (Wold) representation

$$p_t - E_{t-1}(p_t) = \lambda\left\{\alpha\left[n_t - E_{t-1}(n_t)\right] + (1-\alpha)\left[p_t - E_{t-1}(p_t)\right]\right\} + \alpha E_{t-1}(n_t - p_t)$$

Solution:

$$p_t = \left[\frac{\alpha\lambda}{1-(1-\alpha)\lambda}\right](n_t - n_{t-1}) + n_{t-1},$$

$$y_t = \left[1 - \frac{\alpha\lambda}{1-(1-\alpha)\lambda}\right](n_t - n_{t-1}).$$

Prediction:

Aggregate supply is non-vertical and it is flatter if higher information or real rigidities.

Common predictions: partial information

Key tool: signal-extraction formula

$$\hat{E}_{it}(n_t) = E_t\left(n_t \middle| x_{it} = n_t + \varepsilon_{it}\right) = E_{t-1}(n_t) + \left(\frac{\tau}{1+\tau}\right)\left[x_{it} - E_{t-1}(n_t)\right]$$

Solution:

$$p_t = \left(\frac{\alpha\tau}{1+\alpha\tau}\right)\left(n_t - n_{t-1}\right) + n_{t-1}$$

$$y_t = \left(1 - \frac{\alpha\tau}{1+\alpha\tau}\right)\left(n_t - n_{t-1}\right)$$

Prediction:

Aggregate supply is non-vertical and it is flatter if higher information or real rigidities.

Common predictions: persistence

Sticky information (Mankiw, Reis, 2002)

- Every period, randomly-drawn fraction λ receives new information
- Tool: method of undetermined coefficients

Imperfect common knowledge (Woodford, 2002)

- Every period, each firm receives a new private signal of precision τ
- Tool: Kalman filter

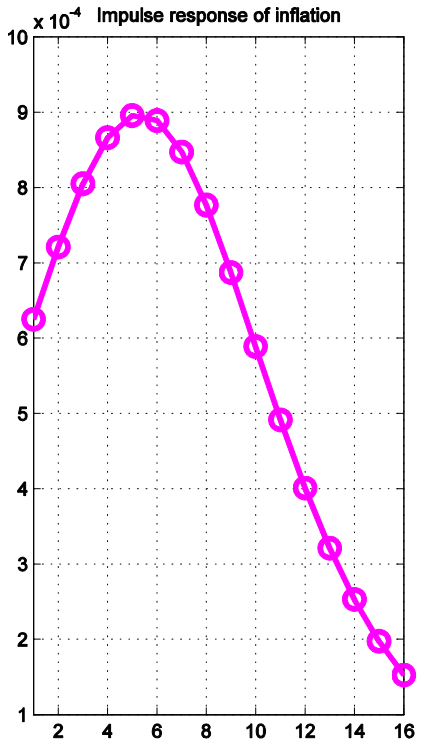
Prediction:

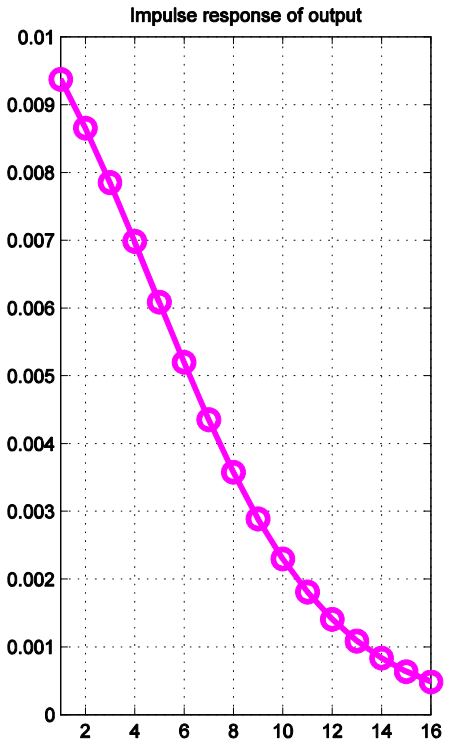
Persistent effects of aggregate-demand shocks

Common predictions: persistence

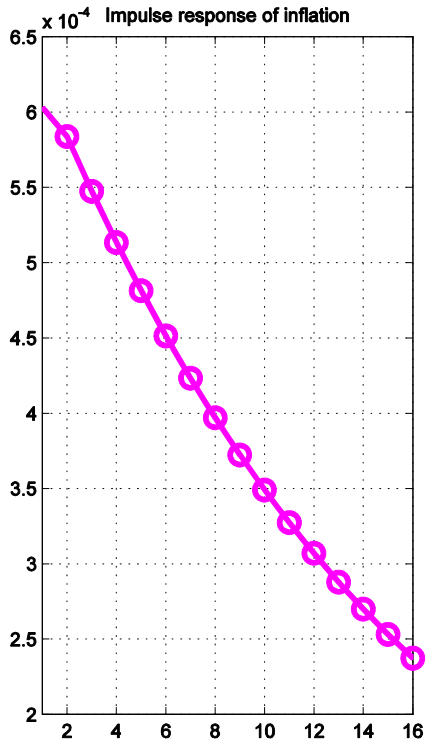
Models are not observationally equivalent

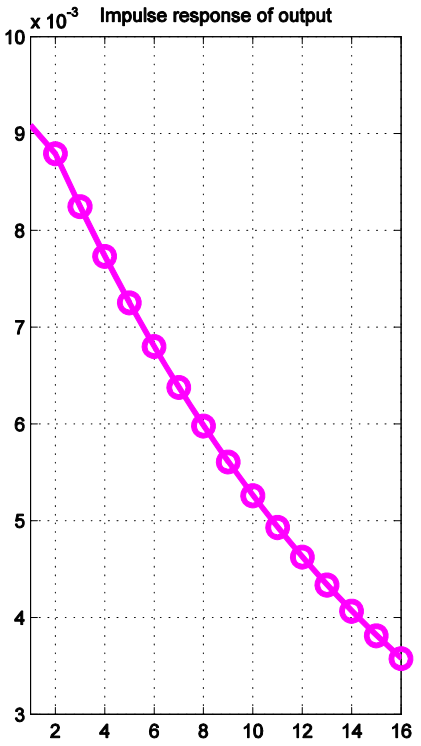
sticky information





imperfect common knowledge





Common predictions: two sources of shocks

Aggregate shocks to nominal demand and idiosyncratic shocks to productivity. Two approaches

1) Mankiw-Reis (2006)

- Only one source of information, one λ and τ
- Micro-founded: optimal for single signal on $n_t - a_{it}$.

2) Mackowiack Wiederholt (2008), Carroll Slacaleck (2007).

- Two signals, so have λ^n, λ^a, τ^n, τ^a.
- For slope of aggregate supply, it is λ^n, τ^n that matters.
- Interesting: can have $\lambda^a > \lambda^n$, $\tau^a > \tau^n$ matching frequent price changes and Klenow-Willis (2007) findings.

3. Novel insights: disagreement and surveys

In delayed information, there is endogenous disagreement

- Different groups have different information and this evolves endogenously as shocks hit economy.
- With partial information, exogenous so uninteresting.

Use surveys of inflation expectations to test predictions

- Impulse responses of disagreement to shocks.
- Carroll (2003), Mankiw Reis Wolfers (2004), Branch (2007), Coibion Gorodnichenko (2008), Curtin, (2009)
- Micro data supports sticky information.

Hope that will discipline imperfect-information models.

Novel insights: transparency

Partial information, endogenous weight on multiple signals

- In addition to private signal, there is a public signal that has an upper limit on its precision.
- With delayed information, exogenous so uninteresting.

Effects of public noise

- New shock common to all (Lorenzoni, 2008a, b)
- Better signal makes firms rely less on private signals, and strategic complementarity causes externality.
- Morris and Shin (2002), Svensson (2006), Roca (2006), Amador Weill (2008) Angeletos Pavan (2007)

Hope that can be measurable, so testable and policy-useful

4. Micro-foundations: inattentiveness

Inattentiveness model (Reis, 2006) for delayed information

$$V_i(n_t) = \max_d E_t \left\{ \sum_{s=0}^{d-1} \beta^t \max_{p_{i,t+s}} \left[X_i(p_{i,t+s},.) \right] - \beta^d k + \beta^d V_i(n_{t+d}) \right\}$$

Solution:

- Numerically, it is unconventional, but easy.
- Closed-form: linear-quadratic, log-isoelastic, exp-normal.
- Bifurcation theory for general theorems.

Predictions:

- Increases with k, falls with variance of shocks
- Second-order costs lead to first-order inattentiveness
- Exponential distribution can be justified (strict conditions)

Micro-foundations: rational inattention

Rational inattention model (Sims, 2003), partial information

$$\max_{f(n_t \| x_{it})} \left[\max_{p_{it}} X(p_{it}, n_t) \right] \quad \text{s.t.: } H(n_t) - H(n_t \,||\, x_{it}) \leq k.$$

Solution:

- Constrain set of distributions—normal maps k to τ.
- Closed-form: linear-quadratic.
- Numerically: open challenge.

Way forward:

- Merge finite capacity (multiple signals) with intertemporal choice (intertemporal substitution)

5. The research frontier

a) Merging incomplete information with sticky prices

- Sticky information and Calvo: Bonomo Carvalho (2004, 2008), Dupor Kitamura Tsuruga (2008)
- Imperfect common knowledge and Calvo: Nimark (2008), Angeletos La'O (2009).
- Sticky information and Ss: Knotek (2006), Gorodnichenko (2008)
- Endogenize both incomplete information and sticky prices: Woodford (2009).

The research frontier

b) Optimal policy

- Sticky information: Ball Mankiw Reis (2005) Reis (2009)
- Inattentiveness: Branch et al (2008)
- Partial information: Adam (2007, 2009), Lorenzoni (2008), Angeletos Pavan (2007, 2009)

c) Other choices beyond prices

- Workers and wages: Koenig (2004)
- Consumption: Reis (2007), Luo (2008), Tutino (2009)
- Physical investment: Angeleots Pavan (2007)
- Portfolio choice: Abel, Eberly, Panageas (2007, 2008)
- Exchange rates: Bachetta van Wincoop (2006, 2009), Crucini, Shintani Tsuruga (2008)

The research frontier

d) Strategic interactions in information adjustment

- Carvalho (2007) and Carvalho Schwartzman (2008) using sticky information.
- Hellwig Veldkamp (2008) on inattentiveness.
- Missing on partial information or rational inattention.

e) Medium-scale DSGEs and computational methods

- Sticky information: Mankiw Reis (2006, 2007) and Reis (2009a, 2009b), Meyer-Gohde (2009).
- Rational Inattention: Mackowiack and Widerholt (2009).
- Missing both inattentiveness and partial information.