Discussion of Bachmann and Ma (2012) 'Lumpy Investment, Lumpy Inventories' prepared for CIREQ Macroeconomics Conference

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Starting line

Starting with a general equilibrium model with (S,s) inventory investment in intermediate goods, Bachmann and Ma replace a representative intermediate goods producer with heterogeneous firms facing idiosyncratic, nonconvex capital adjustment costs.

The (S,s) inventory model is Khan and Thomas (2007) 'Inventories and the business cycle: An equilibrium analysis of (S, s) policies' *American Economic Review* **97**, 1165-88.

The first-generation lumpy investment model is Khan and Thomas (2003) 'Nonconvex factor adjustments in equilibrium business cycle models: do nonlinearities matter?' *Journal of Monetary Economics* **50**, 331-60.

Nonetheless, the variability of aggregate investment in Bachmann and Ma (2012) is lower than that in either of these papers.

Results

Bachmann and Ma find that nonconvex capital adjustment costs have significant aggregate effects in the presence of inventories.

They conclude that the addition of a capital good allows households to smooth consumption with less change to aggregate fixed investment series that appears in partial equilibrium.

Microeconomic heterogeneity in a lumpy investment model now has strong effects on aggregate investment. This is figure 1 in the introduction, and it seems to be about *dampening the response of aggregate investment* to exogenous shocks.

> *What is the aspect of the data that makes these models better than linear ones at explaining aggregate investment dynamics? ... it is the flexible cyclical elasticity of the increasing hazard model which allows it to better capture the high skewness and kurtosis imprinted on aggregate data by brisk investment recoveries.* – *Caballero (1999)*

Overview

It's misguided to argue nonconvex costs can't have aggregate effects. Adjustment costs, if large enough, will always reduce the variance of investment.

However representative firm models with convex adjustment costs will produce a similar aggregate response. The issue has always been about higher moments. Skewness and kurtosis not variance.

We also know that inventories, micro-founded, dampen the variability of final sales and thus fixed investment.

In this paper, large adjustment costs and inventories dampen the variability of fixed investment.

There is some question of whether adjustment costs are too high.

Lumpy Investment without inventories

$$
\begin{aligned}
y &= zF(k,n) \\
k' &= (1-\delta)k + i \\
\xi &\in [0, \overline{\xi}] \text{ where } \xi \sim G(\xi)
\end{aligned}
$$

$i \neq 0$	adjustment cost $= \omega\xi$	unconstrained: $k' \in \mathbf{R}_+$
$i = 0$	adjustment cost $= 0$	constrained: $k' = (1-\delta)k$

- There are no idiosyncratic productivity terms and the incidence of capital adjustment costs is not a function of the level of investment (see Khan and Thomas 2008).
- This is a first generation model that *won't reproduce the empirical distribution of investment rates.*

target capital

$$k^*(z_i, \mu) \equiv \arg\max_{k' \in \mathbf{R}_+} R(k', z_i, \mu) \tag{1}$$

ξ^T threshold adjustment costs

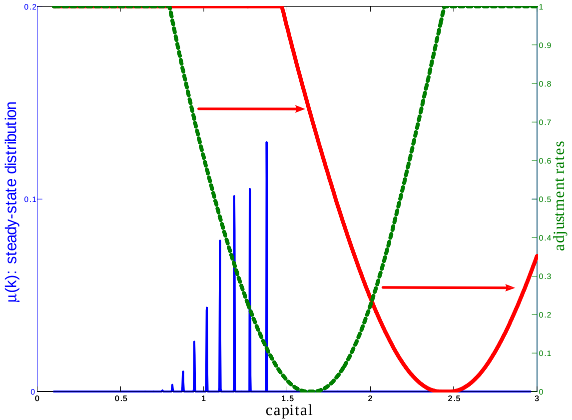
$$-p(z_i, \mu)\,\omega(z_i, \mu)\,\xi^T(k; z_i, \mu) + R(k^*, z_i, \mu) = R((1-\delta)\,k, z_i, \mu)$$

adjustment rates

$$G\left(\xi^T(k; z_i, \mu)\right)$$

Rising hazard model and nonlinearities

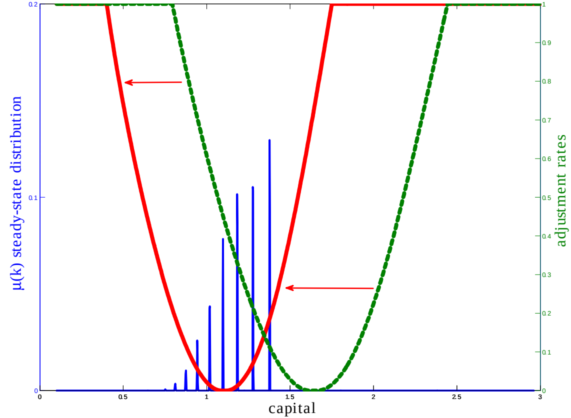
A positive shock to total factor productivity in partial equilibrium



target rises from 1.38 to 2.06, 98.6% of firms adjust capital, I/K increases by 0.73.

Rising hazard model and nonlinearities

A negative shock in partial equilibrium



target capital stock falls to 0.926, 15.9% of firms adjust, I/K falls by 0.125

General equilibrium

- The same 2 standard deviation shocks to TFP move target capital far less in general equilibrium (1.48 and 1.35).
- Movements in the stochastic discount factor sharply restrain firms' target capital.
- Adjustment rates vary little (3.6 and 3.0 percentage points). I/K rises by 0.029 and falls by 0.026.
- Nonlinearities disappear.
- This has nothing to do with large adjustment costs. The costs in this example were bounded above by 0.014.

Large adjustment costs and the empirical distribution of investment rates

Returns to Scale

In Bachmann and Ma, returns to scale are 0.7149 which implies *an aggregate annual capital to output ratio of 0.9345*.

Khan and Thomas had returns to scale of 0.905 and K/Y = 2.6.

Bachmann and Ma set $\xi = 0.1841$. Khan and Thomas assumed $\xi = 0.002$.

ξ seems too high to be consistent with 18.6 percent of firms having lumpy investment ($\frac{i}{k} > 0.2$).

The number of inactive firms is likely near 70 percent (its 8 percent in the data).

Spreading the hazard with large adjustment costs

effect upon investment variability

Large nonconvex capital adjustment costs dampen the variability of aggregate investment rates. Spreading the adjustment hazard, they slow movements in aggregate investment. There is no effect on higher moments.

Large capital adjustment costs explain part of the dampened response in aggregate investment in Figure 1 of Bachmann and Ma (2012).

They drive the difference of 1.9% between the dampened response in NI1 (10.01% with capital adjustment costs without inventories) relative to NI2 (8.10% with no capital adjustment costs or inventories).

The rest has to do with inventories.

Khan and Thomas (2007) Model

The inventory model generalises the following environment.

- intermediate goods firms: $zG(k, n_I)$
  - supply intermediate good (relative price q), purchase investment goods
- final goods firms: $F(m, n)$
  - supply consumption and investment goods
  - holds stocks, $s \in S \subseteq R_+$,due to fixed order costs
- aggregate state vector: (z, K, μ)
  - aggregate TFP shock: $z \in \{z_1, \ldots, z_{N_z}\}$ with $\pi^z_{lm} = \Pr(z' = z_m \mid z = z_l)$
- This is also a first-generation model that's not consistent with the variability of firm-level sales or the high-frequency behaviour of inventory investment (see Khan and Thomas 2010).

Bachmann and Ma (2012) Model

Bachmann and Ma embed the firms from Khan and Thomas (2003) in place of the representative intermediate goods producer.

Notice that inventories are not a second capital good. They are not a factor of production. Stocks of intermediate goods not used in current production are held by final goods producers. These stocks exist because of a friction. When the friction is eliminated, they disappear.

In our general equilibrium model of inventories, the procyclicality of inventory investment (0.67 in the data) dampened fluctuations in final sales.

This is their role in the Bachmann and Ma model. However the effect may be stronger because of sharp decreasing returns to scale.

Mechanics of procyclical inventory investment

We know that an empirically consistent model of inventories dampens the variability of fixed investment.

% std devs.	GDP	NII	FS	C	I	TH	N(i)	N(fg)
control	1.94	–	1.94	0.57	9.56	1.45	1.45	1.45
inventory model	1.89	0.32	1.70	0.52	8.90	1.48	1.77	1.33

1. Why NII is procyclical
   - A. rise in z predicts persistent rise in demand
   - B. average stock must rise to avoid more frequent orders

2. Why procyclical NII does not raise GDP volatility
   - A. given capital, diminishing MPL tempers rise in intermediate goods
   - B. trade-off: procyclical NII diverts intermediate goods
   - C. dampened FS slows capital accumulation, prolonging the above

Reductions in the variability of fixed investment

In figure 1, Bachmann and Ma compare the impact date response of fixed investment, following a positive productivity shock, across 4 models.

- Large nonconvex capital adjustment costs reduced the response of aggregate investment in the models without inventories, -1.91%
  - compare 8.10% in NI1 [only capital adjustment costs] to 10.01% in NI2 [no frictions]

- Adding a stronger inventory effect explains the remaining reduction in the response of fixed investment, -2.08%
  - compare 6.02% in I1 [order and capital adjustment costs] to 8.10% in NI1 [only capital adjustment costs]

That elusive second capital stock

- Bachmann and Ma argue that inventories are a second capital stock that allows the household to separate its consumption path from the path of fixed investment.
  - 'Fixed capital stocks do not need to respond to shocks as much when inventories are absent [present]' (paragraph 1. page 16)
- But fixed investment is far more variable in partial equilibrium!
- If anything, the path of consumption is now more tightly linked to the path of fixed investment. This follows from the procyclicality of inventory investment in a model with an additional friction, fixed order costs for intermediate goods.
- Final goods inventories might have led to a different result, but they're not very cyclical.