ECOM 009 Macroeconomics 11

Lecture 11

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Testing the convex adjustment model

- Implications of the model
  1. Investment/disinvestment is always ongoing rather than lumpy. With convex adjustment costs it is optimal to spread investment as much as possible.
  2. Given the current stock of capital q is the only determinant of investment. The relationship between I_t and q_t is monotonic.
  3. In the absence of shocks, the capital stock converges to its Jorgensonian level.
- *If* there are constant returns to scale to K_t, L_t and I_t and perfect competition in factor and product markets, Hayashi (1982) showed that the model (unobservable) marginal q_t coincides with the (observable) average $Q_t = \frac{V_t}{p_t^K K_t}$.
- Unfortunately, estimating equation (**??**) returns coefficients of Q_t which are extremely small, implying unrealistically large values for c - i.e. enormous adjustment costs.

Problems with empirical tests

What can explain the empirical failure of the neoclassical theory of investment (both in its Jorgensonian and its modern incarnation)?

a) Q measured with errors, because either V_t or the resale value of capital are measured with error.
   - V_t is noisy if stock market values deviate from fundamentals (bubbles).
   - The resale value of capital is likely to be measured with error due to the difficulty of correctly measuring depreciation and the price of second hand equipment.

b) Non-competitive markets imply that the average Q used in the empirical analysis differs from q which is the true determinant of investment. One possible way to address both problems estimate q and use such an estimate in the investment equation.

Problems with empirical tests II

c) (Jorgensonian theory) Endogeneity of r. If both investment and the cost of capital increase in response to common shocks, such as shocks to total factor productivity, then OLS estimates of the coefficient on the cost of capital is biased downward.
   Solutions:
   - long run: use cointegration techniques (superconsistency).
   - short run: look at large exogenous changes in the user cost of capital, such as major tax reforms.

d) The problem with the endogeneity of regressors (in particular q) applies also to tests of the Q theory.

e) A different form for adjustment costs implies a non-linear relationship between I_t and q_t.

Better empirics - Long run

- Problems with early tests of this theory may have stemmed from testing the long run implications of the theory *jointly* with a particular short run specification of the adjustment process.
- Both strands of the neoclassical theory imply that in the **long run** the capital stock converges to its optimal Jorgensonian value.
- Cointegration techniques allow to take care of the fact that the target capital stock is unobserved (provided deviations from it are stationary) and the endogeneity of user cost.
- Correcting for small sample problems the coefficient on the user cost of capital is close to -1.

In the long run the user cost of capital does matter for capital choice.

Better empirics - Short run

Finding a short run relationship between the user cost of capital (and/or Q) and investment required resorting to microdata and exploit natural experiments, such as exogenous tax reforms.

- Cost of capital matter if changes are big: In particular, Cummins, Hassett and Hubbard find that looking at tax reforms raises the coefficient on q from 0.05 to 0.65.
- At firm-level, investment is lumpy rather than smooth: Doms and Dunne (1993) document how a large proportion of plants experience increase in the stock of capital close to 50% in a single year. 40% of total investment for the median plant takes place in one or two subsequent years.
- Lumpiness may not wash out in the aggregate: Doms and Dunne (1993) find that 18% of *aggregate* investment is accounted for by the top 100 projects.

Fixed costs of adjustment: infrequent action

- The assumption of convex adjustment costs (smooth rather than lumpy adjustment) may explain the inability of the theory to account for the short run properties of the data.
- For infrequent adjustment to be optimal there must be increasing returns to scale to investment. This is the case if there are fixed costs that have to be born independently from the size of the adjustment.

A lumpy-adjustment model

- One period. The representative firm has capital stock K_0 at the beginning of period 1.
- Production function $Y = AK$.
- If the firm expands its capital stock in period 1 it faces a convex cost $C(I) = cI^2/2$ but also a fixed cost d. For simplicity, we assume that the firm cannot reduce its capital stock.
- At the beginning of the period one the firm observes total factor productivity and has to decide:
  (a) whether to invest or not
  (b) in case it chooses to invest, the size of the addition to its capital stock.
- Invest if the marginal return compensate for the price plus the marginal adjustment cost **and** the extra profit covers the fixed cost d.

The firm's optimization problem

The firm's maximization problem is given by

$$V_1 = \max\left\{AK_0, \max_I A\left(K_0 + I\right) - I\left(1 + \frac{c}{2}I\right) - d\right\}. \quad (173)$$

The marginal product of capital equals A independently from the investment decision. $\rightarrow q = A$.
Backward induction.

(b) Conditional on investing, the optimal investment level satisfies

$$A = q = 1 + cI \rightarrow I = c^{-1}\left(q - 1\right). \quad (174)$$

If there were no fixed cost of investment - $d = 0$ - the above expression would fully determine the firm's decision to invest. But ...

The firm's optimization problem II

... now investment is carried out only if it increases profits by a discrete amount which exceeds d.

(a) Work out the value of profits in case the firm invests - the second term in the curly bracket in (177). Replace for I in (177) and remember that $q = A$.

$$\max \left\{ qK_0, q\left(K_0 + c^{-1}(q-1)\right) - c^{-1}(q-1)\left[1 + \frac{c}{2}c^{-1}(q-1)\right] - d \right\}.$$

Cancelling qK_0 from both terms this can be rearranged as

$$\max \left\{ 0, c^{-1}\left(q^2 - q - q + 1 - \frac{1}{2}(q-1)^2\right) - d \right\}. \quad (175)$$

The firm will invest only if the second term is larger than 0; i.e.

$$(q-1)^2 \geq 2cd. \quad (176)$$

Model's implications

- The inequality
$$(q-1)^2 \geq 2cd$$
requires $q > 1 + \sqrt{2cd}$ or $q < 1 - \sqrt{2cd}$.
- The latter inequality implies negative investment which cannot be given that we have assumed that the firm cannot reduce its capital stock.
- So, the firm invests only if $q > 1 + \sqrt{2cd} \rightarrow$ if $q < 1 + \sqrt{2cd}$ there is no relationship between investment and marginal q.
- Furthermore, $V_1 = AK_0$ and $Q = A = q$ which can be larger than 1. So there is also no relationship between investment and average Q.

Heterogeneity and general equilibrium

- All the above analyses assume that the interest rate r and wage w_t are exogenously given. In fact, these are equilibrium prices which must clear markets.
- It turns out that in general equilibrium lumpy adjustment costs at the level of the firm do not necessarily imply lumpy adjustment in aggregate investment.
- Thomas (2001), assuming firms have the same TFP, shows that in response to exogenous shocks prices rather than investment adjust the most. not investment. Intuition: aggregate saving must equal aggregate investment. The interest elasticity of saving is low as consumers want to smooth consumption. Hence, the interest rate has to adjust to maintain equilibrium.

Heterogeneity and general equilibrium II

- Khan and Thomas (2008) obtain similar results even after allowing for heterogeneous productivity across firms. The lumpyness survives in the aggregate at exogenous prices but washes out in general equilibrium.
- Bachmann, Caballero and Engel (2013), use a similar general equilibrium model with lumpy adjustment costs but different parameterization. They find that microeconomic lumpiness accounts for 60% of aggregate investment smoothness.

The lumpy-adjustment model revisited

Working hypothesis: failure to establish a significant (linear) statistical relation between price variables and aggregate investment is due to non-linearities (due to microeconomic lumpiness) which carry over to the aggregate.

Consider a variant of the lumpy-adjustment model

$$V^i = \max\left\{\frac{A\epsilon_i K_{i0}^{\alpha}}{1+r}, \max_{I_i}\frac{A\epsilon_i\left(K_{0i}+I_i\right)^{\alpha}}{1+r} - I - d\right\},\ 0<\alpha<1. \tag{177}$$

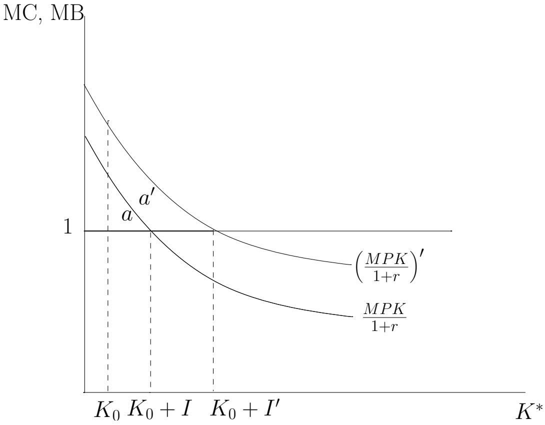
Three main differences:

- Firm heterogeneity: firm-specific TFP shock ϵ_i
- Decreasing returns to capital and, just for simplicity, only fixed adjustment cost.
- Output accrues at the end of the period (discounting, r matters).

The lumpy-adjustment model revisited II

If investment take place, it satisfies

$$1 = \alpha \frac{A\epsilon_i (K_{0i} + I_i)^{\alpha-1}}{1+r}. \quad (178)$$



The lumpy-adjustment model revisited III

- $K_i^* = K_{0i} + I_i$ is called the *target* level of capital to stress that it is actually reached *only if* investment takes place. So $I_i = K_i^* - K_{0i}$ is the desired adjustment.
- Investment takes place only if the area (a or a') between the two curves (the extra profits) exceeds the fixed adjustment cost d, i.e. only if the difference $K_i^* - K_{0i}$ is large enough. $\rightarrow$ fixed adjustment costs generate inaction.
- *Coeteris paribus,* $K_i^* - K_{0i}$ is decreasing in K_{0i} (firms with lower capital are closer to adjusting) and increasing in K_i^* (i.e. increasing in TFP and decreasing in r).
- *Conditional on investing* the capital stock follows the Jorgensonian rule, but the unconditional average response of <u>actual</u> *firm-level* investment to changes in TFP and r is non-linear.

Aggregation

Aggregation: aggregate investment is the sum of $K_i^* - K_{0i}$ over all firms i which do invest.

- With $d = 0$ all firms adjust with probability one and no micro nor macro non-linearity (Jorgensonian theory).
- With $d > 0$ the probability of adjustment to a positive shock is higher for firms with higher desired adjustment $K_i^* - K_{0i}$. The larger the shock the higher the increase in the proportion of firm with high desired investment.
- In recessions, the opposite is the case. Since firms have excessive capital (because of adjustment costs) they are in the inaction area. They will not invest until depreciation has reduced their capital stock enough. Anything that slows down depreciation increases the proportion of firms in the inaction range. → **Asymmetric and non-linear response**

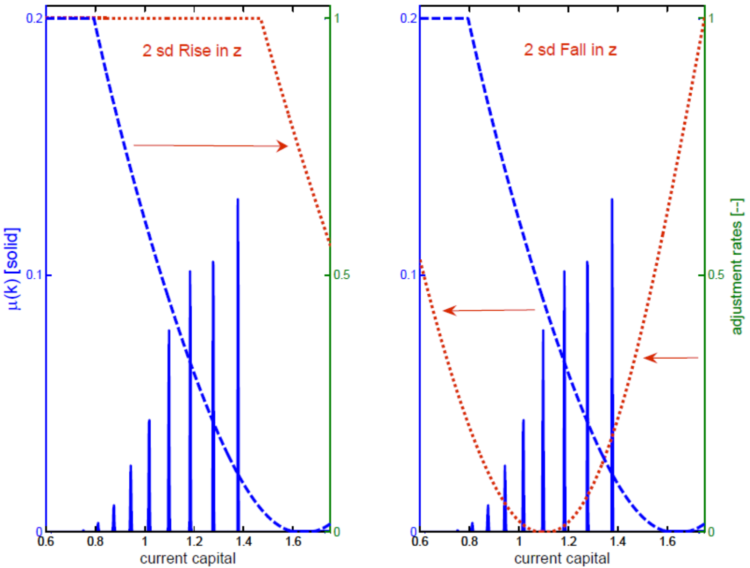


Figure 12 : Source: Khan and Thomas (2006)

General equilibrium - Khan and Thomas 2008

Khan and Thomas (2007):

- Calibrate the model to match, among other things, the volatility of investment at the **plant/establishment** level (this is rather high, so they have relatively small fixed adjustment costs).
- Partial eq. (exogenous r and w): the non-linearity carries over to the aggregate. Aggregate investment responds little to small TFP shocks and a lot to large ones.
- General eq.: the non-linearity basically disappears. An increase in TFP increases r and w. This offsets the increase in profitability and implies that micro investment responds less than in partial equilibrium and that the number of firms adjusting (hence aggregate investment) responds less.

General equilibrium - Bachmann et al. 2013

- Bachmann, Caballero and Engel (2013) argue that Khan and Thomas (2008) fits aggregate investment but generates too high investment volatility at **sectoral** level. It generates aggregate smoothness from micro smoothness more than GE.
- They introduce **compulsory** and large maintenance investment. This offsets depreciation and increases the probability of being in the inaction range. *This* assumption is most and not uncontroversial.
- Contrary to Khan and Thomas, they find that microeconomic lumpiness accounts for 60% of aggregate investment smoothness.

Bottom line: still not clear whether we really need a non-linear model to fit the aggregate data?