Investment and Capacity Utilisation in a Putty-Clay Framework

ESCoE Conference on Economic Measurement 2022

Kevin Lee
Michael J. Mahony
Paul Mizen

University of Nottingham

May 25 - 27 2022

Outline

- Introduction
- Model setup
- Data
- Results
- Conclusion

Introduction

Research Question and Motivation

- Past decade has seen sustained periods of low investment for the UK economy
  - For example, while the ratio of investment to total expenditure was (on average) 13.5% in 2007 it was still only 10.9% in 2012
  - This is below a G7 average of 14.6%
  - Furthermore, by 2013Q2 gross fixed capital formation spending was around 25% below its pre-GFC peak (2007Q3)
- Weak firm-level investment has been postulated as a driver of the UK productivity puzzle (the failure of productivity to return to its pre-GFC trend)
- Thus, understanding the reasons behind this weak firm-level investment is important
- However, do existing empirical models provide an adequate explanation for the low levels of post-GFC investment?

Introduction

Key Conclusions

- By using a unique matched dataset this paper documents the important role of capacity utilisation as a short-term buffer
  - Updates Abel (1981) framework to derive putty-clay accelerator model of investment (includes capacity error correction term)
  - In the short-run when factors of production are fixed, firms instead adjust their rate of capacity utilisation to meet demand
- Ignoring the role of capacity utilisation as a short-term buffer overestimates the adjustment of capital back to its long-run equilibrium
  - Results in capital error correction term being too large (in absolute terms) in standard accelerator models
- Key conclusion: omitting capacity utilisation from an accelerator model of investment overestimates the adjustment speed of capital as it ignores the ability of firms to adjust their utilisation of capital, which could provide an explanation for sluggish investment in the UK economy post-GFC

Introduction

Existing Literature

- Traditional models of investment
  - Brainard and Tobin (1968), Tobin (1969), Abel (1979), Hayashi (1982), Abel and Eberly (1994, 1996), Doms and Dunne (1994), Caballero, Engel and Haltiwanger (1995), Cooper, Haltiwanger and Power (1999), Cooper and Haltiwanger (2005)
- Accelerator models of investment/empirical literature
  - Mairesse et al. (1999), Ghosal and Loungani (2000), Temple et al. (2001), Bond et al. (2003), Bloom et al. (2007), Driver et al. (2008), Bassetto and Kalatzis (2011) and Kang et al. (2014)
- Investment with putty-clay technology
  - Abel (1981), Gilchrist and Williams (2005), Auernheimer and Trupkin (2014) and Bachmann (2015)

Model Setup

Putty-Putty Capital versus Putty-Clay Capital

- Standard models of investment often assume capital is putty-putty
  - Firms can freely adjust their stock of capital
  - Firms can instantaneously purchase, install, and begin using new machines, as well as reorient existing machines to accomplish new tasks
  - No under-utilised capital
  - In reality it takes time to purchase, receive delivery and install this new capital
  - Existing machines are usually task specific and cannot easily be reoriented to new tasks
  - Data from the CBI ITS shows that 59% of survey responses state firms have under-utilised capital
- Alternative: capital is putty-clay
  - Capital is fixed in the short-run
  - Rather than adjusting their capital stock, firms can instead adjust the utilisation rate of their existing capital (i.e. they change their rate of capacity utilisation)

Model Setup

Standard Accelerator Model of Investment

- Consider a simple firm maximisation problem, where the firm maximises the present value of its flow of funds as in Equation 1

$$max \sum_{t=0}^{\infty} \beta^t (p_{j,t} A_{j,t} K_{j,t}^{\alpha} L_{j,t}^{1-\alpha} - \hat{p}_{j,t} I_{j,t}^{K}) \quad (1)$$

- Subject to the constraint $K_{j,t+1} = I_{j,t}^{K} + (1-\delta)K_{j,t}$
- For firm j in period t $p_{j,t}$ is the price of output, $A_{j,t}$ is the state of technology, $K_{j,t}$ is capital stock, $L_{j,t}$ is labour stock, $\hat{p}_{j,t}$ is the price of capital, $I_{j,t}^{K}$ is investment in capital goods and δ is the rate of capital depreciation

Model Setup

Standard Accelerator Model of Investment

- Solving firm maximisation problem yields Equation 2:

$$K_{j,t} = \alpha \frac{Y_{j,t}}{\phi^K_{j,t}} \tag{2}$$

- $Y_{j,t}$ is output and $\phi^K_{j,t}$ is the user cost of capital
- Taking logs of Equation 2:

$$k_{j,t} = y_{j,t} + \varphi_{j,t} \tag{3}$$

- In the long-run capital is proportional to output (or sales) and the user cost of capital

Model Setup

Standard Accelerator Model of Investment

- Following Mairesse et al. (1999) and Bond et al. (2003) the model setup of Equation 1 to Equation 3 is used to construct an accelerator model of investment with error correction

$$\Delta k_{j,t} = \xi_0 + \xi_2 \Delta y_{j,t} + (\xi_1 - 1)(k_{j,t-1} - y_{j,t-1}) + \eta_{j,t} \qquad (4)$$

- For each firm j in period t $\Delta k_{j,t} = k_{j,t} - k_{j,t-1}$ is the investment rate, $\Delta y_{j,t} = y_{j,t} - y_{j,t-1}$ is the growth in sales, $(\xi_1 - 1)$ is the capital error correction coefficient and $(k_{j,t-1} - y_{j,t-1})$ is the degree of the breakdown in the long-run relationship between $k_{j,t}$ and $y_{j,t}$
- Equation 4 is the accelerator model of investment with error correction
- Short-run dynamics, measuring the immediate impact of $\Delta y_{j,t}$ on $\Delta k_{j,t}$, are captured by ξ_2
- Long-run dynamics, measuring the correction of the disequilibrium each period, are encapsulated in $(\xi_1 - 1)$

Model Setup

Standard Accelerator Model of Investment

- Following literature augment Equation 4 with
  - Lagged investment ($\Delta k_{j,t-1}$) captures the dynamic adjustment of the investment rate (Ghosal and Loungani, 2000; Bond et al., 2003; Bassetto and Kalatzis, 2011; Kang et al., 2014)
  - Sales growth squared ($(\Delta y_{j,t})^2$) captures potential non-linear effect of sales growth on investment (Bloom et al., 2007; Kang et al., 2014)
  - Cash-flow (and its lag) ($c_{j,t}$) can reflect finance constraints, future profitability opportunities or measurement errors (Ghosal and Loungani, 2000; Bond et al., 2003; Bloom et al., 2007; Bassetto and Kalatzis, 2011; Kang et al., 2014)
  - Investment constraints - for example, uncertainty (Ghosal and Loungani, 2000; Temple et al., 2001; Bloom et al., 2007; Driver et al., 2008; Kang et al., 2014)

Model Setup

Standard Models of Investment

- Equation 5 is the accelerator model of investment, augmented with additional control variables

$$\Delta k_{j,t} = \xi_0 + \zeta_1 \Delta k_{j,t-1} + \zeta_2 \frac{c_{j,t}}{K_{j,t-1}} + \zeta_3 \frac{c_{j,t-1}}{K_{j,t-2}} + \zeta_4 (\Delta y_{j,t})^2 + \xi_2 \Delta y_{j,t} + (\xi_1 - 1)(k_{j,t-1} - y_{j,t-1}) + \eta_{j,t} \quad (5)$$

- Long-run dynamics, measuring the correction of the disequilibrium each period, are encapsulated in $(\xi_1 - 1)$
  - $-1 < (\xi_1 - 1) < 0$ indicating that future investment increases when capital falls below its desirable long-run level
  - The closer $(\xi_1 - 1)$ is to 0 (-1) the slower (quicker) the disequilibrium correcting process
  - An adjustment mechanism exists where previous period equilibrium deviations (measured by $(k_{j,t-1} - y_{j,t-1})$) lead to an adjustment in $k_{j,t}$

Model Setup

A Firm-Level Investment Equation in a Putty-Clay Framework

- The firm optimisation problem is to maximise the present value of its flow of funds with decision variables capacity utilisation ($\Omega_{j,t}$), investment in capital stock ($I^K_{j,t}$) and investment in labour stock ($I^L_{j,t}$) – see Equation 6:

$$\max_{\Omega, I^K, I^L} \sum_{t=0}^{\infty} \beta^t \left(p_{j,t} A_{j,t} K^{\alpha}_{j,t} (\Omega_{j,t} L_{j,t})^{1-\alpha} \right. \\ \left. - \left(\frac{w_{j,t}}{2} \Omega_{j,t} \right) (\Omega_{j,t}) L_{j,t} - \frac{\gamma}{2} \left(\frac{I^K_{j,t}}{K_{j,t}} \right)^2 I^K_{j,t} - \frac{\varepsilon}{2} \left(\frac{I^L_{j,t}}{\Omega_{j,t} L_{j,t}} \right)^2 I^L_{j,t} \right) \tag{6}$$

- Subject to $K_{j,t+1} = I^K_{j,t} + (1-\delta) K_{j,t}$ and $\Omega_{j,t+1} L_{j,t+1} = I^L_{j,t} + (1-\mu) \Omega_{j,t} L_{j,t}$

Model Setup

A Firm-Level Investment Equation in a Putty-Clay Framework

- The steady-state of the system (i.e. the long-run values of capital and capacity utilisation) resulting from Equation 6 is provided by Equation 7 and Equation 8.

$$K^* = \alpha \frac{Y}{\phi^K} \tag{7}$$

$$\Omega^* = \frac{\phi^L}{w} \tag{8}$$

- Where $\phi^L_{j,t}$ is the user cost of labour
- Note that Equation 7 is the same as Equation 2

Model Setup

A Firm-Level Investment Equation in a Putty-Clay Framework

- Following Abel (1981) a system linearised around the steady-states can be derived in terms of $\Delta k_{j,t}$ and $\Delta\Omega_{j,t}$
- Focusing on the investment in capital goods component of this linearised system yields Equation 9 - which provides a description of the adjustment (in investment in capital goods) in the local area around the steady-state

$$\Delta k_{j,t} = \lambda_1^k \Delta k_{j,t-1} + \lambda_2^k (k_{j,t-1} - k^*_{j,t-1}) + \lambda_3^k (\Omega_{j,t-1} - \Omega^*_{j,t-1}) + \epsilon^k_{j,t} \quad (9)$$

- For each firm j in period t $(k_{j,t-1} - k^*_{j,t-1})$ is the investment in capital error correction term and $(\Omega_{j,t-1} - \Omega^*_{j,t-1})$ is the capacity utilisation error correction term

Model Setup

A Firm-Level Investment Equation in a Putty-Clay Framework

- Augmenting Equation 9 with additional controls yields Equation 10

$$\Delta k_{j,t} = \xi_0^k + \lambda_1^k \Delta k_{j,t-1} + \zeta_2^k \frac{c_{j,t}}{K_{j,t-1}} + \zeta_3^k \frac{c_{j,t-1}}{K_{j,t-2}} + \zeta_4^k (\Delta y_{j,t})^2 + \xi_2^k \Delta y_{j,t} + \lambda_2^k (k_{j,t-1} - k_{j,t-1}^*) + \lambda_3^k (\Omega_{j,t-1} - \Omega_{j,t-1}^*) + \epsilon_{j,t}^k \quad (10)$$

- λ_2^k is the capital error correction term coefficient
- λ_3^k is the capacity error correction term
  - Captures the previous periods deviation of capacity from its long-run equilibrium value
  - $\lambda_3^k > 0$ as firms unable to adjust their capital stock (since it is fixed in a putty-clay environment) instead alter their rate of capacity utilisation
  - $|\lambda_2^k| < |(\xi_1 - 1)| \Rightarrow$ in a putty-clay environment capital takes longer to adjust to its long-run equilibrium value

Data

Data Sources

- Confederation of British Industry (CBI) Industrial Trends Survey (ITS)
  - Direct measure of the rate of capacity utilisation
- Bureau van Dijk FAME
  - Fixed tangible assets (K), turnover (Y), cash-flow from operating activities (C) and the user cost of labour (v^L)

Data

Industrial Trends Survey (ITS)

- Manufacturing firms
- Data available from 2000Q1 to 2018Q4
- A direct firm-level measure of the rate of capacity utilisation is provided by question 4a which asks firms to detail their current rate of operation as a percentage of full capacity
- Question 16c of the ITS asks firms what are the likely factors (either wholly or partly) which could limit investment over the next twelve months; with possible answers "inadequate net return on proposed investment", "shortage of internal finance", "inability to raise external finance", "cost of finance", "uncertainty about demand", "shortage of labour" and "other".

Results

Estimation

- The results of estimating Equation 5 and Equation 10 using system GMM
- For all estimates presented the Arellano-Bond test for autocorrelation rejects second-order serial correlation (and above) in the first-differenced residuals while the Hansen test does not reject the validity of overidentifying restrictions
- Following Bloom et al. (2007) the set of instruments for the first-difference equation are the second and third lags of the endogenous variables and the set of instruments for the level equation is the first lag of the endogenous variables
- The set of endogenous variables are all the quantitative FAME variables

Results

Coefficient Estimates

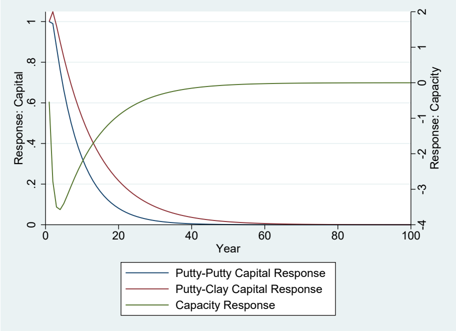
Table 1: Econometric Results of Equation 5 and Equation 10

Investment Rate, $\Delta k_{j,t}$	(1) Coeff./SE	(2) Coeff./SE
Lagged Investment Rate, $\Delta k_{j,t-1}$	0.105*	0.115**
	(0.05)	(0.06)
Sales Growth, $\Delta y_{j,t}$	0.381***	0.395***
	(0.13)	(0.14)
Capital Error Correction, $k_{j,t-1} - y_{j,t-1}$	-0.115**	-0.065*
	(0.05)	(0.04)
Cash-Flow, $\frac{c_{j,t}}{K_{j,t-1}}$	2.089***	3.414***
	(0.81)	(1.11)
Lag Cash-Flow, $\frac{c_{j,t-1}}{K_{j,t-2}}$	-2.498***	-2.466***
	(0.68)	(0.65)
Sales Growth Square, $(\Delta y_{j,t})^2$	-0.039	-0.799
	(0.91)	(0.95)
Capacity Error Correction, $\Omega_{j,t-1} - \Omega^*_{j,t-1}$		0.002***
		(0.00)
Constant	-0.070**	-0.223***
	(0.04)	(0.08)
Observations	2110	1425
Firms	652	416
m1	0.00	0.00
m2	0.79	0.99
Hansen	0.66	0.30

Results

Generalised Impulse Response Functions

Figure 1: The Dynamic Response of Capital and Capacity to a System-Wide Shocks

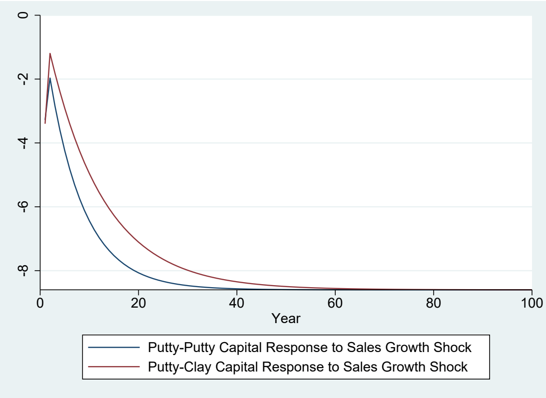


- Figure 1 depicts the dynamic path of $k_{j,t}$ to a simultaneous 1% $\epsilon^{k}_{j,t}$ and -0.5348% $\epsilon^{\Omega}_{j,t}$ shock
- Same long-run effect, but dynamics different

Results

Negative Sales Shock

Figure 2: The Dynamic Response of Capital to a (Permanent) Negative Sales Shock



- Figure 2 depicts the dynamic path of $k_{j,t}$ following a (permanent) negative 8.6% shock to sales - replicating a drop in output in 2009

Conclusions

- Relaxes the implicit assumption of a putty-putty environment in the accelerator model, instead estimating a dynamic investment equation where factors of production are fixed
- In this putty-clay environment, firms adjust their rate of capacity utilisation in order to meet demand
- Excluding capacity dynamics (in the form of a capacity error correction term) from the standard accelerator model of investment overestimates the adjustment speed of capital back to its long-run equilibrium value
- This provides an explanation for sluggish investment following the GFC (and recessions in general)

Thank You!

Lee, K., Mahony, M. and Mizen, P. (2022), "Investment and Capacity Utilisation in a Putty-Clay Framework", ESCoE Discussion Paper 2022-03, Economic Statistics Centre of Excellence (ESCoE).

Available at: https://www.escoe.ac.uk/publications/investment-and-capacity-utilisation-in-a-putty-clay-framework/