“Knowledge cycles and corporate investment” by Bustamante, Cujean, and Frésard

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What this paper does

Theory Q-theory model with knowledge cycles

knowledge $= Z_t =$ perceived drift of productivity growth

cycles $=$ occasional knowledge reset

$$\implies i(Z_t) = \delta + \frac{1}{\gamma}\left(q(Z_t) + c(Z_t) - 1\right)$$

Data Patent data to identify knowledge resets

investment/q dynamics around resets consistent w/model

Why should we care?

1. How do firms learn about the potential profitability of new projects?

   Berk, Green, Naik (2004)

   endogenous choice to discard a project and "explore"

   exploration is a "gamble"

2. Has the investment-q relationship changed over time, and why?

   Peters and Taylor (2017), Andrei, Mann, and Moyen (2018), Crouzet and Eberly (2018, 2020)

   sign of the investment/q wedge depends on state of the knowledge cycle

Roadmap

Sketch of theory

Identification

Empirics

Sketch of theory

Basic elements

$$\Pi_t = A_t^{1-\eta} K_t^{\alpha(1-\eta)} N_t^{-\eta}$$

$$\begin{aligned} dK_t &= (i_t - \delta) K_t dt && \text{(investment)} \\ \text{Net income} &= (1 - \gamma(i_t))\Pi_t \end{aligned}$$

$$\begin{aligned} \frac{dA_t}{A_t} &\quad \text{drift} \propto Z_t && \text{(passive "learning")} \\ dZ_t &= \mu_Z Z_t dt + \sigma_Z d\hat{B}_t \end{aligned}$$

$$\frac{dN_t}{N_t} = \phi Z_t^2 \mathbf{1}\{Z_t \geq 0\} \qquad \text{(knowledge dissipation)}$$

Adding ”exploration”

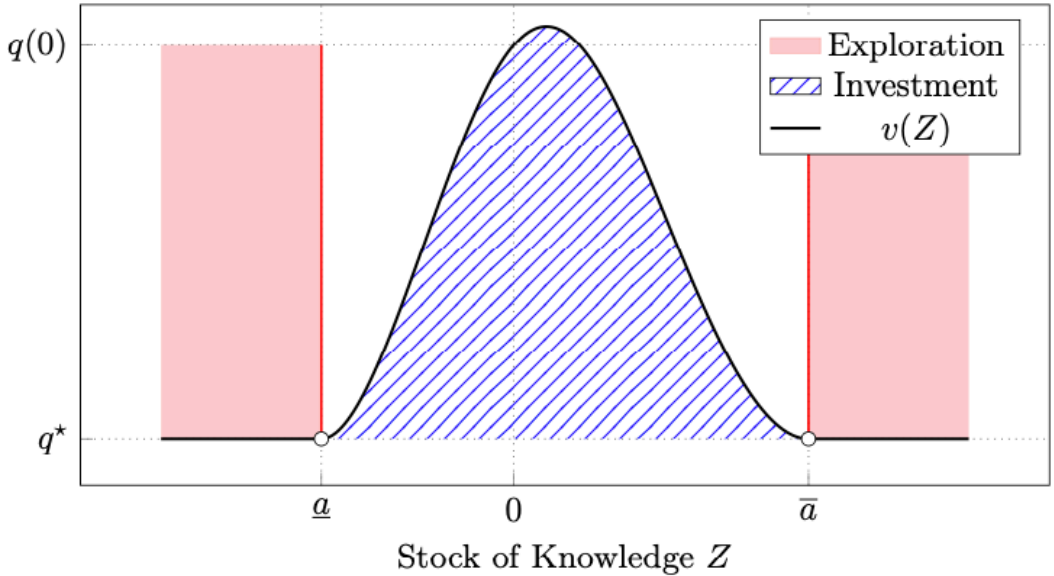
Without ”exploration”:

exit if Z_t sufficiently low —— $V_t < 0$

but also if Z_t sufficiently high —— as N_t grows

always true, or depends on α? interpretation?

Allow the firm to reset Z_t to $Z_{t^+} = 0$ (”exploration”)


$q(0)$
$q^\star$
Exploration
Investment
$v(Z)$
$\underline{a}$
0
$\overline{a}$
Stock of Knowledge Z

The model with only ”exploration”

Knowledge cycles

cycle = period between resets

Non-monotonic relationship between Z_t and q_t

But standard investment-q relationship holds

$$\iota(Z_t) = \delta + \frac{1}{\gamma}\left(q(Z_t) - 1\right)$$

Introducing "experimentation"

Assume drift of Z_t to depend positively on $i(Z_t)$

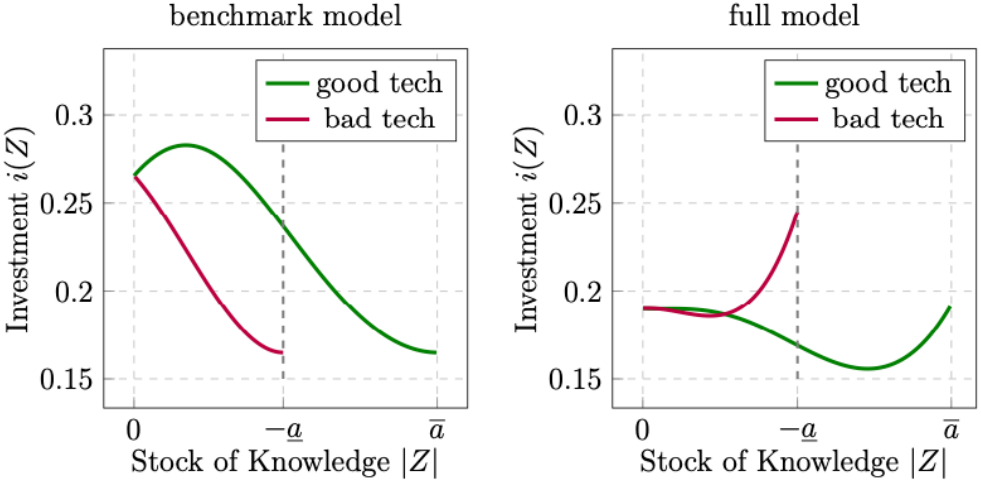
Investing more now increases Z_t, all other things equal

$$c(Z_t) \equiv \text{incremental value due to effect of investment on knowledge}$$

$$\propto v'(Z_t)Z_t + \underbrace{v''(Z_t)}_{\gtrless 0}$$

Investment-q relationship is now:

$$\iota(Z_t) = \delta + \frac{1}{\gamma}\left(q(Z_t) + c(Z_t) - 1\right)$$


benchmark model
full model
good tech
bad tech
Investment $i(Z)$
0.3
0.25
0.2
0.15
0
$-\underline{a}$
$\overline{a}$
Stock of Knowledge $|Z|$

Theory: comments/suggestions

1. Insight: sign of $c(Z_t)$ can change as reset gets close
   - *Increasing* investment – "gambling for exploration"
   - What makes the firm "effectively" risk-sensitive?
   - Is this a numerical result? What does it depend on?
   - Is $q(Z_t)$ always decreasing close to the reset boundary?

2. Assumption: limited obsolescence upon reset
   - But investment and Z_t tied during the "experimentation" phase
   - What is K_t? General purpose tech?

Identification

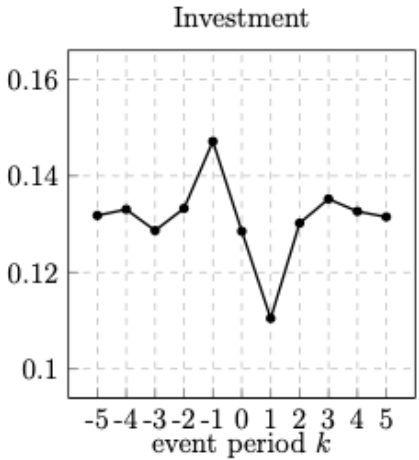
Identifying the "knowledge channel"

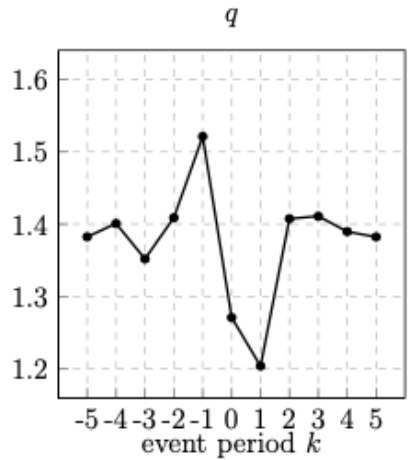
$$i(Z_t) \quad = \quad \delta + \frac{1}{\gamma}\left(q(Z_t) + c(Z_t) - 1\right)$$

Investment-Q slope *conditional on* stage of the knowledge cycle:

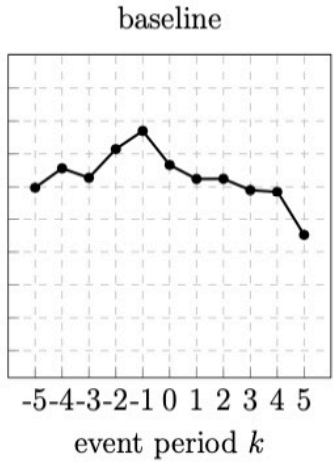
$$\hat{\beta}_{Z_t \in [Z_1, Z_2]} \quad = \quad \frac{1}{\gamma}\left(1 + \frac{cov(q(Z_t), c(Z_t) | Z_t \in [Z_1, Z_2])}{var(q(Z_t) | Z_t \in [Z_1, Z_2])}\right)$$

No closed form, so use simulation





event period 0 = technology reset



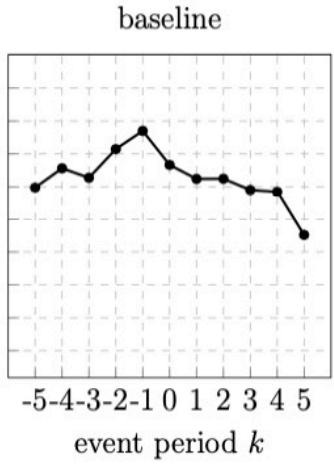
$\hat{\beta}_k$, with k = time from reset; max for $k = -1$

Identification: comments/suggestions

1. Why is $\hat{\beta}_{Z_t \in [Z_1, Z_2]}$ highest right before reset?
   - $i \uparrow$ "gambling on exploration"
   - $q \uparrow$?

     (seems inconsistent with earlier model discussion)

2. Enough power to reject the null $\hat{\beta}_{Z_t \in [Z_1, Z_2]} = \frac{1}{\gamma} \; \forall \; Z_t \in [Z_1, Z_2]$?



$\hat{\beta}_k$, with k = time from reset; max for $k = -1$

Identification: comments/suggestions

1. Why does $\hat{\beta}_{Z_t \in [Z_1, Z_2]}$ spike right before reset?
   - $i \uparrow$ "gambling on exploration"
   - $q \uparrow$?

     (seems inconsistent with earlier model discussion)

2. Enough power to reject the null $\hat{\beta}_{Z_t \in [Z_1, Z_2]} = \frac{1}{\gamma} \quad \forall\, (Z_1, Z_2)$?
   - simulate from same size data ($\approx$ 1200 firms, 2000 resets)

Empirics

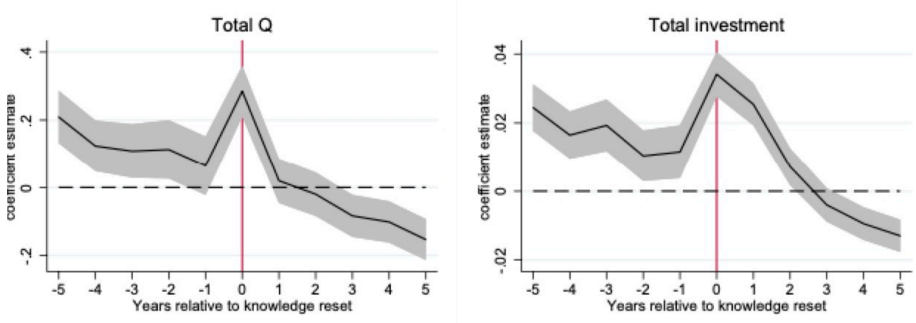
Measuring technology resets

$v_{f,t} = 38 \times 1$ vector

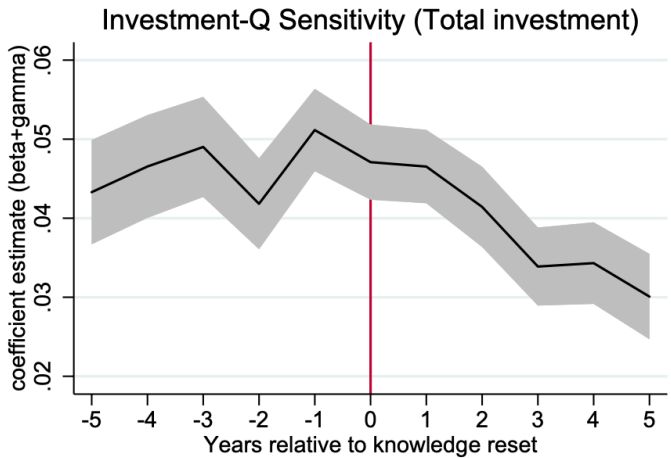
% of patents cited by f in each of the 38 tech subclasses from $t-5$ to t

$$\Delta v_t^f = \frac{v_t^f}{|v_t^f|} \cdot \frac{v_{t-1}^f}{|v_{t-1}^f|}$$

Reset event: $\Delta v_t^f < E(\Delta v^f) - \theta\sigma(\Delta v^f)$



Investment and average Q conditional on time to reset



Investment-*Q* sensitivity conditional on time to reset

Empirics: comments/suggestions

1. "Reset" in the data $\stackrel{?}{=}$ "exploration" in the model

   existing patents not scrapped following reset
   reset is byproduct of R&D, not "coin toss"
   reset continuous, not discrete
   discuss individual examples

2. Q in the data $\neq q$ in the model
   - model: marginal $q(Z_t)$; data: average Q_t
   - model: denominator = profits; data: denominator = capital

3. How informative are the conditional investment-Q sensitivities?
   - significance pre/post of decline?
   - does the decline happen specifically around resets? (placebo wrt other events)

Conclusion

- Creative model + interesting facts
- Directions for progress
  - key assumptions
  - validity+intuition for identification
  - what are ″resets″ in the data?