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

Nicolas Crouzet

Kellogg School of Management, Northwestern University

SFS Cavalcade 2021
What this paper does

Theory Q-theory model with knowledge cycles

knowledge = $Z_t$ = perceived drift of productivity growth

cycles = occasional knowledge reset

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

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

Sketch of theory

Identification

Empirics
Sketch of theory
Basic elements

\[ \Pi_t = A_t^{1-\eta} K_t^{(1-\eta)} N_t^{-\eta} \]

\[ dK_t = (i_t - \delta) K_t dt \quad \text{(investment)} \]

Net income \[ = (1 - \gamma(i_t)) \Pi_t \]

\[ \frac{dA_t}{A_t} \quad \text{drift} \propto Z_t \quad \text{(passive "learning")} \]

\[ dZ_t = \mu_Z Z_t dt + \sigma_Z dB_t \]

\[ \frac{dN_t}{N_t} = \phi Z_t^2 1 \{Z_t \geq 0\} \quad \text{(knowledge dissipation)} \]
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 $\alpha$? interpretation?

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

$$\iota(Z_t) = \delta + \frac{1}{\gamma} (q(Z_t) - 1)$$
Introducing “experimentation”

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

Investing more now increases $Z_t$, all other things equal

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

\[ \propto \nu'(Z_t)Z_t + \nu''(Z_t) \geq 0 \]

Investment-$q$ relationship is now:

\[ \iota(Z_t) = \delta + \frac{1}{\gamma} (q(Z_t) + c(Z_t) - 1) \]
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"

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

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

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

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 $k = -1$
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 $\hat{\beta}_{Z_t \in [Z_1, Z_2]} = \frac{1}{\gamma} \forall (Z_1, Z_2)$?
   - simulate from same size data ($\approx 1200$ firms, $2000$ resets)
Empirics
Measuring technology resets

\( v_{f,t} = 38 \times 1 \text{ vector} \)

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

\[
\Delta v^f_t = \frac{v^f_t}{|v^f_t|} \cdot \frac{v^f_{t-1}}{|v^f_{t-1}|}
\]

Reset event: \( \Delta v^f_t < E(\Delta v^f) - \theta \sigma(\Delta v^f) \)
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 ≠ "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 ≠ $q$ 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?