Uncertainty and Capital Accumulation:
Empirical Evidence from African and Asian Firms

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**Motivation–Puzzle**

- Why in general economic convergence doesn’t happen?
- Could low capital accumulation be one possible explanation?

**Table 1- Proportion of Zero Investment in Micro-Level Data (%)**

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>sample</td>
<td>proportion</td>
<td></td>
</tr>
<tr>
<td>LRD</td>
<td>8.1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Compustat</td>
<td>China</td>
<td>22.8</td>
<td>62.4</td>
</tr>
<tr>
<td>India</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morocco</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Ghana</td>
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</tbody>
</table>

Note: Data source for BSW(2007b): Enterprises Surveys, World Bank
Motivation–Explanations

- **Investment Decision**
  
  Marginal Product of Capital = User Cost of Capital

- **Technological Constraint**
  
  Uncertainty-Capital Adjustment Costs (BSW, 2007a, b)

- **Financing Constraint**
  
  Capital Market Imperfections (BSW, 2007c)
Motivation–Theoretical Interest

- uncertainty-investment/capital accumulation
- Hartman-Abel: positive Jensen’s inequality effect
- Pindyck-Dixit: negative marginal call option effect
- Abel-Eberly: (-) user cost effect v.s. (+) hang over effect
- Highlighting the importance of empirical work
This Paper (BSW, 2007b)
Introduction

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  - Ask how costly is capital adjustment and what is the level of uncertainty
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- Ask how costly is capital adjustment and what is the level of uncertainty
- Provide structural estimation by simulated method of moments
- Use firm-level data from China, India, Morocco and Ghana
- Simulate the counterfactual short-run adjustment and long-run accumulation due to an exogenous decrease in uncertainty
The Model

- **Dynamic Programming**

  \[ V_t(X_t, K_t) = \max_{I_t} \Pi(X_t, K_t; I_t) + \frac{1}{1 + r} E_t \left[ V_{t+1}(X_{t+1}, K_{t+1}) \right] \]

- **Law of motion for capital**

  \[ K_{t+1} = (1 - \delta) (K_t + I_t) \]

- **Law of motion for demand**

  \[
  \begin{align*}
  x_t &= \ln X_t = x_0 + \mu t + z_t \\
  z_t &= \rho z_{t-1} + \varepsilon_t \\
  \varepsilon_t &\sim \text{iid } N(0, \sigma^2)
  \end{align*}
  \]

- \( \sigma \) is the measure of uncertainty in this model
The Model

- Net Revenue = operating profit - purchase cost - adjustment cost

\[ \Pi(X_t, K_t; I_t) = X_t^\gamma (K_t + I_t)^{1-\gamma} - I_t - G(I_t, K_t) \]

- Without adjustment cost, analytical solution

\[ \frac{I_t^*}{K_t} = \text{const} \cdot \frac{X_t}{K_t} - 1 \]
\[ \hat{K}_t^* = K_t + I_t^* = \text{const} \cdot X_t \]

- Adjustment Cost = partial irreversibility + fixed cost + quadratic cost

\[ G(I_t, K_t) = -b_i I_t 1_{[I_t<0]} + b_f 1_{[I_t \neq 0]} X_t^\gamma (K_t + I_t)^{1-\gamma} + \frac{b_q}{2} \left( \frac{I_t}{K_t} \right)^2 K_t \]
Solution—Partial Irreversibility Only

- Capital is Firm-Specific; Adverse Selection Problem
Solution—Fixed Costs of Adjustment Only

- Indivisibilities in Capital; IRS; License or Permission
Solution—Quadratic Adjustment Costs Only

- Capital Installation; Labour Training; Organization Reconstruction

[Graph showing Investment Policy-Quadratic Costs Only with two lines: quadratic costs and no adjustment cost vs. const*\(X_t/K_t - 1\)]
Partial Irreversibility Only
Uncertainty-Investment Relationship—Short Run

- Fixed Costs of Adjustment Only

![Graph showing short-run effects with fixed costs only.](image-url)
Uncertainty-Investment Relationship—Short Run

- Quadratic Adjustment Costs Only
Uncertainty-Investment Relationship—Long Run

- Partial Irreversibility Only

![Graph showing the long-run effect with partial irreversibility only](image)
Uncertainty-Investment Relationship–Long Run

- Fixed Costs of Adjustment Only
Uncertainty-Investment Relationship–Long Run

- Quadratic Adjustment Costs Only
Towards Estimation

- Both in the short-run and long-run, the effects of uncertainty depend on the form and the magnitude of adjustment costs.
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To study and quantify these effects, we need to know which forms of adjustment costs are significant and how large they are.
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- How to estimate these unobservable underlying structural parameters?
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- How to estimate these unobservable underlying structural parameters?

- Simulated Method of Moments: link the model to the data.
Simulated Method of Moments

1. DGP
   - Observe Empirical Dataset with $N \times T$
   - Estimate a set of Empirical Moments $\hat{\Phi}^D$

2. Structural Model
   - Guess Structural Parameters ($\Theta$)
   - Simulate $H$ Datasets with $N \times T$
   - Estimate same set of Simulated Moments $\frac{1}{H} \sum_{h=1}^{H} \Phi^S_h(\Theta)$

3. Compare $\Theta^*$ with $\Theta$
   - If yes, MATCH?
   - If no, NO
Simulated Method of Moments

- **Estimate**

\[ \hat{\Theta} = \arg \min_{\theta} L = \left( \hat{\Phi}^D - \frac{1}{H} \sum_{h=1}^{H} \hat{\Phi}_h^S (\Theta) \right)' \Omega \left( \hat{\Phi}^D - \frac{1}{H} \sum_{h=1}^{H} \hat{\Phi}_h^S (\Theta) \right) \]

- **Property**

\[ \sqrt{N} \left( \hat{\Theta} - \Theta^* \right) \overset{D}{\rightarrow} N \left( 0, W (H, \Omega) \right) \]

- **Test**

\[ OI = \frac{NH}{1 + H} L \sim \chi^2 \left[ \dim (\hat{\Phi}) - \dim (\Theta) \right] \]

- **Algorithm**

simulated annealing algorithm to avoid local minima
Identification

- **10 Parameters**
  - parameters for capital adjustment costs
  - parameters characterising demand process
  - s.d. of measurement errors in investment and sales

- **14 Moments**
  - proportion of zero and spike investment rate
  - first and second moments of investment rate and sale growth rates
  - serial correlation between investment rates and sales growth rates

- **Criterion of Moment Choice**
  - variation in moments is informative about changes in parameters
The effect of varying $b_f$ on the proportion with zero investment
# Empirical Results

## Table 2-Estimation Result for the China Small Sample

<table>
<thead>
<tr>
<th>parameters</th>
<th>symbol</th>
<th>estimate</th>
<th>t-value</th>
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<tbody>
<tr>
<td>irreversibility</td>
<td>$b_i$</td>
<td>0.005</td>
<td>0.0004</td>
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<tr>
<td>fixed cost</td>
<td>$b_f$</td>
<td>0.046</td>
<td>3.4755</td>
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<tr>
<td>quadratic cost</td>
<td>$b_q$</td>
<td>3.133</td>
<td>12.887</td>
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<tr>
<td>demand growth rate</td>
<td>$\mu$</td>
<td>0.029</td>
<td>9.1115</td>
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<tr>
<td>level of demand uncertainty</td>
<td>$\sigma$</td>
<td>0.463</td>
<td>6.5754</td>
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<tr>
<td>profit function curvature</td>
<td>$\gamma$</td>
<td>0.586</td>
<td>19.767</td>
</tr>
<tr>
<td>measurement error 1</td>
<td>$\sigma_{YP}$</td>
<td>1.042</td>
<td>5.8318</td>
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<tr>
<td>measurement error 2</td>
<td>$\sigma_{YT}$</td>
<td>0.128</td>
<td>0.0001</td>
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<tr>
<td>measurement error 3</td>
<td>$\sigma_{IP}$</td>
<td>0.732</td>
<td>22.292</td>
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<tr>
<td>measurement error 4</td>
<td>$\sigma_{IT}$</td>
<td>0.563</td>
<td>19.296</td>
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<td>criterion value</td>
<td>$OI$</td>
<td>21.1</td>
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<tr>
<td>over-identifying restrictions</td>
<td>dim $\left( \widehat{\Phi} - \Theta \right)$</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>
Counterfactual Simulation

- Short-Run Adjustment
Counterfactual Simulation

- Long-Run Accumulation

![Graph showing long-run effect in China with unsmoothed and smoothed lines.](image-url)
Conclusions

- A rich specification of adjustment costs—both convex and non-convex is necessary to fit firm-level investment data.
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- A lower level of uncertainty would induce firms to operate with substantially higher capital stock in the long run.
Further Research

- Turn on Hartman-Abel effect and estimate its importance empirically.
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- Introduce unobservable heterogeneity in uncertainty and firm size.
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- Turn on Hartman-Abel effect and estimate its importance empirically.
- Introduce unobservable heterogeneity in uncertainty and firm size.
- Introduce incomplete market or risk-aversion through discount rate.
The End.
Thank You Very Much.
Questions and Comments Welcome!