Process intangibles and agency conflicts
by Chen, Kakhbod, Kazemi, and Xing

Discussion by Nicolas Crouzet

Kellogg
Overview

Measurement:

\[ \text{process intensity} \equiv \frac{\text{process patent claims}}{\text{process + product patent claims}} \]

\[ \uparrow \text{process intensity} \iff \uparrow \text{managerial compensation} \]

more so for firms with higher physical investment rates

Model:

\( \text{process intangibles} \equiv \text{asset that can increase } MRT (I \rightarrow K) \)

\( \text{agency conflict} \equiv \text{requires managerial effort} \)

\[ \text{process intensity} \approx \text{impact of managerial effort on } MRT (I \rightarrow K) \equiv 1 - \theta \]

Implications:

\[ \uparrow 1 - \theta \iff \uparrow \text{compensation}; \quad \uparrow \text{deferral of compensation} \]

\[ \uparrow 1 - \theta \iff \uparrow \text{physical investment rates} \]
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\[ \uparrow 1 - \theta \iff \uparrow \text{Compensation}; \uparrow \text{Deferral of compensation} \iff \uparrow 1 - \theta \iff \uparrow \text{Physical investment rates} \]
Overview

**Measurement**: process intensity $\equiv$ process patent claims / (process + product patent claims)
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Measurement: process intensity \equiv \frac{\text{process patent claims}}{\text{(process + product patent claims)}}

↑ process intensity \iff ↑ managerial compensation
Process intensity and compensation

![Graph showing the comparison between Full Process and Full Product against average executive compensation per unit capital across different intangibility bins.]
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Measurement: process intensity $\equiv$ process patent claims / (process + product patent claims)

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Process intensity, compensation, and physical investment
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**Model**: process intangibles s.t. agency conflict
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process intangibles $\equiv$ asset that can increase $MRT(I \rightarrow K)$
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$\uparrow 1 - \theta \iff \uparrow$ compensation; $\uparrow$ *deferral* of compensation

$\uparrow 1 - \theta \iff \uparrow$ physical investment rates
Roadmap

1. Measurement

2. Model
1. Measurement
Process innovation

Learn

by
doing:

[Arrow (1962), Lucas (1988), ...]

unit costs fall with cumulative production

Or
gain
capital:

[Tomer (1987), Atkeson and Kehoe (2005), ...]

firms make deliberate investments to lower unit costs

Levitt, List, Syverson (2013): evidence for an automobile plant

Eisfeldt and Papanikolaou (2013), Crouzet and Eberly (2023): impact on firm value

Common thread:

process innovation is about lowering unit costs, not necessarily changing MRT ($I \rightarrow K$)

This paper: process innovation is all about changing MRT ($I \rightarrow K$); no direct impact on unit costs
Process innovation

Learning by doing:

[Arrow (1962), Lucas (1988), ...]
Process innovation

Learning by doing:

unit costs fall with cumulative production
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Organizational capital:

[Arrow (1962), Lucas (1988), ...]

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[Arrow (1962), Lucas (1988), ...]

[Tomer (1987), Atkeson and Kehoe (2005), ...]
Process innovation lowers unit costs

[Levitt, List, Syverson, 2013]
Process innovation

Learning by doing:
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Eisfeldt and Papanikolaou (2013), Crouzet and Eberly (2023): impact on firm value
Process innovation contributes to firm value

Vertical axis = \[ \frac{\text{Enterprise value of public, non-financial US firms}}{\text{PPE replacement cost}} - 1 \]
Process innovation

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unit costs fall with cumulative production

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Evidence on process innovation and physical investment

**Fact 1:** \( \text{cov} (1 - \theta, I_t/K_t) > 0 \), but \( \text{cov} (1 - \theta, S_t/K_t) = 0 \)
Fact 1

<table>
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<tr>
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<th>Physical Investment / Physical Capital</th>
<th>Intangible Investment / Physical Capital</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Process Intensity</td>
<td>0.027***</td>
<td>0.022***</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.008)</td>
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<tr>
<td>Intangibility</td>
<td>0.187***</td>
<td>0.124***</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.012)</td>
</tr>
</tbody>
</table>
Evidence on process innovation and physical investment

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Fact 2: Process intangibles ($O_t$) and $I_t$ are complements in the production of $K_t$
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**Fact 2:** Process intangibles \((O_t)\) and \(I_t\) are complements in the production of \(K_t\)

\[
G_{f,t-1,t+i}^{(K)} = \alpha_f + \beta_f (1 - \theta_{f,t}) \times (I/K)_{f,t} + \gamma_f (O/K)_{f,t} \times (I/K)_{f,t} + \varepsilon_{f,t}, \quad i = 1, 3
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Requires variation in \(\theta_{f,t}\) within firm?

Inconsistent with rest of paper?

Why retain only estimates with \(\beta_f \geq 0\) and \(\gamma_f \geq 0\)?
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Suggestion: How do process patents describe their goal? Does it involve \(K_t\)?
## Fact 2

<table>
<thead>
<tr>
<th>Ratio Regression</th>
<th>ProcIn.</th>
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<tbody>
<tr>
<td>$i = 1$</td>
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<tr>
<td>Mean</td>
<td>0.0123</td>
</tr>
<tr>
<td>Median</td>
<td>0.144</td>
</tr>
<tr>
<td>$i = 3$</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.027</td>
</tr>
<tr>
<td>Median</td>
<td>0.299</td>
</tr>
</tbody>
</table>
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**Fact 3:** \( \text{cov} (1 - \theta, \text{Sales}_t/K_t) < 0 \) (!)
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\(1 - \theta\) increase future sales/capital
Future sales $f_{t+i} = \theta_{f,t} \times \frac{\text{Sales}_{f,t+i}}{O_{f,t+i}}$
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**Suggestion:** How do process patents describe their goal? Does it involve \(K_t\)?
Key facts:

- Compensation and deferred compensation both increase with $1 - \theta$.
- Conditional on $O_t/K_t$ [Ward (2023)].

Clarify economic magnitude?

Suggestions:

- Compare to other sources of cross-sectional variation in executive compensation.
  - Edmans, Gabaix, Jenter (2017): size; volatility; CEO tenure; CEO age.

Incremental $R^2$-squared of $1 - \theta$, relative to these factors?

Selection remains an issue

Incremental effect of $1 - \theta$ in sample of switching CEOs, controlling for CEO fixed effects?
Process intensity and executive compensation

**Key facts:** compensation and deferred compensation both increase with $1 - \theta$

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Suggestion: compare to other sources of cross-sectional variation in executive compensation? Edmans, Gabaix, Jenter (2017): size; volatility; CEO tenure; CEO age

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Process intensity and executive compensation

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Conditional on $O_t/K_t$ [Ward (2023)]
# Process intensity and executive compensation

<table>
<thead>
<tr>
<th></th>
<th>Dependent variable:</th>
<th>Total Compensation / Physical Capital</th>
<th>Deferred Compensation / Physical Capital</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Process Intensity</td>
<td>0.034*</td>
<td>0.066***</td>
<td>0.054**</td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td>(0.011)</td>
<td>(0.025)</td>
</tr>
<tr>
<td>Intangibility</td>
<td>0.896***</td>
<td>0.717***</td>
<td>0.912***</td>
</tr>
<tr>
<td></td>
<td>(0.029)</td>
<td>(0.020)</td>
<td>(0.033)</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td></td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td></td>
<td>0.076***</td>
<td>0.828***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.031)</td>
<td></td>
</tr>
</tbody>
</table>
Process intensity and executive compensation

![Graph showing the comparison between Process vs Product with different intangibility bins. The y-axis represents Average Executive Compensation per Unit Capital, and the x-axis shows Intangibility Bin numbers from 1 to 5. The graph uses two colors: grey for Full Process and blue for Full Product. The intangibility bins 3 and 5 show a higher compensation for Full Process compared to Full Product.](image-url)
Process intensity and executive compensation

**Key facts:** compensation and deferred compensation both increase with $1 - \theta$

Conditional on $O_t/K_t$  

[Ward (2023)]
Process intensity and executive compensation

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**Suggestion:** compare to other sources of cross-sectional variation in executive compensation?
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Edmans, Gabaix, Jenter (2017): size; volatility; CEO tenure; CEO age
Cross-sectional variation in executive compensation

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(Firm value\textsubscript{t-1})</td>
<td>0.426***</td>
<td>0.459***</td>
<td>0.456***</td>
<td>0.455***</td>
<td>0.303***</td>
</tr>
<tr>
<td></td>
<td>[0.008]</td>
<td>[0.008]</td>
<td>[0.008]</td>
<td>[0.009]</td>
<td>[0.017]</td>
</tr>
<tr>
<td>Volatility\textsubscript{t-1}</td>
<td>2.842***</td>
<td>1.488***</td>
<td>1.606***</td>
<td>1.527***</td>
<td>0.00727</td>
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<tr>
<td></td>
<td>[0.177]</td>
<td>[0.185]</td>
<td>[0.199]</td>
<td>[0.197]</td>
<td>[0.233]</td>
</tr>
<tr>
<td>ln(Age\textsubscript{t})</td>
<td></td>
<td></td>
<td></td>
<td>(-0.163^*)</td>
<td>0.950</td>
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<td></td>
<td></td>
<td></td>
<td>[0.083]</td>
<td>[0.864]</td>
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<tr>
<td>ln(Tenure\textsubscript{t})</td>
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<td></td>
<td>0.00854</td>
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<td>0.0365*</td>
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<td>[0.017]</td>
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<td>[0.056]</td>
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</table>

Note: column 5 contains CEO fixed effects.
Process intensity and executive compensation

**Key facts:** compensation and deferred compensation both increase with $1 - \theta$

Conditional on $O_t/K_t$  

Clarify economic magnitude?

**Suggestion:** compare to other sources of cross-sectional variation in executive compensation?

Edmans, Gabaix, Jenter (2017): size; volatility; CEO tenure; CEO age

[Ward (2023)]
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2. Model
Model overview

Key agency conflict involves accumulation of $K_t$

$$dK_t = \left( I_t - \delta K_t \right) dt + \sigma K_t dZ_t$$
Model overview

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$$dK_t = \left( \left( I_t^\rho + \frac{1-a}{a} e_t ((1 - \theta) O_t)^\rho \right)^{\frac{1}{\rho}} - \delta_k K_t \right) dt + \sigma_t K_t dZ_t$$
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$$e_t \in \{0, 1\} \quad \text{managerial effort}$$
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$O_t$ also enters the production function

$$Y_t = \mu \left( (1-\phi)K_t^\psi + \phi (\theta O_t)^\psi \right)^{\frac{1}{\psi}}$$
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Optimal contract exposes manager to $dK_t$, and:

- defers compensation, i.e. only pays out when $u_t = \bar{u}(O_t/K_t)$
- $\uparrow 1-\theta \implies$ higher compensation
- $\uparrow 1-\theta \implies$ more deferred compensation
Model suggestions

\[ dK_t = \left( \left( I_t^\rho + \frac{1-a}{a} e_t ((1 - \theta)O_t)^\rho \right)^{\frac{1}{\rho}} - \delta K_t \right) dt \quad \text{and} \quad Y_t = \mu \left( (1 - \phi)K_t^\psi + \phi (\theta O_t)^\psi \right)^{\frac{1}{\psi}} \]
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Main issue: \( O_t \) two has separate purposes; but firm can’t control \( \theta \).
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2. Why is \( \theta \) a measure of process intensity, as opposed to \( a \)?
   \[ a = 1: \text{no agency conflict}; a \to 0: \text{large hold-up problem} \]
   Are comparative statics of compensation w.r.t. \( a \) different?
Model vs. data

Calibration + qualitative comparison to data
Model vs. data

Calibration + qualitative comparison to data

1. What is the impact of agency frictions on physical investment?
   compare first-best to optimal contract

2. Does the model replicate well estimates of performance-pay sensitivity
   contract exposes compensation to
   \( dK_t \)
   is that true in the data? how close are model and data elasticities?

3. Data: no relationship between \( 1 - \theta \) and intangible investment rates
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   Again, case \( \phi = 0 \) might be clearer
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Provide more empirical support for this take

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