Revisiting declining R&D productivity in Korea

Team YSJ
Name: Dongjoo Kim, Sungwoo Jang, Hyunsik Yoon
R&D Productivity

Aggregate level

\[ \text{GDP growth rate} \div \text{R&D intensity} \]

Industry level

\[ \text{Sales growth rate} \div \text{R&D intensity} \]

R&D intensity

\[ \frac{\text{R&D expenditure}}{\text{GDP}} \]
Trend of R&D Intensity
Key paper:

Nicholas Bloom (2019, NBER working paper)
- finds R&D productivity has been declining since 1980’s in the US
Objectives

1. The firm-level R&D productivities in Korea for the last 15 years, by using the financial statement data (KisValue).
2. Time varying effects of R&D intensity on firm’s economic activity
3. Comparison between electronics and non-electronics
Data and Sample

Data
- KOSPI and KOSDAQ listed firms’ financial statements panel data from KisValue
- Period: 2001~2018
- The number of firms: 2,228 (based on 2018)

Our sample
- Removing data if R&D investment is zero or omitted during the period
- Removing upper 1% data to adjust bias
- The number of firms: 1,439
Measure of R&D expenditure/output

R&D expenditure =

Development cost + R&D cost + Ordinary development expense

R&D output

- Total sales growth rate
- Profit ratio
- Tobin’s q
Aggregate R&D intensity and Sales growth rate of the Listed firms

Year

Aggregate Sales growth rate
Aggregate R&D intensity
Sector: Electronics vs Non-Electronics

**R&D intensity**
- Electrical Electronics
- Non Electronic Electronics
- Average

**R&D Expenditures**
- Electrical Electronics
- Non Electrical Electronics
Panel analysis – Fixed effect model

\[ y_{it} = \alpha + \beta x_{i,t-n} + X_{it} \gamma + \lambda_i + \epsilon_{it} \]

*where*  
\( y_{it} = \) Firm’s R&D output at \( t \) period  
\( x_{i,t-n} = \) Firm’s R&D intensity at \( (t - n) \) period \( (3 \leq n \leq 7) \)  
\( \lambda_i = \) the unobservable individual heterogeneity

\[
X_{it} = \begin{bmatrix}
\log (\text{Ad Expenditure Ratio})_{it} \\
\text{Debt Ratio}_{it} \\
\log (\text{total equity})_{it} \\
\text{Real GDP Growth}_t
\end{bmatrix}
\]
# Time lag effects (Sales growth rate)

- Time lags between R&D and actual performances: 3~7 year
- The effect of $R&D intensity_{t-n}$ on $R&D outputs_t$ ($3 \leq n \leq 7$)

Whole period (2001~2018)

<table>
<thead>
<tr>
<th>$R&amp;D intensity_{t-n}$</th>
<th>$n = 3$</th>
<th>$n = 5$</th>
<th>$n = 7$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total firms</td>
<td>0.485*** (5.27)</td>
<td>0.193*** (5.79)</td>
<td>0.097*** (3.35)</td>
</tr>
<tr>
<td>Electronics</td>
<td>2.046*** (2.69)</td>
<td>-0.353 (-0.42)</td>
<td>-1.767** (-2.03)</td>
</tr>
<tr>
<td>Non-Electronics</td>
<td>0.472*** (5.03)</td>
<td>0.193*** (5.71)</td>
<td>0.098*** (3.36)</td>
</tr>
</tbody>
</table>

*: 10% significance level  **: 5% significance level  ***: 1% significance level

The number in parentheses means t-value
Panel analysis

The effect of R&D intensity on R&D outputs with 3 years time lag

• The effect during the whole period 2004-2018
• The effect during 2004–2010 and 2011-2018
• Compare the effect between former period and latter period
• Compare the effect between electronics and non-electronics
## Panel Analysis Result (Sales growth rate)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Sales growth&lt;sub&gt;t&lt;/sub&gt;</td>
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<td></td>
</tr>
<tr>
<td>R&amp;D intensity&lt;sub&gt;t-3&lt;/sub&gt;</td>
<td>0.485*** (5.27)</td>
<td>0.687*** (3.51)</td>
<td>0.463*** (3.68)</td>
</tr>
<tr>
<td>Log(Ad Ratio)&lt;sub&gt;t&lt;/sub&gt;</td>
<td>-0.027*** (-9.05)</td>
<td>-0.020*** (-3.41)</td>
<td>-0.039*** (-8.97)</td>
</tr>
<tr>
<td>Debt Ratio&lt;sub&gt;t&lt;/sub&gt;</td>
<td>0.256*** (6.41)</td>
<td>0.582*** (7.04)</td>
<td>0.434*** (7.61)</td>
</tr>
<tr>
<td>Log(total equity)&lt;sub&gt;t&lt;/sub&gt;</td>
<td>0.047*** (4.78)</td>
<td>0.123*** (5.57)</td>
<td>0.138*** (8.47)</td>
</tr>
<tr>
<td>Real GDP growth&lt;sub&gt;t&lt;/sub&gt;</td>
<td>0.027*** (10.20)</td>
<td>0.016*** (4.65)</td>
<td>0.045*** (3.88)</td>
</tr>
<tr>
<td>Constant&lt;sub&gt;t&lt;/sub&gt;</td>
<td>-1.013*** (-3.74)</td>
<td>-2.800*** (-4.88)</td>
<td>-3.741*** (-8.39)</td>
</tr>
</tbody>
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## Panel Analysis Result (Sales growth rate)

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<tr>
<td>R&amp;D intensity&lt;sub&gt;t-3&lt;/sub&gt;</td>
<td>2.046*** (2.69)</td>
<td>5.725*** (3.00)</td>
</tr>
<tr>
<td>Log(Ad Ratio)&lt;sub&gt;t&lt;/sub&gt;</td>
<td>-0.029*** (-2.74)</td>
<td>-0.033 (-1.63)</td>
</tr>
<tr>
<td>Debt Ratio&lt;sub&gt;t&lt;/sub&gt;</td>
<td>0.333** (2.23)</td>
<td>0.372 (1.00)</td>
</tr>
<tr>
<td>Log(total equity)&lt;sub&gt;t&lt;/sub&gt;</td>
<td>0.052 (1.29)</td>
<td>0.246*** (2.82)</td>
</tr>
<tr>
<td>Real GDP growth&lt;sub&gt;t&lt;/sub&gt;</td>
<td>0.020** (2.37)</td>
<td>0.010 (0.98)</td>
</tr>
<tr>
<td>Constant&lt;sub&gt;t&lt;/sub&gt;</td>
<td>-1.242 (-1.15)</td>
<td>-6.318*** (-2.69)</td>
</tr>
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Other R&D Outputs

- **Profit ratio**
  \[
  \text{Profit ratio} = \frac{\text{Gross Margin}}{\text{Sales}}
  \]
  ➔ It reflects the profitability of the firms.

- **Tobin’s q**
  \[
  \text{Tobin’s q} = \frac{\text{Total Market Value of Firm}}{\text{Total Asset Value of Firm}}
  \]
  : Relationship between market valuation and asset value.
  ➔ Tobin’s q reflects the future value of the firms.
## Panel Analysis Result (Profit ratio)

### Electronics vs. Non-Electronics

<table>
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<tbody>
<tr>
<td>R&amp;D intensity&lt;sub&gt;<em>t-3</em>&lt;/sub&gt;</td>
<td>0.452*** (2.99)</td>
<td>0.905*** (2.85)</td>
<td>-0.185 (-0.93)</td>
<td>0.056*** (2.86)</td>
<td>0.067** (2.07)</td>
<td>0.048* (1.90)</td>
</tr>
<tr>
<td>Log(Ad Ratio)&lt;sub&gt;<em>t</em>&lt;/sub&gt;</td>
<td>0.004* (1.72)</td>
<td>-0.005 (1.57)</td>
<td>-0.003 (-1.17)</td>
<td>0.003*** (5.08)</td>
<td>0.004*** (4.56)</td>
<td>0.002*** (2.80)</td>
</tr>
<tr>
<td>Debt Ratio&lt;sub&gt;<em>t</em>&lt;/sub&gt;</td>
<td>-0.790** (-2.70)</td>
<td>-0.160*** (-2.66)</td>
<td>-0.059 (-1.41)</td>
<td>-0.101*** (-11.56)</td>
<td>-0.038*** (-2.72)</td>
<td>-0.114*** (-9.67)</td>
</tr>
<tr>
<td>Log(total equity)&lt;sub&gt;<em>t</em>&lt;/sub&gt;</td>
<td>0.022*** (2.90)</td>
<td>0.007 (0.51)</td>
<td>0.058*** (4.36)</td>
<td>0.001 (0.77)</td>
<td>0.001 (0.34)</td>
<td>0.012*** (3.72)</td>
</tr>
<tr>
<td>Real GDP growth&lt;sub&gt;<em>t</em>&lt;/sub&gt;</td>
<td>0.002 (1.42)</td>
<td>-0.000 (-0.13)</td>
<td>0.000 (0.04)</td>
<td>0.002*** (3.90)</td>
<td>0.000 (0.15)</td>
<td>0.004** (2.01)</td>
</tr>
<tr>
<td>Constant&lt;sub&gt;<em>t</em>&lt;/sub&gt;</td>
<td>-0.303 (-1.45)</td>
<td>0.159 (0.41)</td>
<td>-1.372*** (-3.82)</td>
<td>0.334*** (5.62)</td>
<td>0.356*** (3.62)</td>
<td>0.035 (-0.38)</td>
</tr>
</tbody>
</table>

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# Panel Analysis Result (Tobin’s q)

## Whole industries

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</thead>
<tbody>
<tr>
<td>R&amp;D intensity&lt;sub&gt;t-3&lt;/sub&gt;</td>
<td>1.014*** (5.37)</td>
<td>1.466*** (5.26)</td>
<td>0.805*** (2.86)</td>
</tr>
<tr>
<td>Log(Ad Ratio)&lt;sub&gt;t&lt;/sub&gt;</td>
<td>0.085*** (13.76)</td>
<td>0.062*** (7.49)</td>
<td>0.088*** (9.10)</td>
</tr>
<tr>
<td>Debt Ratio&lt;sub&gt;t&lt;/sub&gt;</td>
<td>-0.165** (-2.02)</td>
<td>-0.074 (-0.63)</td>
<td>-0.396*** (-3.10)</td>
</tr>
<tr>
<td>Log(total equity)&lt;sub&gt;t&lt;/sub&gt;</td>
<td>-0.049** (-2.44)</td>
<td>-0.317*** (-10.13)</td>
<td>-0.070* (-1.90)</td>
</tr>
<tr>
<td>Real GDP growth&lt;sub&gt;t&lt;/sub&gt;</td>
<td>-0.009 (-1.63)</td>
<td>0.021*** (4.39)</td>
<td>-0.126*** (-4.84)</td>
</tr>
<tr>
<td>Constant&lt;sub&gt;t&lt;/sub&gt;</td>
<td>4.866*** (8.79)</td>
<td>10.751*** (13.20)</td>
<td>5.989*** (6.00)</td>
</tr>
</tbody>
</table>

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Summary

1. R&D productivities have been declining for the last 15 years. (All listed firms, electronics firms, and non-electronics firms)

2. The effects of R&D investment on sales growth rate, profit ratio and Tobin’s q show declining trend.

3. R&D productivities in electronics show steeper declining trend. Despite the trend, R&D productivities in electronics are higher than non-electronics.
Further research

1. Insufficient Electronics sample
   • Collecting more data from KONEX

2. Foundation year as proxy of firm size
   • Omitted variable problem caused by fixed effect

3. Policy implications for decreasing R&D productivity
   • Misallocation of R&D expenditure
Thank you for listening