Mergers and R&D Revisited: Exploring the Use of the Propensity Score to Control for Merger Probability

Bronwyn H. Hall
UC Berkeley and NBER
Motivation (Economic)

• U.S. manufacturing sector in the 1980s experienced a major wave of restructuring and acquisitions
• Critiqued as inimical to long term investment strategies, and especially to R&D
• Did increased levels of debt and merged operations cause a decline in R&D in certain sectors?
• Did these mergers increase productivity?
Motivation (methodological)

• Interest centers on measuring the outcomes post-merger for merging firms

• Prior studies of merger outcomes have generally ignored non-random nature of selection into merger:
  – due to differences in observables (this paper)
  – due to differences in unobservables (extensions to this paper?)

• Research agenda: explore the use of methods from the quasi-experimental literature on “treatment” effects to analyze merger outcomes

• Major problem not yet addressed: merger is a “match,” not a simple treatment - focus on acquiring firms for now
Conclusions from Prior Research (1)

- US in early 1980s - firms facing foreign competition and high real interest rates
  - existing capital stock excessive compared to returns being generated (Blair, Schary, …)
  - Q values well below one in autos, steel, machinery, rubber, …
  - Q above one in pharmaceuticals and some parts of computing/electronics
Conclusions from Prior Research (2)

- Firms responded during the 1980s:
  - went private via leveraged transactions
  - leveraged in response to hostile takeover bid or
  - were taken over, and perhaps restructured

- Why leverage?
  - high real interest rates - debt cheaper than equity
  - ties up free cash flow (internal inv. opportunities low)
  - enables investment and employment reductions ("back to the wall")
This paper

- Updates previous facts to 1995; for the most part confirms them (*see paper*)
- Explores the use of hazard rate models for estimating exit probabilities (*see paper*)
- Explores the use of propensity score methods to compare R&D growth for merging and non-merging firms, controlling for probability of merger
Data

- United States publicly traded manufacturing firms between 1976 and 1995
- drawn from Compustat annual industrial, full coverage, and annual research files
- ~50,000 firm-years for ~6,000 firms
- ~3,000 exits, and the reason for exit, reduced to about 2,100 true exits
Who exited the sector?

- 989 (861) - acquisition by another public firm
- 630 (530) - went private, often through an LBO or other leveraged transaction
- 367 (202) - went bankrupt, was liquidated, or lost their charter (nonpayment of taxes)
- 134 (82) - other or not found
- 2120 (1675) - total in the current sample

(nos. in parentheses are the sample after cleaning)
Is R&D Cut After Merger?

- My previous work - “differences of differences” - compare change in R&D intensities between merging and non-merging firms
- Problem - “treatment” and “control” samples are different, so results may be biased
- Possible solution - “propensity score” methodology of Rosenbaum and Rubin (1983, 1984). Stratify by probability of merger and compare within groups
Propensity Score Method (1)

**Key assumption:** outcome $Z$ is independent of $M$ (treatment assignment) given the predictors $X$.

$Z_1 =$ outcome for treated; $Z_0 =$ outcome for controls

We observe

$$E[Z_1 | X, M=1] - E[Z_0 | X, M=0]$$

We want to measure

$$E[Z_1] - E[Z_0]$$ or perhaps $$E[Z_1 | X] - E[Z_0 | X]$$

This is called the *treatment effect*. By the assumption above, if we control completely for $X$, our measure is unbiased.
Propensity Score Method (2)

Problem: stratifying by X to construct control groups difficult when there are many X’s.

Define the propensity score \( b(X) = \Pr(M=1|X) \)

*Theorem (R&R 83):* subclassification by \( b(X) \) will *balance* \( X \), in the sense that the distribution of \( X \) will be the same for the treatment and control groups:

\[
\Pr(X,M|b(X)) = \Pr(X|b(X)) \Pr(M|b(X))
\]

Use this result to construct a control group conditioned on \( X \), with far fewer cells. Estimate \( b(X) \) using a probability model, group data by \( b(X) \) and compare outcomes within groups.
R&R (1983) prove the following large sample result:
\[ E[Z_1|b(X), M=1] - E[Z_0|b(X), M=0] \]
\[ = E[Z_1|b(X)] - E[Z_0|b(X)] \]
if \( b(X) \) is a balancing score and if the outcomes \( Z_0, Z_1 \) are strongly ignorable given \( X \).

Use this result to construct different types of measures:
- average treatment effect based on \( E_{b(X)}[Z_1 - Z_0|b(X)] \)
- matched samples, matched by closest \( b(X) \)
- changes in treatment effect as a function of \( b(X) \)
Application in this paper

• “Treatment” is that a firm buys another public firm.
• Outcome is the change in R&D intensity between the combined firms pre-merger and the merged firm post-merger.
• X’s are pre-merger characteristics of the buyer, size, Q, R&D intensity, industry, year, etc.
• Compute b(X) using a Logit model.
• Compare changes in R&D for treatment and controls with similar B(X):
  – medians
  – distribution free tests (Kruskal-Wallis or ranksum)
  – box plots
Variables for Predicting Exit

- Log E - log of employment in 1000s
- Log KL - log of P&E to employment (1987$1000)
- Log Q - log of Tobin’s Q (trimmed at .1,25)
- R/S - R&D to sales ratio (trimmed at 1.0)
- log CF/S - cash flow to sales ratio (trimmed at 0.5), entered separately for negative and positive values.
- D (Q missing or very small); D(Q>25)
- D (R&D missing or zero); D(R/S>1)
- D (CF missing or zero)
Table 5: Acquisition Probability
57,217 Obs. on 5,724 Firms

<table>
<thead>
<tr>
<th>Number Acquisitions/Acquired</th>
<th>Buyers 884</th>
<th>Sellers 928</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log employment</td>
<td>0.532 (0.021)</td>
<td>-0.022 (0.018)</td>
</tr>
<tr>
<td>R&amp;D-sales ratio</td>
<td>-5.04 (1.69)</td>
<td>-0.34 (0.90)</td>
</tr>
<tr>
<td>D (no R&amp;D)</td>
<td>0.02 (0.10)</td>
<td>-0.16 (0.09)</td>
</tr>
<tr>
<td>D (R/S&gt;0.5)</td>
<td>1.64 (0.93)</td>
<td>-1.20 (0.69)</td>
</tr>
<tr>
<td>Log of capital-labor ratio</td>
<td>0.093 (0.060)</td>
<td>0.068 (0.045)</td>
</tr>
<tr>
<td>Log Tobin's Q</td>
<td>0.453 (0.073)</td>
<td>-0.093 (0.055)</td>
</tr>
<tr>
<td>D (Q missing)</td>
<td>-2.16 (0.32)</td>
<td>-0.63 (0.13)</td>
</tr>
<tr>
<td>D (Q&gt;10)</td>
<td>-0.08 (0.42)</td>
<td>-1.75 (1.01)</td>
</tr>
<tr>
<td>Log (cash flow/sales) pos.</td>
<td>0.092 (0.070)</td>
<td>-0.102 (0.042)</td>
</tr>
<tr>
<td>Log (cash flow/sales) neg.</td>
<td>0.121 (0.075)</td>
<td>-0.078 (0.044)</td>
</tr>
<tr>
<td>D (cash flow zero)</td>
<td>-1.05 (1.02)</td>
<td>NA</td>
</tr>
<tr>
<td>Other controls</td>
<td>time, industry dummies</td>
<td>time, industry dummies</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-3,718.5</td>
<td>-4,491.3</td>
</tr>
<tr>
<td>Pseudo-R-squared</td>
<td>0.185</td>
<td>0.053</td>
</tr>
<tr>
<td>Chi-squared (p-value) for X's</td>
<td>1690.0</td>
<td>500.1</td>
</tr>
</tbody>
</table>
Box Plot for Probability (Firm Makes an Acquisition)
Box Plot for Probability (Firm Is Acquired)
Change in R&D Intensity Around the Time of Merger

3-Year Differences in R&D Intensity
Growth In R&D Around the Time of Merger

3-Year Growth in Real R&D

Not acquiring

Acquiring

Growth in Real R&D

-2 -1 0 1 2
TFP Growth Around the Time of Merger

TFP Growth around Merger

TFP Growth

Not acquiring

Acquiring

TFP Growth around Merger
## Growth in R&D at the Time of Merger by Propensity Score Groups

Table 6  
**R&D and TFP at Merger Controlling for Propensity to Merge**

<table>
<thead>
<tr>
<th>Est. Propensity to Merge (number)</th>
<th>Change in R/S (%)</th>
<th>Annual Growth in Real R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 2% (79)</td>
<td>0.016%</td>
<td>0.014%</td>
</tr>
<tr>
<td>2 to 4% (75)</td>
<td>0.014%</td>
<td>-0.087%</td>
</tr>
<tr>
<td>4 to 6.5% (82)</td>
<td>0.015%</td>
<td>0.040%</td>
</tr>
<tr>
<td>6.5 to 8.5% (82)</td>
<td>0.016%</td>
<td>0.094%</td>
</tr>
<tr>
<td>8.5 to 11% (79)</td>
<td>0.014%</td>
<td>0.096%</td>
</tr>
<tr>
<td>&gt;11% (82)</td>
<td>0.039%</td>
<td>0.052%</td>
</tr>
<tr>
<td>All (479)</td>
<td>0.016%</td>
<td>0.043%</td>
</tr>
</tbody>
</table>
### TFP Growth at the Time of Merger by Propensity Score Groups

<table>
<thead>
<tr>
<th>Est. Propensity to Merge (number)</th>
<th>Semi-parametric</th>
<th>Regression Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Acq.</td>
<td>Acq.</td>
</tr>
<tr>
<td>0 to 2% (159)</td>
<td>-0.54%</td>
<td>-0.63%</td>
</tr>
<tr>
<td>2 to 4% (150)</td>
<td>-0.58%</td>
<td>-0.12%</td>
</tr>
<tr>
<td>4 to 6.5% (139)</td>
<td>-0.50%</td>
<td>-0.10%</td>
</tr>
<tr>
<td>6.5 to 8.5% (115)</td>
<td>-0.41%</td>
<td>0.55%</td>
</tr>
<tr>
<td>8.5 to 11% (106)</td>
<td>-0.52%</td>
<td>0.20%</td>
</tr>
<tr>
<td>&gt;11% (116)</td>
<td>-0.60%</td>
<td>0.61%</td>
</tr>
<tr>
<td>All (785)</td>
<td>-0.53%</td>
<td>0.20%</td>
</tr>
</tbody>
</table>
Conclusion

- Overall, still not much evidence that merging firms increase or decrease R&D, but….
- Firms with a low propensity to acquire others tend to reduce R&D after merger, and their TFP does not increase.
- Firms with a high propensity to acquire others increase their R&D after merger, and experience higher TFP growth.
- Effects are small but significant, probably related to the fact that mergers are heterogeneous.
Some questions for further work

- Other methods:
  - match on $b(X)$ - same sample size
  - use parametric sample selection model
- Controlling for probability of being acquired:
  - combine both propensities?
  - construct $Pr(i$ matches with $j)$?