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

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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

$$E[Z_1] - E[Z_0] \text{ or perhaps } E[Z_1|X] - E[Z_0|X]$$

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.

Propensity Score Method (3)

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

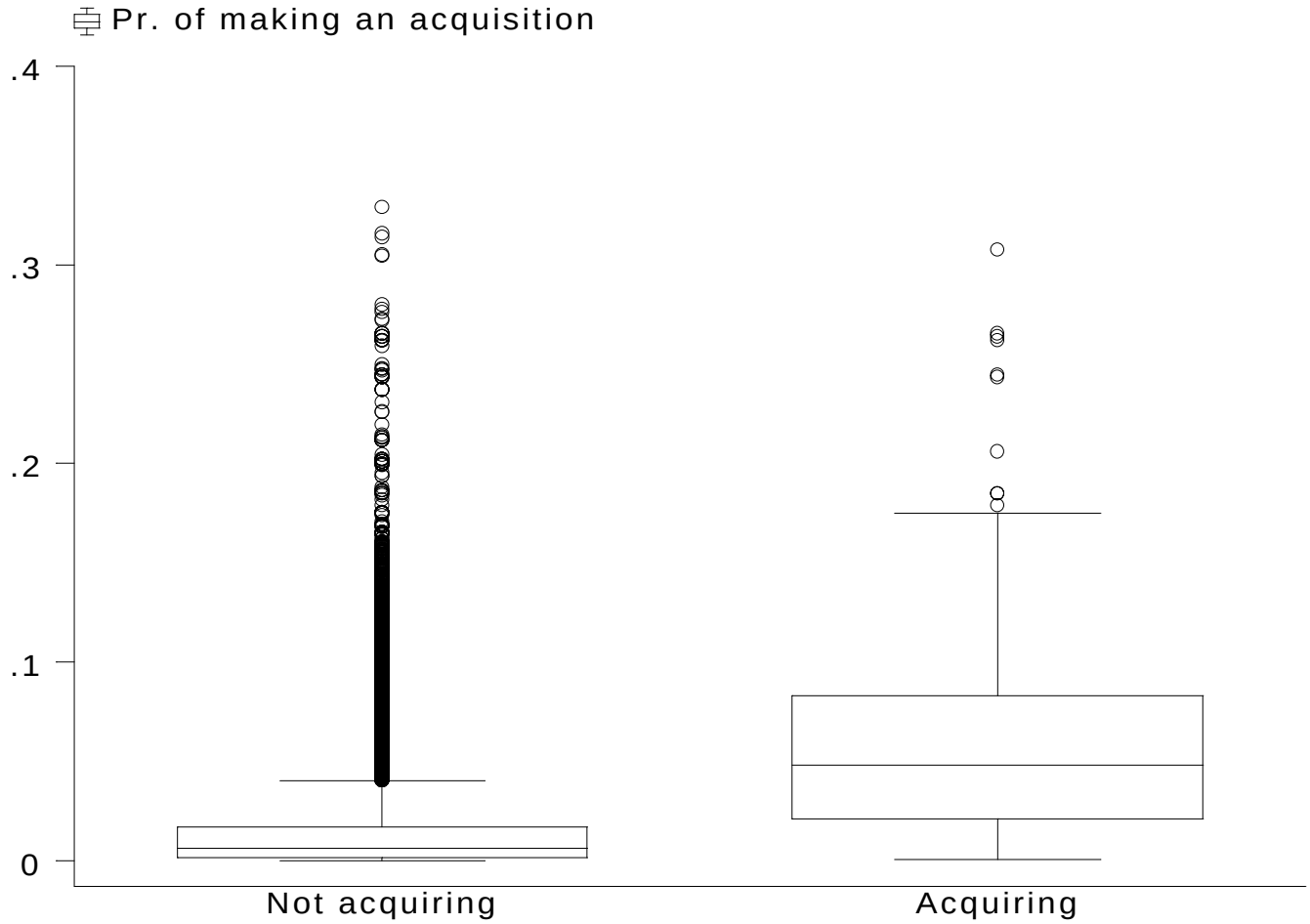
Variables for Predicting Exit

- 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)

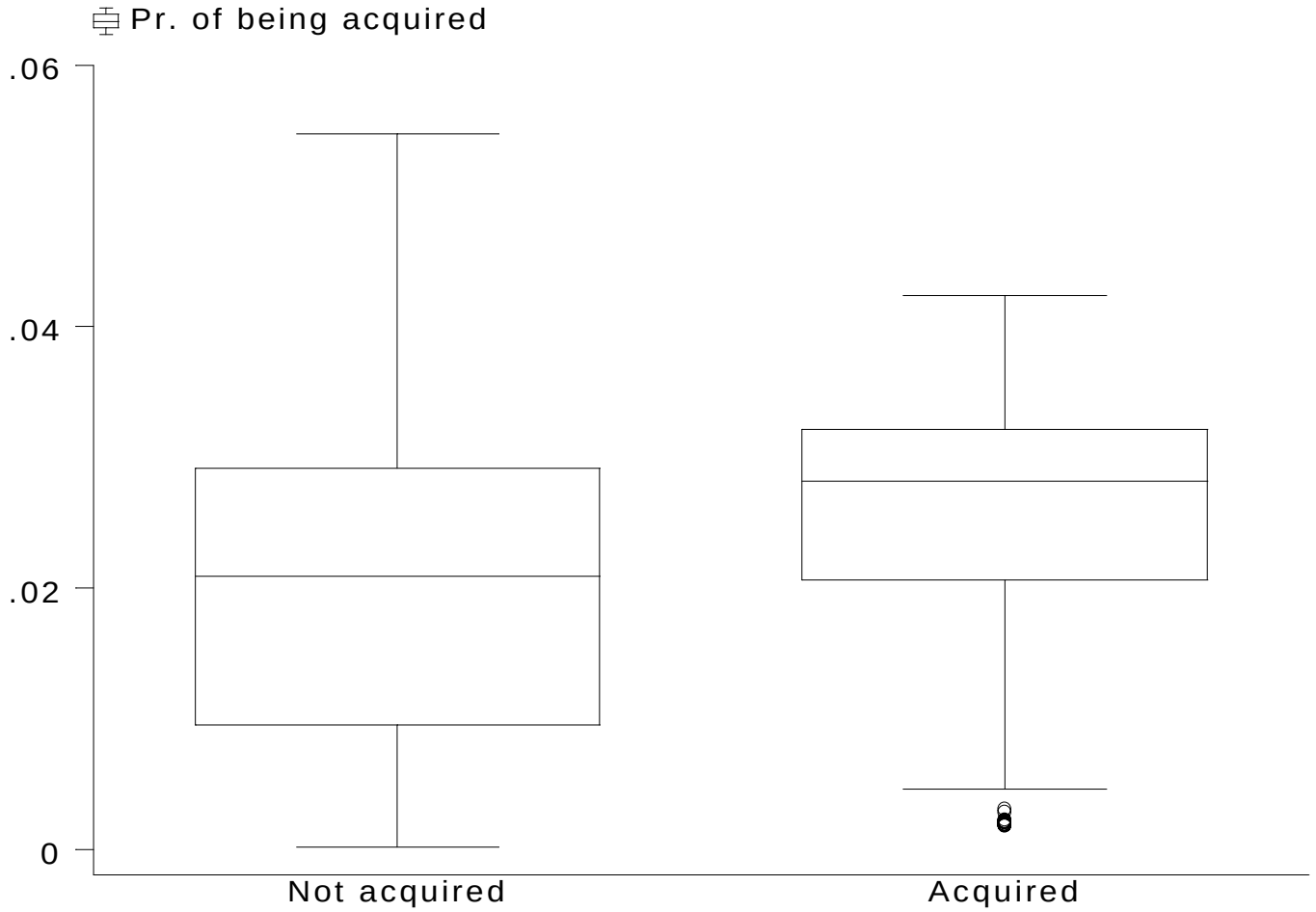
Table 5: Acquisition Probability
57,217 Obs. on 5,724 Firms

Number Acquisitions/Acquired	Buyers 884		Sellers 928	
Log employment	0.532	(0.021)	-0.022	(0.018)
R&D-sales ratio	-5.04	(1.69)	-0.34	(0.90)
D (no R&D)	0.02	(0.10)	-0.16	(0.09)
D (R/S>0.5)	1.64	(0.93)	-1.20	(0.69)
Log of capital-labor ratio	0.093	(0.060)	0.068	(0.045)
Log Tobin's Q	0.453	(0.073)	-0.093	(0.055)
D (Q missing)	-2.16	(0.32)	-0.63	(0.13)
D (Q>10)	-0.08	(0.42)	-1.75	(1.01)
Log (cash flow/sales) pos.	0.092	(0.070)	-0.102	(0.042)
Log (cash flow/sales) neg.	0.121	(0.075)	-0.078	(0.044)
D (cash flow zero)	-1.05	(1.02)	NA	
Other controls	time, industry dummies		time, industry dummies	
Log likelihood	-3,718.5		-4,491.3	
Pseudo-R-squared	0.185		0.053	
Chi-squared (p-value) for X's	1690.0	0.0000	500.1	0.0000

Box Plot for Probability (Firm Makes an Acquisition)

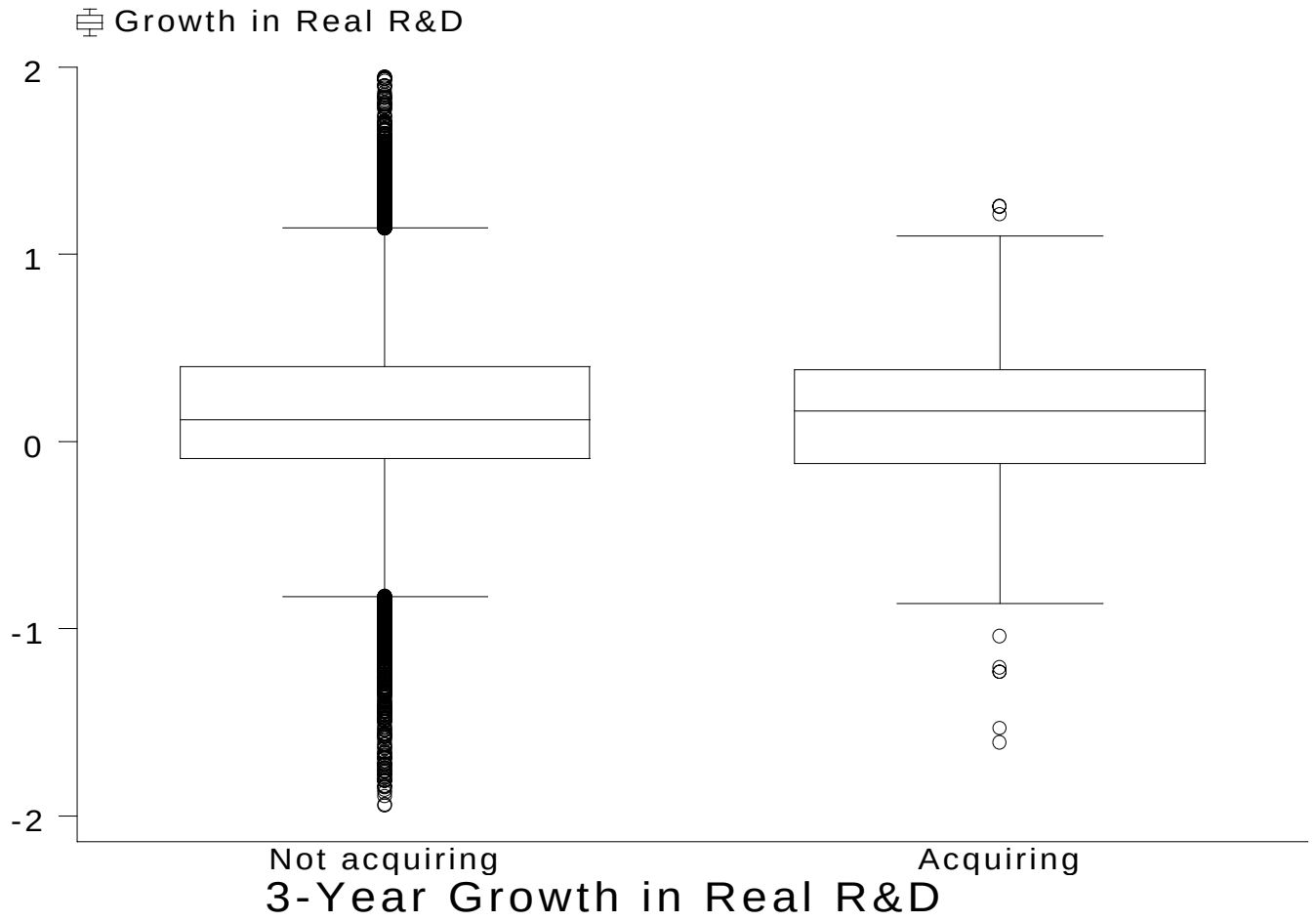


Box Plot for Probability (Firm Is Acquired)

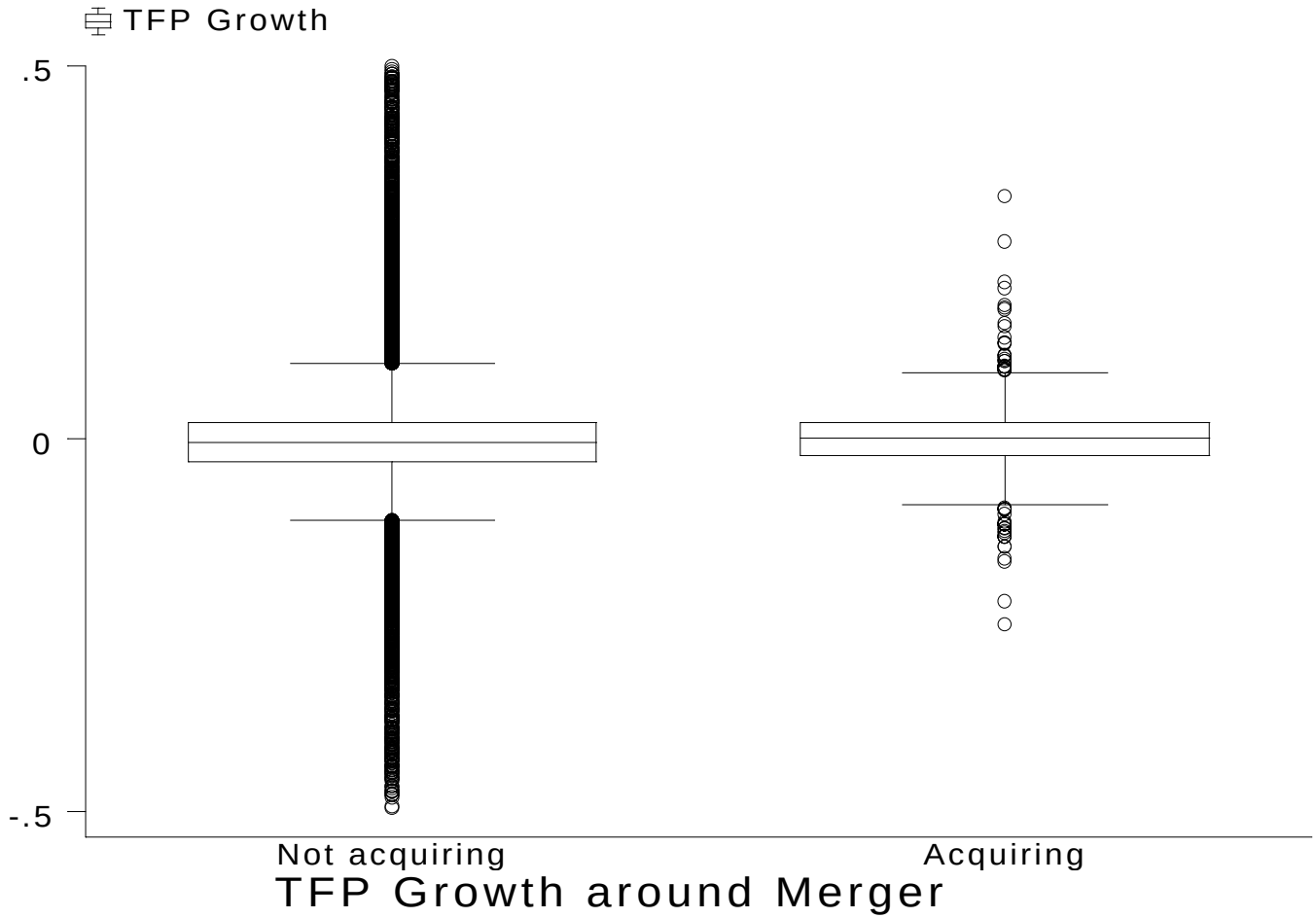


Change in R&D Intensity Around the Time of Merger

Growth In R&D Around the Time of Merger



TFP Growth Around the Time of 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

Est. Propensity	Change in R/S (%)			Annual Growth in Real R&D		
to Merge (number)	No Acq.	Acq.	K-W Test	No Acq.	Acq.	K-W Test
0 to 2% (79)	0.016%	0.014%	0.34 (.560)	-0.16%	-0.09%	0.27 (.603)
2 to 4% (75)	0.014%	-0.087%	13.64 (.000)	-0.23%	-1.20%	5.03 (.025)
4 to 6.5% (82)	0.015%	0.040%	0.74 (.390)	-0.49%	-0.46%	0.13 (.714)
6.5 to 8.5% (82)	0.016%	0.094%	13.59 (.000)	-0.58%	0.37%	8.31 (.004)
8.5 to 11% (79)	0.014%	0.096%	11.93 (.001)	-0.64%	0.72%	20.60 (.000)
>11% (82)	0.039%	0.052%	0.36 (.550)	-0.63%	0.09%	10.51 (.001)
All (479)	0.016%	0.043%	2.43 (.119)	-0.30%	0.00%	0.09 (.770)

TFP Growth at the Time of Merger by Propensity Score Groups

Est. Propensity	Semi-parametric			Regression Coefficients		
to Merge (number)	No Acq.	Acq.	K-W Test	Dummy (%)	K/L	Scale
0 to 2% (159)	-0.54%	-0.63%	0.30 (.584)	0.12%	0.179	-0.125
2 to 4% (150)	-0.58%	-0.12%	0.19 (.666)	0.46%	0.284	-0.106
4 to 6.5% (139)	-0.50%	-0.10%	1.60 (.206)	0.12%	0.412	-0.124
6.5 to 8.5% (115)	-0.41%	0.55%	11.03 (.001)	0.86%**	0.336	-0.092
8.5 to 11% (106)	-0.52%	0.20%	9.46 (.002)	0.81%**	0.301	-0.132
>11% (116)	-0.60%	0.61%	22.94 (.000)	1.14%**	0.357	-0.184
All (785)	-0.53%	0.20%	13.51 (.000)	0.18%	0.188	-0.124

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)?