

Mergers and Sequential Innovation: Evidence from Patent Citations *

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Abstract

This paper uses patent citation data to determine whether mergers are associated with an increase or a decrease in the rate of sequential innovation. The fact that the FTC and DOJ frequently cite innovation as a reason for concern about a merger implies that this question is relevant for policy. The ability to capture information spillovers may enhance the merged firms' incentives to build upon one another's innovations; yet the fact that the firms are no longer in competition may reduce their incentive to leap-frog one another. I find that, among mergers in the United States between 1980 and 2003, there tends to be an increase in the rate of sequential innovation in the years preceding a merger, and a reduction in the rate of sequential innovation in the years following a merger. This pattern holds across industries. This suggests that firms seek out mergers that will dampen competition in sequential innovation. JEL codes: L1, L4, O3.

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1 Introduction

This paper uses patent citation data to determine whether recent mergers in the United States have encouraged sequential innovation by enabling the firms involved to internalize information spillovers, or discouraged sequential innovation by dampening competition. Innovation is an important driver of economic growth, but there is considerable disagreement over what circumstances give firms the greatest incentive to innovate. Schumpeter (1934, 1942) suggested that large firms operating in a less competitive environment might provide a better platform for innovation than small, competitive firms, due to economies of scale and a better ability to absorb the risk associated with large R&D expenditures. Since then the competition-innovation debate has been lively.

Mergers within an industry lead to larger, less competitive firms. Thus in order to better understand the connection between competition and innovation, it is useful to study the effect of mergers on innovation. Gilbert (2006) notes that out of 109 mergers that were challenged by the Department of Justice and Federal Trade Commission between 2001 and 2003, innovation was mentioned in a full 41 cases as a reason for the challenge. This is particularly striking given that many of the mergers for which innovation was not mentioned as a concern were in industries with little or no research and development. With the DOJ and FTC clearly concerned about the effect of mergers on innovation, the issue is worth exploring.

There are numerous ways in which firm size or market structure may affect innovation. This paper attempts to isolate the relationship between mergers and sequential innovation. Sequential innovation refers to the process whereby innovation A is built upon by innovation B , which is in turn

built upon by innovation C , and so on. I use patent citation data to trace the path of sequential innovation within and across firms. By focusing on the effect of mergers on the rate of sequential innovation, I am focusing on two mechanisms with opposing effects: a spillover effect and a competition effect, described below.

When a firm chooses to make an R&D investment, the firm is motivated by the direct benefits that the potential innovation might reap for the firm. Yet the innovation might also provide information that inspires or enables future sequential innovations. The original innovating firm might not plan on capitalizing on this information; thus it might not include this information in its expected return. This spillover is a positive externality which could lead the market to provide a sub-optimal level of innovation. A merger might improve innovation incentives if it allows the firms involved to capture the information spillovers associated with innovation. Yet the merger might reduce innovation incentives; the firms are no longer in competition, so they no longer have an incentive to steal the profits the other firm is gaining from innovation.

This paper uses patent citation data to look at the extent to which firms build upon one another's innovations before and after a merger. If firms do so more after a merger, this suggests that the ability to capture information spillovers has dominated the incentive to rest on the laurels of the other firm's achievements. The opposite implication holds if the firms do so less after the merger. My results suggest that, among all mergers of publicly traded companies in the United States from 1980 to 2003, firms build upon one another's innovations less after they merge. This implies that the dampening of competition between the firms overwhelms the increased ease with which the firms can use one another's R&D knowledge.

The decision to merge is potentially endogenous; it may be partly driven by innovation incentives. The opposing spillover and competition effects still hold. I find that internal citations tended to increase in the years leading up to the merger, then fall in the years following the merger; this suggests that a sequential innovation race might have encouraged firms to merge in order to reduce competition. This implies that the competition effect overwhelms the spillover effect. Note that I cannot plausibly argue that I am finding a causal effect of mergers on sequential innovation. That is, I cannot extrapolate from my results and argue that if two hypothetical firms were to be forced to merge, this would lead to a reduction in their cross-citations. Instead, the goal of the paper is to make statements about the mergers that have occurred.

The question remains: is it a good or a bad thing that the innovation race was slowed? The answer depends on the nature of the innovation race. If the pre-merger innovation race led to a lot of duplicative innovations and therefore patents, it was probably good for it to be slowed by merger. I look at how the average similarity of patents changes after a merger to determine whether the merger enabled firms to stop wasting resources on duplicative innovation. This part of the paper is still in progress.

2 Related Literature

Quite a few papers have looked at the relationship between innovation and, alternatively, competition, market structure or firm size. Gilbert (2006) gives an excellent review of this literature. Most of these studies have used some measure of R&D expenditures as the outcome variable, though a few have looked at patent counts. Culbertson and Mueller (1985) and Lunn (1986) find

weak evidence of a positive correlation between innovation and both firm size and market concentration. A major advantage of patent data is that we can use citation data to trace the evolution of innovative activity. My focus on sequential innovation and the internalization of information spillovers makes use of this advantage.

Belenzon (2006) develops a model that shows that the more firms are able to internalize the information spillovers associated with innovation, the greater will be their incentive to innovate. He treats the internalization of spillovers as exogenous, and looks at how this affects the R&D and market value of the firm. In this paper I consider the possibility that mergers affect the internalization of spillovers and therefore affect innovation patterns. But while mergers may enable firms to internalize spillovers associated with innovation, they may also dampen competition in the innovation market. This paper estimates the net effect of mergers on sequential innovation in recent history.

3 Model

I use a very simple two-period model to show that when a firm acquires the rights to the latest technology in a particular area of innovation (e.g., through merger), this has an ambiguous effect on the firm's incentive to improve upon this particular technology. In period 1, the firm makes a decision about whether or not to make an investment that would enable it to acquire the latest technology with positive probability p in period 2. If the firm already owns the latest technology in period 1, the investment required to improve upon this technology and acquire the newest technology in period 2 is r ; otherwise the investment required is s . I incorporate information spillovers

by assuming that $r < s$.

If the firm has invented the latest technology in period 2 while no other firm has done so, the firm earns a return of v . For simplicity, suppose there is some probability q that someone else will invent the latest technology, and that in this case the firm earns a smaller return u if it also has the latest technology.

Does owning the latest technology in period 1 make a firm more or less likely to invest in R&D to replace this technology? On the one hand, the firm does not have to invest as much to improve it due to information spillovers ($r < s$). On the other hand, there is some probability $(1 - q)$ that the firm will earn v next period without making any investment.

A firm without the latest technology faces the following investment decision:

$$EU_{notinvest} = 0$$

$$EU_{invest} = (1 - q)(p)(v) + (q)(p)(u) + (1 - p)(0) - s$$

So the firm will invest if $(1 - q)pv + qpu > s$.

A firm with the latest technology faces a different investment decision:

$$EU_{notinvest} = (1 - q)(v) + (q)(0)$$

$$EU_{invest} = (1 - q)(v) + (q)(p)(u) + (q)(1 - p)(0) - r$$

So the firm will invest if $qpu > r$.

Thus, acquiring the latest innovation in a particular area of technology in period 1 (e.g., through merger) will give a firm a greater incentive to invest in that area only if $s - r > (1 - q)pv$; that is, if the advantage gained from capturing information spillovers outweighs the incentive to sit back and earn the (expected) profits from the initial innovation. Whether this occurs is an empirical question, which I attempt to answer using patent citation data.

4 Data

Merger data are from the Securities Data Company (SDC). They include every merger between publicly held companies in the United States from 1980 to the present. The patent data are from the NBER patent database (Hall et al, 2001). The link between the two datasets is the CUSIP number assigned to publicly issued securities by Standard & Poor's Compustat. SDC lists a CUSIP number for each firm in the merger dataset. Patent assignees have been matched to a CUSIP number through a name standardization program.¹ Citation and assignee data are available for patents that were granted from 1976 to the present. In estimation, I use the patent's application date rather than the grant date; this is presumably closer to the date when the actual innovation took place. It typically takes one to three years for a patent to be granted once the application reaches the patent office. Thus the application dates span from 1974 to 2005. Merger data are cut off after 2003 to allow us to observe two years of patent activity after the merger takes place. I am able to identify 864 mergers in which both firms involved have at least one patent.² These mergers involve 562 firms; some firms are involved in multiple mergers.

When patent A cites patent B , I take this as evidence that patent A in some way built upon patent B 's innovation. I want to find out whether,

¹This is a very involved process. For example, IBM patents might be assigned to "IBM," "I.B.M.," "Intl Business Machines," "International Business Machines," etc. A match of patent assignees was originally done to the 1999 universe of companies. The NBER Patent Dataset Project has nearly completed a match to the current universe of companies (due mainly to work by Bronwyn Hall, Iain Cockburn, Megan MacGarvie and Jim Bessen). It is the latter match that I use.

²As far as I know, this is the first paper to undertake a comprehensive match of all recent mergers in the United States to the patent database.

when two firms merge, they begin to build upon one another's innovations more than previously. Looking at a particular merger between firm i and firm j , the question then becomes: do firm i 's (j 's) patents cite firm j 's (i 's) patents more frequently after the merger than they did before the merger? However, the target in the merger often (but not always) ceases to exist after the merger, so that we are often left with only firm i or j in the patent database. In order to deal with this, I identify all citations made by either firm involved in a merger as either "internal" or not. An internal citation is a citation made to either firm i or j . That is, the following are internal cites: i cites i , j cites j , i cites j and j cites i . The following are non-internal: i cites someone other than i or j , j cites someone other than i or j . The question then becomes: Do internal cites made by firms i and j increase after the merger, controlling for non-internal cites made by firms i and j ? Note that I cannot distinguish between the effect on the acquirer and the effect on the target.

5 Estimation

An observation is at the level of a merging pair of firms in a year. For each merger-year observation, it is either pre-merger or post-merger. The question is whether the number of internal citations is greater or less on average in post-merger years than in pre-merger years.

The construction of the dataset is made more complicated by the fact that some firms are involved in multiple mergers. Suppose that firm i acquires firm j in 1980 (call this merger 1), and then this merged firm acquires firm k in 1990 (call this merger 2). If we ignored the fact that these two mergers were related, then for merger 1, we would test whether the following sum

increases after 1980:

$$(i \rightarrow j) + (j \rightarrow i) + (i \rightarrow i) + (j \rightarrow j)$$

where $i \rightarrow j$ refers to i citing j , and so on. And for merger 2, we would test whether the following sum increases after 1990:

$$(i \rightarrow k) + (k \rightarrow i) + (i \rightarrow i) + (k \rightarrow k)$$

However, if we acknowledge that these are sequential mergers, then two corrections must be made. One, a jump in self-citations by firm i after 1990 is probably a result of merger 2, yet this might be incorrectly attributed to merger 1 as well. To deal with this, I cut off observations for each merger at the point when the merged firm is involved in another merger. In this example, observations for merger 1 would span from 1976 through 1989 rather than through 2004. Secondly, internal citations for merger 2 do not include only the above sum, but also $i \rightarrow j$, $j \rightarrow i$, $k \rightarrow j$, $j \rightarrow k$, and $j \rightarrow j$. Thus when we have a sequence of mergers involving the same firm(s), we have to broaden our definition of an internal citation for all but the first merger. In this example, the test for merger 2 would be whether the following sum increases after 1990:

$$(i \rightarrow k) + (k \rightarrow i) + (i \rightarrow j) + (j \rightarrow i) + (j \rightarrow k) + (k \rightarrow j) + (i \rightarrow i) + (j \rightarrow j) + (k \rightarrow k)$$

For firms involved in more than two mergers, the sum becomes even longer, but the logic is straightforward.

As mentioned, the data is annual. The dependent variable in estimation is the annual number of internal citations as discussed above. Control variables are the number of patents applied for by the merging pair of firms, the number of citations (internal and non-internal) made by those patents, the number of

citations received by the merging pair of firms, as well as firm (or pair-of-firm) and year dummies. Therefore results are not driven by an overall increase in citations made by the firms, an overall increase in citations received by the firms, a time trend or any persistent unobserved heterogeneity across firms.

I begin by presenting Ordinary Least Squares results. However, the dependent variable is a count variable. Thus linear regression is not ideal because it can lead to negative predicted values. Complications arise, however, because inclusion of a large number of dummy variables (fixed effects) in a non-linear count model leads to biased coefficients. Hausman et al (1984) develops a fixed-effects Poisson model which attempts to get around this problem. Intuitively, the model predicts not the number of internal citations for each merger in each year, but instead the annual number of internal citations for each merger *as a fraction of the sum of that merger's internal citations over all time periods*. See Hausman et al (1984) for further explanation. I present results from both OLS and the fixed-effects Poisson.

6 Results

The dataset consists of the patent citations activity of 864 merging pairs of firms over a period of 32 years, from 1974 to 2005. Descriptive statistics are presented in Table 1. On average, these pairs of firms apply for 51 patents per year which make an average of 466 citations, receive an average of 403 citations per year and make an average of 0.24 internal citations per year. However, the data are highly skewed; the medians are much less than the means for these variables.

OLS results with year and firm fixed effects are shown in Table 2. The coefficient on the post-merger dummy is positive and statistically significant,

but the magnitude is small. On average, firms cite one another 0.11 more times per year after merging. However, results vary by industry; refer to Table 3.

Furthermore, estimation of the fixed-effects Poisson model leads to a different result altogether. Results are shown in Table 4. The coefficient on the post-merger dummy is negative and statistically significant, and of a greater magnitude than for OLS. On average, firms cite one another 40% less annually after merging. Fixed effects are for merging pairs of firms rather than for firms (which is more stringent). Since the fixed-effects Poisson model is predicting each merger's allocation of internal citations across the years, the merging pair of firms must have at least one internal citation in the sample period in order to be included in estimation. Only 238 of the 864 mergers made at least one internal citation in the sample period.

The sample period includes many years preceding and following most mergers. Therefore, it is not very informative to simply know the average number of internal citations in the years before the merger relative to the average number of internal citations in years after the merger. It would be interesting to see how the internal citations are allocated across years. Figure 1 reveals this. On the x-axis is the number of years since the merger took place. At zero, it is the year of the merger; at -5, it is five years before the merger; at +5, it is five years after the merger.

It appears that internal citations tend to increase in the years leading up to the merger, and begin to fall in the years following the merger. Looking at the plot, it is easy to imagine that the number of internal citations averaged across all years after the merger might be either greater or less than the number of internal citations averaged across all years before the merger, depending on the method of estimation. The year-to-year pattern is more

revealing. The increase in internal citations in the years leading up to the merger suggests an innovation race; the fall in internal citations in the years following the merger suggests a reduction in competition.

Interestingly, the picture is fairly similar across industries. Figure 2 is for the chemical industry, Figure 3 is the electronic equipment industry (not including computer equipment), Figure 4 is for the industrial/computer equipment industry and Figure 5 is for the (mostly medical) instruments industry.

7 Conclusion

Preliminary results suggest that recent mergers in the United States have not led to an increase in sequential innovation. While a merger may enable the firms involved to capture information spillovers associated with innovation, it also leads to a reduction in competition. In fact, a run-up in sequential innovation prior to the merger and a fall after the merger suggests that mergers may have been partly motivated by the desire of firms to squelch an “innovation race.” Future work will look at whether these innovation races tend to produce a lot of duplicative patents, in which case it may be a good thing that firms seek out mergers that slow the pace of these races.

8 References

Belenzon, Sharon. 2006. “Knowledge Flow and Sequential Innovation: Implications for Technology Diffusion, R&D and Market Value.” Economics Series Working Paper 259. Oxford, UK: University of Oxford, Department of Economics.

Culbertson, J. D. and W.F. Mueller. 1985. “The Influence of Market Structure in Technological Performance in the Food-Manufacturing Industries.” *Review of Industrial Organization* 2: 40-54.

Gilbert, Robert. 2006. “Where Are We in the Competition-Innovation Debate?” In Adam B. Jaffe, Josh Lerner and Scott Stern (Eds.), *Innovation Policy and the Economy*, vol. 6. Cambridge, MA: National Bureau of Economic Research.

Hall, B. H., A. B. Jaffe and M. Trajtenberg. 2001. “The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools.” NBER Working Paper 8498. Cambridge, MA: National Bureau of Economic Research.

Hausman, J. A., B. H. Hall and Z. Griliches (1984). “Econometric Models for Count Data with an Application to the Patents-R&D Relationship.” *Econometrica* 52: 909-938.

Lunn, J. 1986. “An Empirical Analysis of Process and Product Patenting: A Simultaneous Equation Framework.” *Journal of Industrial Economics* 34: 319-330.

Schumpeter, Joseph A. 1934. *The Theory of Economic Development*. Cambridge, MA: Harvard University Press.

Schumpeter, Joseph A. 1942. *Capitalism, Socialism, and Democracy*. New York: Harper and Brothers.

Table 1: Descriptive Statistics

Variable (Annual)	Mean	Median	SD
Internal Citations	0.24	0	2
Patents	51	3	190
Citations Made	466	23	1943
Citations Received	403	10	1770

Table 2: OLS Results

Post-Merger Dummy	0.11* (0.03)
Patents	0.001* (0.0002)
Citations Made	-0.00004 (0.00002)
Citations Received	-0.0001* (0.00001)
N	24,948
Number of Mergers	864
Number of Firms	562
Number of Years	32
Adjusted R ²	0.42
* Statistically Significant at 1%	

Table 3: OLS Results by Industry

Industry	Coefficient on Post-Merger Dummy
Chemicals (137 Mergers)	0.41* (0.27)
Electrical Equipment (141 Mergers)	0.04 (0.07)
Industrial & Computer Equipment (128 Mergers)	-0.13* (0.09)
Instruments, esp. Medical (125 Mergers)	0.13 (0.06)*
Transportation Equipment (61 Mergers)	-0.22* (0.09)
Paper Industry (21 Mergers)	-0.11 (0.12)

Table 4: Fixed-Effects Poisson Results

Post-Merger Dummy	-0.40* (0.03)
Patents	0.006* (0.0004)
Citations Made	-0.0004* (0.00005)
Citations Received	-0.0003* (0.00004)
N	6,943
Number of Mergers	238
Number of Years	32
Wald Chi ²	1849
* Statistically Significant at 1%	

Figure 1: Predicted Internal Citations as a Function of Years Since Merger

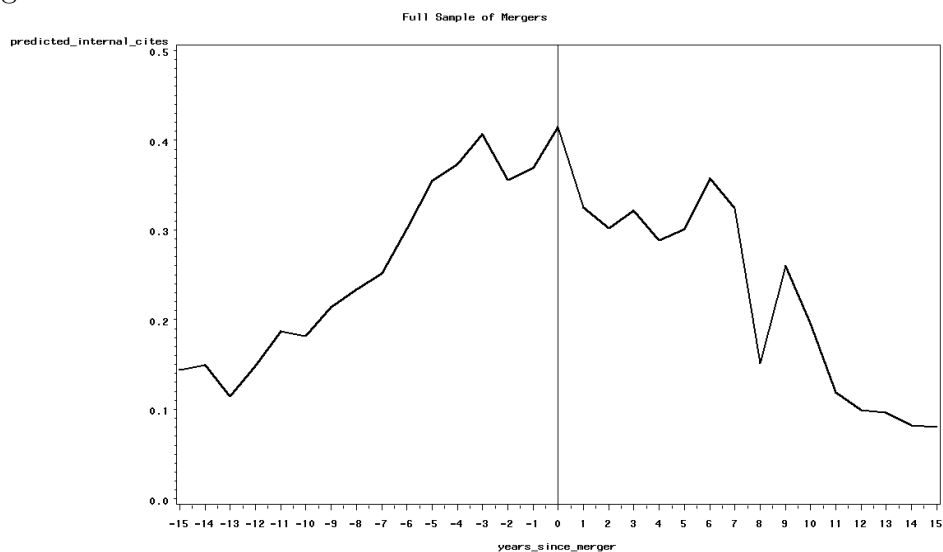


Figure 2: Predicted Internal Citations as a Function of Years Since Merger

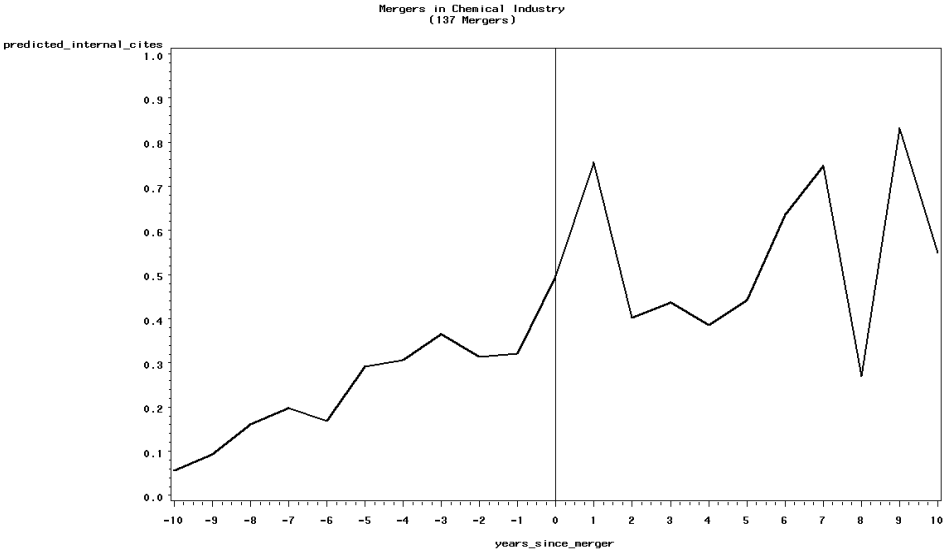


Figure 3: Predicted Internal Citations as a Function of Years Since Merger

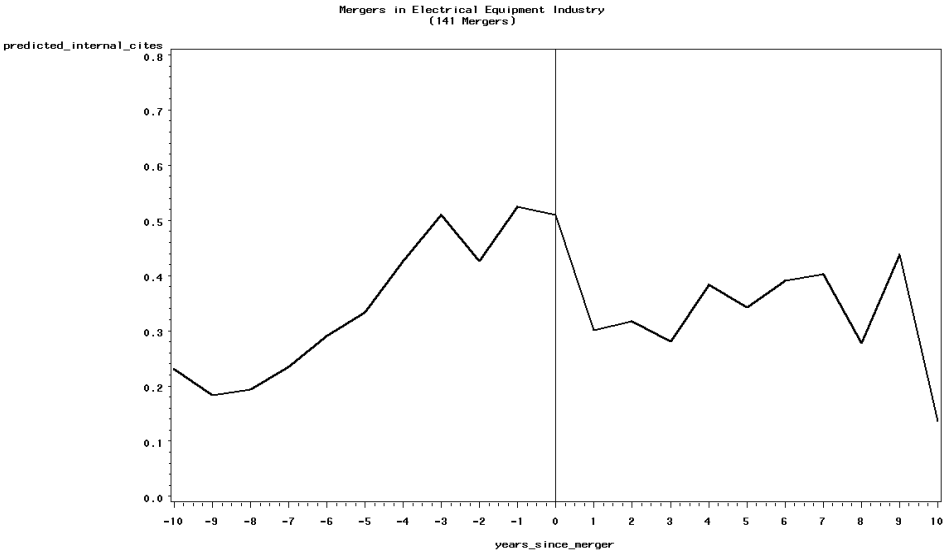


Figure 4: Predicted Internal Citations as a Function of Years Since Merger

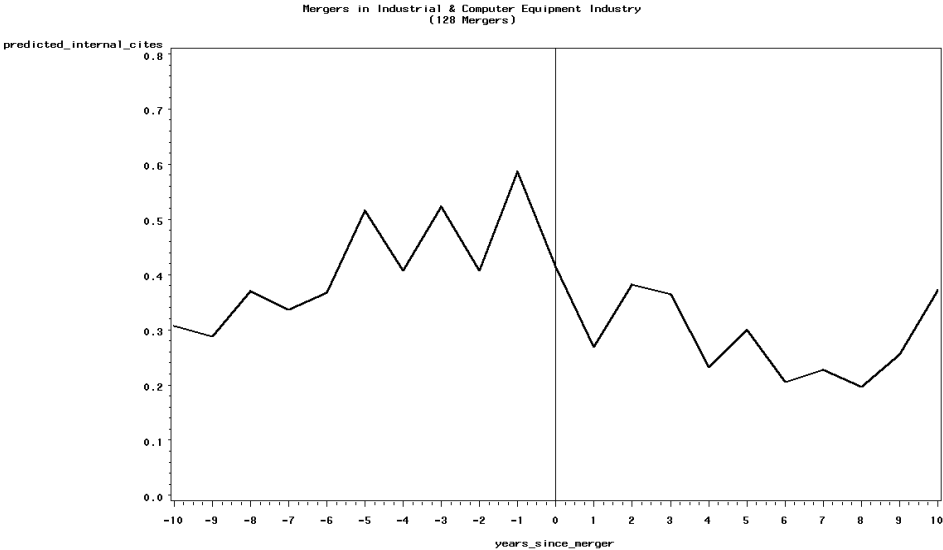


Figure 5: Predicted Internal Citations as a Function of Years Since Merger

