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On a Dynamic Empirical Analysis of Horizontal Mergers and R & D

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ABSTRACT

The relationship between R&D investment and horizontal mergers has been a central concern of scholars and policy-makers for many years. Horizontal mergers lead to increased market concentration, a structure that may lead to reduced R&D expenditures. However, firms may merge to leverage knowledge complementarities, a condition that could lead to higher R&D investments. This paper examines how R&D expenditures are impacted by horizontal mergers using a dynamic empirical analysis. Our findings show that R&D investment may not be significantly impacted by horizontal mergers because there are differential impacts between industries with a positive effect occurring in the computer-related sector and a negative effect observed among life sciences firms.

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1.0 Introduction

Arguments have varied whether mergers have a positive or negative effect on the trend in research and development spending. Some, like Bronwyn Hall (1988), contend that mergers substitute for internal development and therefore reduce future R&D activity. Others[1] suggest that mergers cause firms to limit R&D endeavors, particularly the more risky projects, and also reduce incentives to innovate among research champions.

It seems counterintuitive, however, that firms would reduce post-merger R&D investment over time, particularly since studies have indicated that R&D investments are positively related to long term performance.[2] Perhaps it is difficult to generalize the merger effect on R&D activity across industries. For example, in life sciences, a merger can serve as a defensive move to protect against patent expiration of blockbuster drugs. In this case, the trend in R&D expenditures may not change in any discernible way post merger. In addition, the merger effect may differ depending on the relatedness and size of the companies and R&D activities.

[1] See Hitt et. al. (1991).
[2] See Griliches (1981)

Also, it is possible that the structure of the market affects the merger of R&D-intensive companies. It may be that as R&D-intensive firms merge with their competitors, the merged firm increases its R&D activity to improve its lead over other competitors. Alternatively, firms may reduce their R&D programs to reduce duplication of efforts. The merger effect on R&D activity is a fundamental question for policy makers as they assess the predicted welfare effects of horizontal mergers in R&D-intensive industries.

1.01 Objectives of the study

The primary objective of this paper is to analyze the effect that a change in market concentration has on R&D expenditures. To accomplish this objective, we compare the change in R&D expenditures between three groups of companies: firms that engaged in a merger that was challenged by the government for concentration concerns; large companies that merged where the transaction was not challenged by the government; and large R&D-intensive companies that did not merge. The trend in post-merger R&D expenditure is analyzed between and within these three groups. A secondary objective is to compare the post R&D effect among broadly-defined industries: life sciences, computer-related, and other industrial.

The results show that mergers overall do not have a significant effect on the trend in R&D expenditures except in cases where the merger is challenged by the government for concentration concerns. The findings also show different post-merger effects between the two high R&D-intensity industries, namely life sciences and computer-related sectors.

This paper is organized as follows: section II reviews the literature regarding the effect of mergers on research activity. Section III covers the data set. Section IV covers the methodology for assessing changes in R&D intensity, while Section V details the results and analysis. Section VI provides conclusions and potential policy implications.

2.0 Literature Review

To explain the rationale behind undertaking a merger, analysts generally assess the potential gains that acquirers receive from the merger relative to the cost of the acquisition. Some of the most often cited benefits to a merger include economies of scale and scope, risk diversification, managerial improvements, increased market power, and attainment of intangible assets (Sonenshine, 2010). Economies of scale in R&D are significant due to the high fixed costs associated with development programs. Therefore, R&D intensity could decrease post merger due to the elimination of duplicated efforts; however, R&D efficiency may be higher (Cohen and Levin, 1989; Roller et al., 2001).

Another explanation for a decline in R&D expenditures post-merger is that acquisitions act as a substitute for R&D activity or internal development. Hall (1988) observes that there are two ways to invest in knowledge capital: either by investing within or by purchasing another company whose R&D program has yielded successful results. The advantage of acquiring another company is that the acquirer often gets a more certain outcome than from internal R&D projects, which may be more speculative. Hall (1988) also contends that acquisitions offer immediate entrance to a new market, while R&D investment is a longer term investment. If R&D investment and acquisition activity are indeed substitutes, then increased expenditures on mergers will lead to reduced post-merger R&D activity.

Hitt et al. (1991) add that acquisitions may have a negative impact on the managerial interest to champion activities that may lead to new products, technologies, or processes. There will be fewer internal rewards post-acquisition for innovative activities. M&A activity, they contend, is often followed by the implementation of a short-term oriented financial control system and by the departure of key inventors in the organization (Ernst and Vitt, 2000; Hitt et al., 1991). The result will be a decline in R&D expenditures and output, as measured by patent intensity.

It is also conceivable that the direction of R&D activity post-merger is affected by the degree of leverage used to consummate the acquisition. Jensen and Rubak (1983) argue that the increased expenditures stemming from a merger increase the opportunity cost of funds allocated to R&D, which causes some R&D projects to be eliminated. They also contend that companies become more risk averse in the selection of R&D projects post-merger, again because of the significant funds needed to consummate the merger.

The conclusion that R&D activity will decline post merger is "puzzling", Ahuja and Katila (2001) assert, since acquisitions continue to be a popular strategy for corporate growth in R&D-intensive industries. In recent years more dollars have been invested in acquisition activity than in any other equivalent activity. Ahuja and Katila (2001) add further that R&D activity will grow post merger as firms try to diversify their knowledge base. Their argument is that an acquisition combines firm-specific assets housed within one organization with assets in another organization to improve the productivity of the combined assets (Ahuja and Katila, 2001 and Capron, 1999). They find that with technological acquisitions, absolute differences in the size of the merging firms' knowledge base have a positive impact on innovation output, while relative size reduces innovation output. Absolute size is measured by the number of patents held by the acquired firm, while relative size is determined by the difference in the number of patents held between the acquirer and acquired companies. The authors also find a non-linear relationship regarding the relatedness of knowledge assets, whereby firms that combine with either very similar or different assets have inferior innovation performance relative to the merger of firms whose assets are moderately related. In contrast, Cloodt et al. (2006) use a similar methodology but come to a slightly different conclusion. They find that the acquisition of a large absolute knowledge base only contributes to improved innovative performance in the first few years post-merger. After a few years, the acquisition has a negative influence on the number of patents received (Cloodt et al., 2006).

The direction of R&D expenditures may also be impacted by industry concentration. Schumpeter (1950) posited that innovative activity will increase with firm size and market concentration. More recently, empirical work has suggested that innovation increases with the level of competition.[3] Others, including Scherer (1967), posit an inverted U curve relationship whereby increased competition originally increases and then decreases innovation. Aghion et al. (2005) use a panel data set of computer-related mergers to test the relationship using panel data, correlating the Lerner Index to innovation activity. They indeed find a pattern that approximates the inverted U curve and explain the relationship as follows: "Competition may increase the incremental profit from innovating, labeled the 'escape-competition effect', but competition may also reduce innovation incentives for laggards, labeled the Schumpeterian effect. The balance between these two effects changes between low and high levels of competition, generating an inverted U relationship." (Aghion et al., 2005)

There have been some empirical tests of the relationship between market structure and innovation in response to a wave of mergers in the mid-1980s. One of the first studies was performed by Charles River Associates. Their findings, however, were inconclusive. Ravenscraft and Scherer (1987) engaged in a similar study two years later and found that post-merger R&D activity did decline because many of the acquisitions were failures and divested soon after the merger. Hall (1988) also empirically investigated this relationship but did not find evidence of declines in R&D-intensity stemming from mergers. Her findings did indicate that although on average acquired firms invested the same amount or slightly less in R&D than the industry norm, the R&D they engaged in was valued more highly, as measured by the deal premiums paid by the firms that took them over. In addition, her results suggest that larger gains are generated by acquisitions where both firms involved have high R&D intensity.

Hitt et al. (1991) tested their hypothesis that R&D and patent intensity decline post merger, by regressing R&D intensity post-merger against pre-merger R&D intensity and a number of other factors.[4] They find that acquisitions have a negative effect on R&D intensity and also patent intensity in cases involving a diversifying acquisition.

A more recent study by Danzon et al. (2007) examined the determinants of M&A in the pharmaceutical and biotech industry and in turns their effects on firm performance. For large firms, they conclude that mergers are a response to excess capacity due to anticipated patent expirations and gaps in the company's product pipeline. In a similar study, Cassiman et al. (2005) examine 31 mergers in the

[3] Examples include Geroski (1995), Nickell (1996), and Blundell, Griffith, and Van Reenen (1999).

[4] Other explanatory variables in their model include acquired firm size, diversification dummy variable, leverage (debt divided by equity), and profitability measured by return on assets.

pharmaceutical industry. They find that mergers among technologically complementary companies result in increased R&D activity after the merger. In contrast, when merged entities are technologically substitutive, they decrease their R&D activity after the merger. Second, R&D efficiency increases to a greater extent when the merged entities are technologically complementary than when they are substitutive.

Another approach to examining the trend in corporate R&D expenditure is a dynamic analysis whereby current R&D expenditure is modeled as a function of previous R&D investments plus other factors. Bond et al. (2003) use this approach to test for the importance of cash flow on investment in capital and R&D in Germany and the U.K.[5] The authors estimate capital stock as a log linear function of output and the user cost of capital.

$$K_{it} = \alpha + y_{it} - \sigma J_{it} \quad (1)$$

In this equation K_{it} denotes the natural log of the capital stock for firm i in period t and y_{it} denotes the log of output and J_{it} the log of the user cost of capital. The authors then use an autoregressive distributed two-period lagged dynamic regression model to examine capital as a function of current and prior year capital, output, and the user cost of capital.

$$K_{it} = \alpha_0 + \alpha_1 K_{i,t-1} + \alpha_2 K_{i,t-2} + \beta_0 y_{it} + \beta_1 y_{i,t-1} + \beta_2 y_{i,t-2} + \gamma_0 J_{it} + \gamma_1 J_{i,t-1} + \gamma_2 J_{i,t-2} + \varepsilon_{it} \quad (2)$$

This reduces the investment decision to be:

$$\Delta K_{it} = \alpha_0 + (\alpha_1 - 1)\Delta K_{i,t-1} + \alpha_2 K_{i,t-2} + (\beta_0 + \beta_1)\Delta y_{i,t-1} + \gamma_0 \Delta J_{it} + (\gamma_0 + \gamma_1)\Delta J_{i,t-1} + (1 - \alpha_1 - \alpha_2)(ky)_{i,t-2} + [(\beta_0 + \beta_1 + \beta_2) - (1 \ \alpha_1 - \alpha_2)](k - y)_{i,t-2} + (\gamma_0 + \gamma_1 + \gamma_2)\gamma J_{i,t-2} + \varepsilon_{it} \quad (3)$$

As such, the investment decision (ΔK_{it}) is a function of the change in prior year investment, the capital stock in year_{t-2}, the change in output, the change in the user cost of capital, and the change in the variables in the preceding year.

The authors use a data set of computer-related firms in Germany and Britain to test how cash flow impacts R&D expenditures. They find that cash flow is significant in the U.K. but not in the German investment decision. They interpret the results as suggesting that U.K. firms face a higher wedge between the costs of external and internal finance than German firms. Thus, the British firms are more cautious about undertaking long term commitments to R&D projects than their German counterparts (Bond et al., 2003).

We use a similar autoregressive model in this paper to test how mergers affect R&D investment, recognizing that R&D investment is a function of prior year R&D investment, sales, and other variables. As a robustness check we then compare these results to those using ordinary least squares, excluding the time lag effect of prior year R&D investments. Previous works, such as by Park and Sonenshine (2012), have largely focused on the static or steady-state equilibrium effects on innovation. This paper focuses on the dynamic effects of a merger, where market power is a concern on the growth in R&D expenditures. The paper includes a market concentration variable (change in HHI) to assess the market concentration and R&D growth relationship and examines the differential merger impacts between industries. We find quite significant differences in R&D expenditure growth post-merger between the computer-related industries and life sciences industry.

This study adds to the literature by analyzing the differences in R&D inputs based on whether firms engage in challenged or non-challenged mergers or did not undertake a significant acquisition. The study thus examines how firms engaging in product-related mergers that result in high levels of market concentration, per the government standards, impact an organization's commitment to innovating, as measured by R&D inputs.

[5] The two countries were chosen because of the very different financial systems for R&D investment.

3.0 The Data Set

The goal of the paper is to compare the change in R&D-intensity among a group of companies that merged versus similar companies that did not merge. In addition, we compare R&D-intensity among companies that engaged in mergers that were challenged[6] by the US for concentration concerns with other large mergers that were reviewed but ultimately allowed to proceed.[7] This data set includes only larger mergers exceeding $2 billion in value[8] that occurred between 1997 and 2007.

On average there were 10 observations per company. With this panel data structure, the model regresses R&D expenditures in year (t) on R&D and other covariates in year (t-1). In some cases data were not available for all years.[9] Table 1 details the frequency of observations by industry.

Table 01: Segmentation of the Data by Group

Groups	Number of companies	Number of Observations	Industry Composition
Challenged Mergers	29	272	14 Life Sciences; 4 Computer-related : 11 Industrial;
Mergers – Not Challenged	19	173	5 Life Sciences; 8 Computer-related; 6 Industrial
No Large Mergers	17	166	8 Life Sciences; 5 Computer-related; 4 Industrial
Total	65	611	27 Life Sciences; 17 Computer-related; 21 Industrial

Life Science includes pharmaceutical, biotech, and medical device companies. The 27 life science companies include the top 10 pharmaceutical companies and seven of the top 11 biotech companies' revenue.[10] Three of the life science companies (Pfizer, Teva, and Novartis) were listed twice as two of their mergers fit the criteria to be included in the database. Computer-related includes software, telecommunications, computer hardware, and various other companies that are typically classified by investors as computer-related companies. The list includes seven of the 13 largest global technology companies. Industrial includes all companies that do not fall into the first two categories. Since only companies with large enough R&D intensities are included, a large number of the industrial companies in this study are aerospace/defense and chemical companies.

This study covers approximately 7% of all challenged mergers but roughly 75% of the R&D-intensive mergers challenged from 1997 to 2007. R&D intensive mergers refer to companies with R&D equal or greater than 2% of revenue. The other 25% of the R&D-intensive mergers challenged were not included because of 1) difficulty gathering the R&D information, 2) the merger consisted of a very large company acquiring a very small company, which makes the impact on R&D expenses minimal (e.g. GE's $150 million acquisition of InVision), or 3) the merger was abandoned (e.g. Compuware – Viasoft) after the government challenge..

The study also includes a group of large transactions (>$2 billion) among R&D intensive companies, where the merger was not challenged by the government. These mergers were found in the annual CRS

[6] Challenged mergers refer to mergers that are publicly challenged by the government after a Hart Scott Rodino (HSR) 2nd request.

[7] Typically, per the merger review process, approximately 1,750 to 2,000 mergers are reviewed a year. Roughly 90% of the mergers are cleared during the 30 day waiting period as detailed in the HSR Act and subsequent merger guidelines. 2nd requests are issued by the FTC and DOJ for the other 10% of mergers if the government believes there is a strong possibility that the transaction may be in violation of antitrust laws. The parties must then submit further documentation, and the government decides whether to challenge formally the merger.

[8] The $2 billion is an arbitrary level. Danzon et. al. (2004) used a deal value of $500 million to characterize a transforming merger. I have used a larger size as the threshold for a large merger, since all of the large computer-related, life sciences, and industrial firms engage in acquisitions (many being over $.5 billion) every year. We used $2 billion, as this seemed an appropriate cutoff to separate firms and mergers between groups 2 and 3. We tested this threshold in a sensitivity analysis section versus $1 billion deal value.

[9] For example, the company went public after 1997, so R&D expenditure data was not available for the years when the company was privately-held.

[10] Wikipedia provides list of the largest pharmaceutical companies in the world in 2008 by revenue and the largest biotech companies in 2006 by revenue. See http://en.wikipedia.org/wiki/Pharmaceutical_industry.

Reports to Congress, which list the 50 largest transactions for the year. Just 17 mergers fall in this category, because only a few large R&D intensive mergers occur each year, and many of the mergers are challenged by the government and, therefore are part of the challenged group (see the Appendix for a list of mergers in this category).

The third group of companies covers 17 of the largest life science, computer, and industrial companies that did not engage in a major acquisition (>$2 billion in market capitalization). The source for companies in this category is the Financial Times Global 500 report listing the largest companies as measured by revenues and market capitalization. There were only 17 companies listed in this category, since only large, R&D-intensive companies that did not engage in a significant merger during the 10 year time period were included, (See Appendix for a list of firms in this category).

Industries	Number of Companies	Number of Observations	Mean R&D Expenditures in millions of $	Mean R&D Intensity (R&D /Sales)
Life Sciences	27	252	$1,949	20.8%
Computer-related	17	165	$1,947	14.3%
Industrial	21	193	$842	3.0%
Total	65	611	$1,597	13.4%

Deal size refers to the dollar purchase price of the acquired firm. Relative R&D expense refers to the dollar R&D expense of the target in the two years prior to the merger year divided by dollar R&D expense of the bidder. Table 2 shows the mean R&D expenditures and intensity by industry.

Weighted change in HHI (Herfindahl Index) refers to the change in the HHI index for the products of interest. This amount was calculated by taking the percent of a firm's most recent annual sales that the product line (s) of concern represents and multiplying by the change in HHI as noted in the competitive impact statements or complaints. For example, if the Justice Department sued to stop a merger based in part on the excess concentration that would result in two product lines, we estimated the percent of the target company's sales that each line represents and multiplied these weights by the change in HHI found in the competitive impact statement to determine the significance that the product lines may have to the company's total business.

We see from Table 3 that the average deal size in the life sciences industry is twice as large as the average deal size in the other two industries. We also see that the relative R&D expense is similar between the industries, but the change in HHI is far larger for mergers in the computer sector than among the life sciences or industrial companies.

Table 03: Other Statistics by Group

Industries	Deal Size (in billions)	Relative R&D Expense[1]	Weighted Change in HHI[1]
Life Science	$19.4	.254	181
Computer-related	$8.8	.278	997
Industrial	$9.6	.220	165

4.0 Methodology

To analyze the effect of mergers on R&D activity, a series of regression models were used to assess how lagged R&D expenditures, log sales, and other factors affect R&D investments. To do so, we combined R&D dollar expenditures for the merging companies in the years prior to the merger and compared them to the R&D expenditures of the combined entity after the merger.

Dummy variables were then used for mergers (M) overall as well as mergers that were challenged (C) and not challenged (NC). M, C, and NC were used to mark each of the years that R&D expenditures of the companies are combined into one amount due to a merger, a merger challenge, and a non-challenged merger.

We used both ordinary least squares (OLS) and the Arellano-Bond General Method of Moments (GMM[11]) estimation to assess the effect of mergers on R&D investment for this sample. The Arellano-Bond estimator is often used in studies under the assumption that current year R&D expenditure is a function of last year's R&D expenditures. In this case when using a lagged dependent variable as a covariate, OLS is not an appropriate estimation technique because the unobserved panel-level effects are correlated with the lagged dependent variables, making standard estimators inconsistent. The Arellano-Bond model corrects the error correlation problem by using the lagged levels of the dependent variable and possibly other variables as instrumental variables (Greene, 2003).

Lagged R&D expenditures for two periods were tested in the model. There were no differences in the variables of interest (e.g. C, NC, and M) when using one versus two lags, so one lag was used.

However, it is plausible that with a merger, current year R&D expenditures is not a function of past year R&D expenditures because the R&D efforts get reorganized. Under this assumption, OLS might be appropriate as R&D expenditures would not be a function of prior year R&D activity. As such, we ran each model using OLS in addition to GMM, and compared the results in order to answer the following questions:

1. Does the merger have a positive or negative effect on R&D spending?
2. Is there any difference between challenged mergers and non-challenged mergers in their effect on R&D expenditures?
3. Are there differences among industries in the merger and challenged merger effects on R&D spending?

We test the effects of mergers on R&D investment using the following closely related reduced-form models. We tested the models using a number of specifications that are relevant to the questions of interest and chose the equations listed below because they provided the best fit.

Model 1 – Merger Effect – Arellano-Bond Method

$$\mathrm{Log}(R\&D_{it}) = \beta_1 + \beta_2 \mathrm{Log}(R\&D_{t-1}) + \beta_3 \mathrm{Log}(sales_{it}) + \beta_4 M_{it} + \beta_5 LifeS*\mathrm{Log}(sales_{it}) + \beta_6 Computer*\mathrm{Log}(sales_{it}) + \sum_{j=1}^{10} \beta_j YR_j + \varepsilon \quad (4)$$

Model 2 – Challenge Effect – Arellano-Bond Method

$$\mathrm{Log}(R\&D_{it}) = \beta_1 + \beta_2 \mathrm{Log}(R\&D_{t-1}) + \beta_3 \mathrm{Log}(sales_{it}) + \beta_4 NC_{it} + \beta_5 C_{it} + \beta_6 LifeS*\mathrm{Log}(sales_{it}) + B_7 Computer*\mathrm{Log}(sales_{it}) + \sum_{j=1}^{10} \beta_j YR_j + \varepsilon \quad (5)$$

Model 3 – Industry Effect – Arellano-Bond Method

$$\mathrm{Log}(R\&D_{it}) = \beta_1 + \beta_2 \mathrm{Log}(R\&D_{t-1}) + \beta_3 \mathrm{Log}(sales_{it}) + \beta_4 LifeS*\mathrm{Log}(sales_{it}) + B_5 HighT*\mathrm{Log}(sales_{it}) + \beta_6 LifeS*M + \beta_7 Computer*M + \sum_{j=1}^{10} \beta_j YR_j + \varepsilon \quad (6)$$

YR_j refer to fixed effects for the mergers occurring in the years 1997 through 2007.[12] These variables are used to control for the impact on R&D expenses if this impact occurs in one year versus another. $COMPANY_i$ refers to dummy variables for each of the 65 entities[13]. These variables are used to control for

[11] Autoregressive integrated moving average (ARIMA) can also be used as a dynamic model. The GMM method was chosen as it has advantages when some of the variables are potentially endogenous.

[12] 2007 was dropped for econometric purposes and served as the baseline year.

[13] One of the companies was dropped to avoid multicollinearity.

the particular circumstances occurring in one company that would impact their R&D expenditures overall or in a particular year. Table 4 describes the variables and their purpose in the models.

Table 04: Variable Description

Variable (s)	Description	Purpose
Log R&D dollars Year t, t-1	Combined R&D dollar of the acquisition candidate and bidder in years t, t-1, and t-2.	A measure of the knowledge potential of the firm
Log(Sales)	Growth in sales for each company in year t	Measures a firm's market size
Industry *Log(Sales)	Growth in industry specific sales for each company in year t	Measures the industry market size
Challenged Merger Dummy	Dummy variable for each of the years after the challenged merger	Indicates merger challenge
Non Challenged Merger Dummy	Dummy variable for each of the years after the non-challenged merger	Indicates a non-challenged merger
Industry *Merger Fixed Effect	Industry specific merger effect	Measures how R&D expenditures change per industry
Year fixed effects	Year specific merger effect	Macro control variables
Merger*Ratio	Ratio of target to merged firm R&D expenses interacted with the merger dummy variable	Measure of the level of significance of the merger to bidder's R&D effort
Weighted Average Change in HHI (ΔHHI_m)	Change in HHI multiplied by the percentage of the challenged product revenue	Shows the increase in market concentration from the merger.

This regression focuses on the dummy variable M to examine the effect of mergers on R&D expenditures. The model also includes Log (Sales) as an explanatory variable since managers invest more in R&D when they expect greater sales. The model also includes interactive terms, LifeS*Log($sales_{it}$) and HighT*Log($sales_{it}$), formed by multiplying dummy variables for the two industries times Log($sales_{it}$). These terms are used to capture the market size of the life science and computer-related. The interactive term for the industrial sector was dropped. The coefficient of LifeS*Log($sales_{it}$) and HighT*Log($sales_{it}$) shows the impact of the change in sales on R&D investment for these two industries relative to the industrial sector. The model also includes year fixed effects to control for macroeconomic effects.

In Equation 5, R&D expenditures were regressed challenged (C) and non-challenged (NC) dummy variables in place of the merger (M) variable to assess differences in the merger impact on R&D expenditures on the basis of the merger challenge. Equation 6 is the same as equation 5 except for an interactive terms formed between the industry and merger dummy variables (M*LifeS and M*Computer) to analyze the different effect of mergers between the three industries[14].

The same regressions were run using OLS. With the OLS model, lagged R&D expenditures were excluded and company fixed effects were included. Otherwise, the equations are the same as equations (4) – (6). In addition three separate regressions were run for each industry to cover all companies in an industry (equation 7), all mergers in an industry (equation 8), and challenged mergers in an industry (equation 9).

$$\mathrm{Log}(R\&D_{it}) = \beta_1 + \beta_2 \mathrm{Log}(R\&D_{t-1}) + \beta_3 NC_{it} + \beta_4 C_{it} + \beta_5 \mathrm{Log}(sales_{it}) + \sum_{j=1}^{10} \beta_j YR_j + \varepsilon \qquad (7)$$

$$\mathrm{Log}(R\&D_{it}) = \beta_1 + \beta_2 \mathrm{Log}(R\&D_{t-1}) + \beta_3 NC_{it} + \beta_4 C_{it} + \beta_5 \mathrm{Log}(sales_{it}) + \beta_6 M^{*}\mathrm{logRatio}_{ij} + \sum_{j=1}^{10} \beta_j YR_j + \varepsilon \qquad (8)$$

[14] The industrial sector was dropped to avoid multicollinearity. The coefficients for the life science * merger and computer-related* merger sectors were evaluated relative to the industrial*merger sector.

Equation 8 as well as 9 below include an interactive term (Merger*logRatio) to assess the effect of relative deal size on the growth in R&D investment.

$$Log(R\&D_t)= \beta_1+ \beta_2 Log(R\&D_{t-1}) + \beta_3 NC_{it}+ \beta_4 C_{it} + \beta_5 Log(sales_{it})+ B_6 M*logRatio_{ij} + \beta_7 M*log\Delta HHI + \sum_{j=1}^{10}\beta_j YR_j + \varepsilon \quad (9)$$

Equation 9 covers the challenged mergers in the industry. The variables are the same as models 7 and 8 except for the addition of the interaction term formed between the merger dummy and weighted change in HHI for the merger (identified only for challenged mergers).

5.0 Results

	Arellano-Bond			OLS		
Log $R\&D_{it}$	Merger effect	Challenge effect	Industry effect	Merger effect	Challenge effect	Industry effect
Log $R\&D_{t-1}$	**0.16**** **(0.08)**	**0.19*** **(0.09)**	**0.19**** **(0.09)**	-	-	-
Log Sales[15] $_{t-1}$	**0.36*** **(0.19)**	**0.43*** **(0.15)**	**0.34*** **(0.18)**	**0.48***** **(0.09)**	**0.49***** **(0.10)**	**0.48***** **(0.10)**
All mergers	-0.01 (0.04)	.	-	**0.11*** **(0.06)**	.-	-
Challenged merger	-	0.01 (0.05)	-	-	0.02 (0.05)	-
Non-challenged merger	-	0.01 (0.05)	-	-	**0.24**** **(0.09)**	-
Life Science * Log $Sales_{it}$	-0.17 (0.19)	**0.05*** **(0.025)**	**0.36*** **(0.20)**	**0.17***** **(0.04)**	**0.14***** **(0.04)**	**0.18***** **(0.05)**
Computer-related * Log $Sales_{it}$	0.07 (0.05)	0.09 (0.06)	0.07 (0.05)	**.13***** **(0.03)**	**0.13***** **(0.03)**	**0.14***** **(0.04)**
Merger * Life Sciences	-	-	-0.02 (0.06)	-	-	**0.10*** **(0.05)**
Merger * Computer-related	-	-	0.06 (0.07)	-	-	0.07 (0.07)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Company Effects	-	-	-	Yes	Yes	Yes
Constant	0.05 (1.42)	-0.03 (-.99)	0.05 (1.41)	1.33 (1.22)	1.26 (1.15)	1.27 (1.15)
Observations Companies	478 65	478 65	478 65	610	610	610
Autocorrelation test	Order 2: z = .8	Order 2: z = .80	Order 2: z = .8			
Sargan test of	ChiSq(35) = 84.86 Prob > chi2 = 0.0	ChiSq((35) = 84.86 Prob > chi2 = 0.0	ChiSq((35) = 85.81 Prob > chi2 = 0.0			

Table 05: Notes: Robust standard errors are in parenthesis: legend: * p<.1; ** p<.05; *** p<.01

Table 5 shows the results from the total sample of companies using the Arellano-Bond in the first three columns and the OLS method in the fourth through sixth columns. In the first and fourth column we see the results from the full sample using a merger dummy variable only, referred to as the merger effect, while the second and fifth column show the findings using the challenged and non-challenged merger dummy variables (a.k.a. challenged effect). The third and sixth columns show the results of the regression when the industry dummy variables are included.

[15] 'Log sales' is the explanatory variable in the OLS model.

We see from the Table 5 that the coefficient for lagged R&D expenditures in the Arellano-Bond model and the coefficient for log sales in both models are significant in each of the regression models. This finding was expected, as it implies that R&D expenditures are a positive function of sales and previous R&D expenditures.

We also find that the coefficients for the merger and non-challenged merger dummy variables are significant under the OLS model. However, when looking at the Arellano-Bond model mergers do appear to have a significant effect on R&D investment. Given the contradicting results, it is difficult to conclude that mergers impact R&D expenditures.

However, we do find trends of increasing R&D expenditures in the life sciences industry in both models and the computer-related industry in the Arellano-Bond model. As such, it appears we may not be able to generalize on the impact of mergers on R&D expenditures because the effect may depend on the industry.

5.01 Industry results

	Arellano Bond Method			OLS Method		
Log $R\&D_{it}$	All Life Science Firms	All Life Science Mergers	Challenged Life Science Mergers	All Life Science Firms	All Life Science Mergers	Challenged Life Science Mergers
Log $R\&D_{it-1}$	**0.68*** (0.12)**	**0.75*** (0.08)**	**0.70*** (0.09)**	-	-	-
Log $Sales_{it}$	**0.13*** (0.04)**	**0.15*** (0.05)**	**0.14*** (0.03)**	**0.45*** (0.13)**	**0.53*** (0.17)**	**0.52*** (0.19)**
Challenged Mergers	**-0.11*** (0.04)**	**-0.12*** (0.05)**	-0.12 (0.14)	-0.03 (-0.06)	-0.11 (-0.09)	-0.33 (-0.21)
Non challenged mergers	-0.08 (0.05)	**-0.14** (0.07)**	-	-	**0.11** (0.05)**	0.06 (0.08)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Merger*log Ratio	-	**-.03* (0.016)**	**-.02** (0.01)**	-	-0.02 (0.02)	-0.05 (0.04)
Merger * log Change in HHI	-	-	0.01 (0.01)	-	-	0.03 (1.06)
Constant	**-0.03* (0.016)**	0.02 (0.015)	**0.03** (0.01)**	**2.81** (1.25)**	1.94 (1.66)	1.22 (1.65)
Number of observations Number of Companies	198 27	138 19	100 14	252	177	128
Arellano-Bond Autocorrelation test	Chi2(35) = 44.1 Prob > chi2 = 0.1395	Chi2(35) = 55.2 Prob > chi2 = 0.0162	Chi2(35) = 46.1 Prob > chi2 = 0.09	Chi-Squared Ho: C=NC: Prob >F= .03	Chi-Squared Ho: C=NC: Prob >F= .01	
Sargan test of over identifying restrictions	Order 2: z = .84	Order 2: z = -.77	Order 2: z = -1.96			
Notes: Robust standard errors are in parenthesis: legend: * p<.1; ** p<.05; *** p<.01						

Table 06: Effect of Mergers on R&D Expenditures – Life Science Sample

Tables 6 through 8 show the varying effects within an industry (life sciences, computer-related, and industrial) of mergers between all companies in the sample, all mergers, and just the challenged mergers.[16] In Table 6, we see the results for the life sciences industry. As expected R&D investment in the life sciences industry is a positive function of prior year R&D investment and sales.

The key result from Table 6 is that the coefficient for challenged mergers is negative and significant for all life science firms and life science mergers using the Arellano-Bond regression technique. This finding indicates that the percent change in R&D investment in the life sciences industry for the combined entity appears to decline after companies merge and the transaction is challenged by the government. These challenged mergers, which were ultimately approved, usually with some restructuring, likely result in increased market power for the merged entity. Growth in R&D investment then may be declining as the merged entity consolidates R&D resources, and focuses on other activities that would lead to sustainable competitive advantage.

We also find the coefficient for the interactive term, merger*log ratio to be negative and significant using the Arellano Bond technique. This result indicates that mergers of similar sized life science firms are more likely to result in lower R&D expenditures than mergers of dissimilar size firms. It appears that a merger of similar sized firm may enable the combined entity to gain efficiencies by reducing duplication of R&D efforts to a greater extent than a merger of dissimilar size firms.

Table 7 shows the results for computer-related firms. The coefficient for challenged mergers is positive and significant in each of the Arellano-Bond models and the challenged OLS model. The coefficient for non-challenged mergers is positive but not significant in these models. As such, it appears that mergers that are challenged by the government are more likely to spur increased R&D investment in the computer-related industries. The coefficient for challenged mergers is particularly large implying a large percent change in R&D expenditures within the sample of challenged computer related mergers (columns 3 and 6).[17]

In the OLS equations in Table 7, we could not reject the chi-squared test, as we did in Table 6, that challenged and non-challenged mergers were significantly different. Also, the third Arellano-Bond regression covering challenged mergers for computer related firms failed the Sargan test for over identifying restrictions, and, therefore, these results may not be valid.

In addition, the regression results in Table 7 show a positive, significant coefficient for the merger*log ratio interactive term. This finding indicates that R&D expenditures increase post merger, the larger the ratio or the more similar the size of the R&D budgets. This result is starkly different than the findings for life science firms.[18] Finally, in contrast to the life sciences industry, the coefficient for the interactive term merger*log change in HHI is negative and significant in the Arellano Bond model indicating that R&D investment post merger is inversely related to the change in market concentration resulting from the merger. This finding supports the government's concern that increased market concentration tends to have a negative influence on R&D inputs, which may impact innovation.

Table 8 shows the results for the industrial sector. Here, we see only the coefficients for lagged R&D expenditures and sales are significant in explaining current year R&D expenditures. The coefficient for challenged mergers is not significant, and its sign changes between the equations. The coefficient for non-challenged mergers is positive but not significant in either the merger effect or challenge effect models.

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[16] The merger effect life sciences model did not pass the Sargan test for over-identifying restrictions. As such, one cannot accept the lagged variables as acceptable instruments in this model. The other models pass the Sargan test, but there is evidence of second order auto correlation in the third model.

[17] A separate regression was run using only a merger variable versus a challenge and non-challenge variable. In each equation, the merger coefficient was significant to the 1% and 5% levels.

[18] The difference may be due to the fact that the acquirers were far larger in the life science industry than in the computer-related industry.

Table 07: Effect of Mergers on R&D Expenditures – Computer-related Sample

	Arellano Bond Method			**OLS Method**		
Log $R\&D_{it}$	All Computer-related Firms	All Computer-related Mergers	Challenged Computer-related Mergers	All Computer-related Firms	All Computer-related Mergers	Challenged Computer-related Mergers
Log $R\&D_{it-1}$	**0.64***** **(0.17)**	**0.54***** **(0.08)**	**0.30***** **(0.03)**	-	-	-
Log $Sales_{it}$	**0.12*** **(0.07)**	0.11 (0.14)	0.08 (0.09)	**0.60***** **(0.11)**	**0.51***** **(0.18)**	0.16 (0.15)
Challenged Mergers	**0.22**** **(0.09)**	**0.25***** **(0.09)**	**1.33***** **(0.32)**	-0.04 (0.12)	0.16 (0.10)	**1.27**** **(0.47)**
Non challenged mergers	0.05 (0.06)	0.13 (0.11)	-	0.05 (0.06)	0.24 (0.19)	-
Merger * log Ratio	-	0.06 (0.05)	**0.36***** **(0.06)**	-	.09 (0.07)	**0.63**** **(0.23)**
Merger * log Change in HHI	-	-	**-0.10***** **(0.02)**	-	-	-0.03 (0.06)
Company Fixed Effects	-	-	-	Controlled	Controlled	Controlled
Year Fixed Effects	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Constant	-0.01 (0.03)	0.01 (0.01)	-0.01 (0.01)	1.45 (0.91)	2.62 (1.98)	**4.76***** **(1.10)**
Number of observations Number of Companies	127 17	88 12	26 4	164	114	36
Arellano-Bond Autocorrelation test	Chi2(35) = 58.31 Prob > chi2 = 0.008	Chi2(35) = 45.70 Prob > chi2 = 0.10		Chi-Squared Ho: C=NC: Prob >F= .89	Chi-Squared Ho: C=NC: Prob >F= .19	-
Sargan test for over identifying restrictions	Order 2: z = .29	Order 2: z = -.44				

Robust standard errors are in parenthesis: legend: * p<.1; ** p<.05; *** p<.01

	Arellano Bond			**OLS**		
Log $R\&D_{it}$	**All groups**	**All Mergers**	**Challenged mergers**	**All groups**	**All Mergers**	**Challenged mergers**
Log $R\&D_{it-1}$	**0.13*****	**0.14*****	**0.08*****	**-**	**-**	**-**
	(0.04)	**(0.04)**	**(0.04)**			
Log $Sales_{it}$	**0.72*****	**0.73*****	**0.85*****	**0.95*****	**0.93*****	**0.81*****
	(0.19)	**(0.17)**	**(0.14)**	**(0.14)**	**(0.14)**	**(0.19)**
Challenged Merger Fixed Effect	0.02 (0.50)	0.31 (0.28)	0.86 (0.83)	0.18 (0.13)	-0.12 (0.26)	0.02 (0.67)
Non Challenged Merger Fixed Effect	0.09 (0.16)	-0.53 (0.50)	-	0.66 (0.23)	0.24 (0.37)	-
Merger* log Ratio	-	0.22	-0.23	-	**0.19****	0.09
		(0.19)	(0.16)		(0.09)	(0.08)
Merger * log Change in HHI	-	-	0.08 (0.12)	-	-	-0.03 (0.12)
Company Fixed Effects	-	-	-	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
	0.04	0.03	0.21	**-3.51****	**-3.22***	-0.76
Constant	-0.92	-0.82	-0.89	**(-2.00)**	**(-1.79)**	(-.39)

Number of observations	143	111	76	191	150	103
Number of Companies	21	17	11			
Arellano-Bond Autocorrelation test	Chi2(35) = 78.31 Prob > chi2 = 0.008	Chi2(35) = 62.30 Prob > chi2 = 0.0030	Chi2(35) = 41.65 Prob > chi2 = 0.20	Chi-Squared Ho: C=NC: Prob >F= .001	Chi-Squared Ho: C=NC: Prob >F= .001	-
Sargan test for over identifying restrictions	Order 2: z = 3.77	Order 2: z = -1.04	Order 2: z = 1.50	-	-	-
Robust standard errors are in parenthesis: legend: * p<.1; ** p<.05; *** p<.01						

Table 08: Effect of Mergers on R&D Expenditures – Industrial Sample

5.02 Implications

The results shown in table 6 indicate that mergers do not have a significant impact on R&D activity. Instead, we see that R&D expenditures are influenced primarily by prior year (s) R&D activity and sales. These results mirror the findings from Hall (1999).

When looking at the effect of mergers within an industry, however, we see that mergers have a significant effect on R&D activity and that these effects differ by sector. The results by industry indicate that mergers have a positive effect on R&D expenditures among computer-related firms. The effect is positive in the computer-related sector for each of the equations for mergers overall and also for challenged mergers. In contrast, in the life sciences sector the effect is negative for challenged and non-challenged mergers. In the industrial sector, mergers do not appear to affect R&D investment.

The different results by industry may be the result of varying motivations for undertaking the merger. It has often been argued that mergers in the life sciences industry are frequently the response to expected excess capacity that is triggered by patent expirations and gaps in the pipeline of follow-on products, which depresses expected future earnings growth (Danzon, 2007). Then it might be the case that when products with patent protection are brought into the company through a horizontal merger, the merged company rationalizes its R&D activity and invests its resources to monetize its newly acquired products. For life science companies then, mergers may act as a substitute for internal investment in R&D activity.

In the computer-related sector, mergers appear to increase R&D activity among all three samples. This effect, however, is only significant if the merger is challenged. This finding might indicate that computer-related firms bolster R&D investment after engaging in mergers that result in increased concentration in order to increase barriers to entry, build their brand, and maintain or gain market share. It also may be the case that computer-related acquirers tend not to use debt financing as much as acquirers in other industries, and it is excessive debt that causes post-merger reductions in R&D expenditures (Hall, 1999). However, the explanation in Hall (1999) does not explain the dichotomy between the challenged and non-challenged mergers on R&D expenditures.

R&D-intensity in the industrial sector is considerably lower than in the other two sectors. This may explain why mergers do not have a significant effect on R&D activity among industrial firms. Instead, R&D expenditure among industrial companies is explained by lagged sales and lagged R&D investment.

Finally, in the computer-related industry, R&D investment is negatively affected by the interactive term 'merger*log change in HHI'. This finding suggests that, while overall a merger challenged by the government tends to result in increased R&D expenditures relative to other peer companies, the trend in R&D expenditures declines as market concentration, proxied by the change in HHI, increases from the merger.

6.0 Conclusion

This study uses a dynamic panel analysis in addition to a static model to assess the effect of mergers on R&D expenditures. Our findings do not indicate mergers to have a significant impact on R&D activity across the sample of mergers, because there is a differential impact between the life science and computer related industries. In the former we find mergers to impact R&D expenditures negatively, while in the latter we find mergers challenged by the government to influence R&D activity positively. Our findings explain why there have been conflicting findings regarding the effect of mergers on R&D activity since the results depend on the industry and on the change in market concentration that will likely result from the merger.

While this study examines the relationship between horizontal mergers and R&D inputs, it does not cover R&D output, as measured by patents or clinical trials. The paper also does not cover R&D efficiency. It is left to other research to determine the effects of mergers on R&D outputs or efficiency.

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Appendix:

Data	Source
Listing of challenged mergers and percent of sales overlap	Federal Trade Commission[19] / Department of Justice[20] web sites, complaint documents, annual reports
General Merger Information	Annual Congressional Research Service (CRS) Reports to Congress.
Non-merging companies	Financial Times Global 1,000 Report
Patent Grants and Citations	*National Bureau of Economic Research* Patent Data Project, Files Pat76_06_Assg and Assignee, http://www.nber.org/patents
Sales, R&D Expenditures, Employment, Debt, Equity, Income, and Income Taxes	Standard and Poors' Compustat Data Base, North America – Simplified Financial Extract Report
Sectoral Value Added and Price Indexes	U.S. Department of Commerce, Bureau of Economic Analysis http://www.bea.gov/industry/index.htm#annual

Challenged: Acquirer-Acquired	Merger Year	Sector	**Non-Challenged:** Acquirer-Acquired	Merger Year	Sector
3D Systems-DTM	2001	Computer	Adobe - Macromedia	2005	Computer
ABB-Elsag Bailey	1998	Industrial		2004	Industrial
Allergan- Inamed	2005	Life Sciences			
Amgen – Immunex	2001	Life Sciences	BASF-Engelhard	2006	Industrial
Astra-Zeneca	1998	Life Sciences	Biogen – Idec	2003	Life Sciences
Boston Scientific- Guidant	2005	Life Sciences	Boeing-McDonnell Douglas	1997	Industrial
Cephalon – Cima	2003	Life Sciences	Cisco – Scientific Atlanta	2005	Computer
Computer Associates – Platinum T.	1999	Computer	Eaton-Vickers	1999	Industrial
Dow-Union Carbide	1999	Industrial	General Dynamics - Gulfstream	1999	Industrial
Genzyme- Ilex	2004	Life Sciences	HP – Compaq	2001	Computer
Glaxo-SmithKline	1998	Life Sciences	IBM - Rational Software	2002	Computer
Halliburton - Dresser	1998	Industrial	J&J – Alza	2001	Life Sciences
Honeywell-Allied Signal	1999	Industrial	Juniper - NetScreen	2003	Computer
JDSU-Etek	2000	Computer	Millenium - Cor	2001	Life Sciences
Medtronics-Physio Control	1998	Life Sciences	Motorola - General Instruments	1999	Computer
Novartis –Eon Labs.	2005	Life Sciences	Novartis - Chiron	2006	Life Sciences
Oracle-Peoplesoft	2004	Computer	Teva – Sicor	2003	Life Sciences
P&G –Gillette	2005	Industrial	United Technologies - Sundstrand	1998	Industrial
Pfizer-Pharmacia	2002	Life Sciences	Veritas - Symantec	2005	Computer
Pfizer-Warner Lambert	2000	Life Sciences	Whirlpool - Maytag	2005	Industrial
Precision Cast - Wyman Gordon	2000	Industrial			
Rohm Haas-Morton	1999	Industrial			
Sanofi-Aventis	2004	Life Sciences			
Teva-IVAX	2005	Life Sciences			

[19] See http://www.ftc.gov/os/caselist/index.shtm for a list of Federal Trade Commission cases.
[20] See http://www.justice.gov/atr/cases.html for a list of Department of Justice cases.

Tyco- Mallinckrodt	2000	Industrial
Valspar-Lilly	2000	Industrial

Non-Merging Firms:

Companies	Sector	Companies	Sector
3M	Industrial	Genentech	Life Sciences
Abbott	Life Sciences	Gilead Sciences	Life Sciences
Apple	Computer	Merck	Life Sciences
Baxter	Life Sciences	Intel	Life Sciences
Caterpillar	Industrial	Johnson Controls	Computer
Cytec	Life Sciences	Microsoft	Computer
Deere	Industrial	NCR	Computer
Eli Lilly	Life Sciences	Micro Technology	Computer
Emerson	Industrial		

Watson-Andrx	2006	Life Sciences