Evaluating Mergers in the Presence of Dynamic Competition Using Impacts on Rivals

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Abstract:

In a sample of large pharmaceutical mergers, cumulative abnormal returns on portfolios of non-merging rivals predict post-merger changes in the acquirer's R&D intensity. More favorable impacts on rivals are associated with lower intensities, which is consistent with such mergers softening competition. Matching acquirers to comparable non-merging firms suggests we can attribute the observed changes in R&D intensity (particular positive ones) to the mergers. We highlight two measurement issues. First, we deduct R&D "expenses" associated with accounting for in-process R&D. Second, we find that definitions of rivals that are not too broad and not too narrow are best.

JEL Codes: G34: Mergers and Acquisitions; **L65:** The Pharmaceutical Industry; **G14:** Event Studies; **L44:** Antitrust Policy

Keywords: pharmaceutical mergers; mergers and R&D; mergers and innovation; merger evaluation; impacts on rivals; event studies

Under the Hart-Scott-Rodino Antitrust Improvements Act of 1976, the Department of Justice and the Federal Trade Commission have 30 days (15 for cash offers or bankruptcy sales) to evaluate proposed mergers to determine whether they require further investigation (small mergers are exempt). The agencies' evaluations focus on forecasting impacts on consumers, which is particularly difficult in industries driven by dynamic competition. In such cases, the expected net present value of consumer (and total) welfare might be impacted more by the merger's effects on R&D and innovation than its effects on prices and output. However, effects on R&D and innovation are often harder to predict. Given this, the agencies might overweight prices and outputs in their evaluations, which could lead to inappropriate approvals and challenges.

Our goal is to help improve forecasts of the effects of mergers on R&D and innovation. To this end, we revisit an approach pioneered by Eckbo (1983) and Stillman (1983): we examine the impacts of M&A announcements on rival firms, as measured by the cumulative abnormal returns (CARs) of portfolios of rivals. Positive CARs suggest that the merger softens competition (and hence raises rivals' values), and negative CARs suggest that the merger enhances competition (and hence lowers rivals' values). We add to the small number of studies that compare rival CARs to ex post merger outcomes (McAfee and Williams (1988), Singal (1996), Becher, Mulherin and Walkling (2012), Kwoka and Gu (2013)). Our analysis focuses on the pharmaceutical industry, which is the most prominent example of an industry where R&D is critical and mergers have been important. Competition focuses on new-drug development. We consider whether rival CARs forecast impacts of mergers on the acquirer's R&D intensity, which in expectation would have a long-term impact on rival cash flows through drug introductions.

We construct alternative portfolios of rivals (using broad-to-narrow definitions of a rival) and compute CARs for the portfolios around merger announcement dates. We find a strong and

robust inverse relationship between rival CARs and changes in the acquirer's R&D intensity, and matching acquirers to similar non-merging firms suggests that we can attribute the observed impacts on R&D to the mergers, particularly when the impacts are positive. Thus, harmful announcement effects on rivals predict that the merger will lead to more R&D competition. On the whole, our results suggest that rival CARs should be among the metrics that the agencies examine when evaluating mergers in dynamic settings.

Our approach and results also highlight two measurement issues. First, accounting standards involve expensing all or part of the target's intermediate R&D outputs as "in-process R&D," and Compustat includes such "expenses" as part of R&D. When mergers involve large R&D intensive firms, in-process R&D can be a substantial component of the recorded R&D expense. We deduct in-process R&D to focus on current R&D outlays. Second, our results highlight a tradeoff between broad and narrow definitions of a rival: overly broad measures introduce excessive noise because the "rivals" are only loosely related to the merging firms, and overly narrow measures introduce excessive noise because results rely too much on the idiosyncratic shocks of the small number of firms considered to be rivals.

II. Event Studies, Mergers, R&D and Innovation

Event Studies of Impacts of Merger Announcements on Rivals

If stock markets are semi-strong form efficient, a firm's stock price reflects the aggregation of investor assessments of the firm's value based on all public information, and stock prices adjust rapidly in response to new public information (such as a merger announcement).[1] The component of the firm's stock return that can be attributed to a merger announcement measures

[1] Bodie, Kane and Marcus (2011) discuss evidence for and against market efficiency. Semi-strong form efficiency is a reasonable approximation to reality.

the expected impact of the news on the firm's value.[2] Event studies attempt to isolate this impact. An event study requires a model of "normal" returns; the residual measures the "abnormal return" associated with news (MacKinlay (1997)). To conduct inference in settings where firms are similar and all experience the same event on the same day, the standard approach combines firms in an equal-weighted portfolio prior to estimating the model. The resulting portfolio variance allows for any covariance between the returns of the different firms:

$$Var\left(\frac{\sum_{i=1}^{n} R_{it}}{n}\right) = \frac{1}{n^2}\left(\sum_{i=1}^{n} Var(R_{it}) + \sum_{i=1}^{n}\sum_{j\neq i} Cov(R_{it}, R_{jt})\right) \quad (1)$$

where i indexes firms, there are n firms in the portfolio and R_{it} is firm i's return on day t.

The cumulative abnormal returns of portfolios of rivals (rival CARs) should be associated with expected changes in product market outcomes that impact subsequent cash flows. This suggests we might be able to use rival CARs to help forecast changes in product market outcomes. The agencies are primarily concerned with preventing or modifying mergers that are likely to "encourage one or more firms to raise price, reduce output, diminish innovation, or otherwise harm consumers…" (*2010 Horizontal Merger Guidelines*) and as a result they focus on forecasting impacts of mergers on these outcomes. Effects on innovation are likely often the most difficult of the three outcomes to predict.

The prior literature most closely related to ours consists of studies that follow McAfee and Williams (1988) by comparing rival CARs at the point of the merger announcement to actual

[2] As we discuss further below, rival CARs only capture the portion of the impact of the merger that is a surprise: if investors anticipate the merger announcement, they might also anticipate the impact on the rivals, and in that case any expected impacts on cash flows will already be incorporated into stock prices. Our empirical results suggest that this concern does not prevent rival CARs from being useful predictors. Similarly, there is a potential concern that investors might anticipate that antitrust agencies will block a merger or force divestitures, etc. on the merging firms, but it is still worth assessing whether rival CARs can be useful despite such potential contamination.

ex post merger outcomes. McAfee and Williams (1988) investigate a single merger that was revealed ex post to be anticompetitive and show that event studies of impacts on rivals would have failed to predict the anticompetitive outcome (the acquirer essentially shut down the target and increased its price). They attribute this to rival diversification: product lines impacted by the merger might have a small impact on the value of the whole firm when the firm is diversified, so an event study might not distinguish the impact of the merger announcement from the other news that arrives around the announcement day. We attempt to mitigate this problem in our context by considering alternative definitions of a rival.

A few studies that follow McAfee and Williams (1988) explore the links between rival CARs and product market outcomes in particular industries.[3] In a study of 14 airline mergers, Singal (1996) finds that rival CARs are positively correlated with changes in industry concentration due to the merger, which is consistent with a general increase in market power. Singal (1996) also finds that rival CARs are negatively correlated with the number of common airports between the merging firms and the rival, which is consistent with merger-generated efficiency effects that harm close competitors. Becher, Mulherin and Walkling (2012) examine utility mergers and conclude that rival CARs and observed changes in product prices are both consistent with merger gains due to synergies rather than collusion. In a recent more comprehensive analysis, Kwoka and Gu (2013) rely on several prior studies of mergers in which

[3] We focus on studies that compare rival CARs to product market outcomes and do not attempt to provide a comprehensive review of other studies that examine rival CARs. Initial studies of impacts of mergers on rivals (Eckbo (1983), Stillman (1983), Eckbo and Weir (1985)) conclude that mergers generally lack anticompetitive effects. Prager (1992) and Schumann (1993) question this conclusion. An important study that precedes McAfee and Williams (1988) is Eckbo (1985), which challenges the use of industry concentration metrics to forecast impacts of mergers on prices by showing that changes in concentration are not positively related to rival CARs. Other notable studies that examine rival CARs include McGuckin, Warren-Boulton and Waldstein (1992), Banerjee and Eckard (1998), Warren-Boulton and Dalkir (2001), Fee and Thomas (2004) and Shahrur (2005). For expanded discussions of the literature see Pautler (2003), Cichello and Lamdin (2006) and Betton, Eckbo and Thorburn (2008). In another related study, Chevalier (1995) finds that supermarket leveraged buyouts (changes in capital structure, not mergers) increase the value of the buyout chains' local rivals and soften product-market competition.

the authors have estimated the post-merger price changes associated with mergers using difference-in-differences or similar methods. They conclude that concentration forecasts these post-merger price changes better than rival CARs, and that rival CARs would identify only 23% of the anticompetitive mergers.

Prior research has under-emphasized non-price impacts, and we help address this gap by examining whether rival CARs forecast impacts of the merger on the acquirer's R&D intensity. Rival CARs include short-term impacts on cash flows due to expected changes in product market prices but also include long-run impacts due to expected changes in R&D. Prior authors have not examined this feature of rival CARs: rival CARs might be most useful for predicting long-run non-price impacts, where there are fewer competing metrics, and less useful for predicting short-run price impacts, where competing metrics (concentration and others discussed in the *2010 Horizontal Merger Guidelines*) are relatively effective.[4]

Impacts of Mergers on R&D and Innovation

Predicting the impacts of mergers (or increased concentration more generally) on innovation has proved to be challenging. The only clear consensus on the concentration/innovation relationship is that a merger to monopoly will likely lead to a reduction in innovation when entry barriers are high (Katz and Shelanski (2007)).[5] Rival CARs can be examined only when the merger does not

[4] Schumann (1993) describes how in the mid-1980s "economists in the Department of Justice's Antitrust Division routinely examined rivals' stock returns in the course of their merger investigations." However, we are not aware of any prior attempts to use rival stock returns to predict the impacts of the merger on R&D.

[5] In an authoritative review of the pre-1990s literature, Cohen and Levin (1989) conclude that there is not a strong empirical relationship between concentration and innovation. This view still represents the current consensus, and most scholars today emphasize the importance of other determinants of innovation (the nature of the demand, technological opportunities, appropriability conditions, and availability of complementary assets, for example). Katz and Shelanski (2007) and Sidak and Teece (2009) provide more recent guides to the theoretical and empirical literature. To the extent that authors still search for a robust relationship between concentration and innovation, the recent debate focuses on whether lower concentration is always better or whether there is an inverted-U relationship between concentration and innovation. The results of Aghion et al. (2005) suggest an inverted-U relationship, but Boldrin and Levine (2013) summarize follow-up studies that question this finding, and Katz and Shelanski (2007) point out that the measures of the extent of competition used in Aghion et al. (2005) (which are based on markups

result in monopoly (otherwise there are no rivals), but it appears these are the most difficult cases to assess. Attempts to estimate the impacts of mergers on R&D at the industry/time-period level have not yielded a consensus on whether mergers increase, decrease or have little-to-no effect on R&D.[6] Recent studies that focus specifically on pharmaceutical mergers also do not yield a consensus. Higgins and Rodriguez (2006) find that acquirers typically improve their product pipelines post-merger (and suggest that this improvement motivates mergers), and Grabowski and Kyle (2008) conclude that projects initiated after mergers are more likely to advance at each stage in the development process. However, Danzon et al. (2007) conclude that mergers have essentially no impact on R&D, and Ornaghi (2009), LaMattina (2011) and Comanor and Scherer (2013) suggest that mergers have detrimental effects on R&D, particularly in the long run. LaMattina (2001) (former President of Pfizer Global R&D) emphasizes that the focus required to rationalize and integrate the merged firms' R&D programs results in a lack of new programs for several months after the merger. Comanor and Scherer (2011) emphasize that separate firms are more likely to pursue parallel paths of R&D.

On the whole, results in the literature are consistent with the view that some mergers increase innovative activities while others do not, and thus whether one finds a positive, negative, or no effect in the aggregate depends on merger-specific characteristics. The lack of clear empirical or theoretical results has led several authors to propose that merger analysis in the presence of dynamic competition should deemphasize concentration and focus more on direct evidence of likely effects on price competition and innovation.[7] Our approach is consistent with

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and employ 2-digit SIC code industries) do not easily translate into variables that matter for antitrust analysis (which normally requires the direct observation of market structure in narrowly defined markets).

[6] Contributions include Hall (1988, 1990), Hitt et al. (1991, 1996), Ahuja and Katila (2001), Cassiman et al. (2005), Bertrand and Zuniga (2006), Cloodt et al. (2006), Higgins and Rodriguez (2006), Danzon et al. (2007), Grabowski and Kyle (2008), Ornaghi (2009), and Park and Sonenshine (2012a, 2012b).

[7] Katz and Shelanski (2007) and Sidak and Teece (2009) provide the main arguments and citations to the literature. The direct approach could be a useful complement to other approaches, such as constructing an "innovation market"

this: rival CARs can potentially distinguish effects of mergers on R&D intensity directly at the level of the individual merger. Katz and Shelanski (2007) conclude based on their review of the literature that "it will be very likely to be difficult to derive empirical generalizations that are not conditional on a number of characteristics of the parties and/or the markets in which they operate." (page 27) Our results suggest some reasons to be optimistic about the role of rival CARs in this respect: the estimated impact of rival CARs on acquirer R&D intensity does not weaken when controls are included in the regression.

Of course, an increase in R&D intensity is not necessarily a welfare-improving event. One concern is that firms might be spending more on R&D because they are deploying inputs inefficiently. Even if inputs are allocated efficiently, game-theoretic patent races (in which the first to innovate obtains a prize and other firms obtain nothing) demonstrate that R&D can be socially excessive because each firm does not internalize the negative impact of its R&D on the likelihood that others obtain the prize. However, empirical work generally finds enormous social returns to R&D (Jones and Williams (1998)), and these returns are particularly high in the pharmaceutical industry that we focus on (see Murphy and Topel (2003, 2006). Thus, higher R&D intensity is likely socially desirable.[8] In any case, our forecasting method does not require higher R&D intensity to be socially desirable, and the agencies could potentially determine separately whether an increase or decrease in R&D intensity would be more socially beneficial. Our approach just assumes that higher anticipated acquirer R&D intensity is more of a competitive threat to rival firms (and hence results in lower rival CARs).

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to attempt to consider firms participating in innovation activities (and potential entrants) as a well-defined market (Gilbert and Sunshine (1995)). Innovation markets have had several critics because of a lack of strong theoretical or empirical foundations for a link between the structure of the innovation market and the production of innovations (Carlton (1995) was an early critic; also see Katz and Shelanski (2007) and Sidak and Teece (2009)).

[8] Katz and Shelanski (2007) point out that under the consumer welfare standard the agencies employ (as opposed to a total welfare standard), even socially excessive R&D in patent races would not pose a problem, because consumers benefit from the increased likelihood that the innovation arrives sooner.

In principle we could examine other innovation outcomes. However, we restrict our attention to the one and two years following a merger.[9] Given the long time it takes for R&D to yield drug candidates and new products and the low likelihood of success (an average of 4 years from beginning discovery research to beginning human clinical trials involving thousands of rejected compounds, and an average of 8 years from beginning human clinical trials to introducing a new approved drug with approximately a 1 in 5 chance of success), it is unlikely that we would see important changes in the rate of patenting, clinical trial starts, or new drug approvals within a two-year period that could plausibly be attributed to a merger. Any such events are far more likely to be due to efforts that were already underway and would have occurred without the merger.[10] Thus, we focus on R&D intensity.

We view the merger as a particular type of investment the acquiring firm undertakes that might have implications for future R&D plans. The acquirer's rivals are impacted by these plans. We do not examine particular mechanisms that could cause the acquirer's R&D intensity to change after a merger is completed, but there are several possible mechanisms. Some examples: First, the target might face financing constraints that the acquirer can overcome. Second, synergies between the two firms could put the acquirer in a better position to exploit the returns from new drug introductions (or other innovations such as improvements in R&D technology). Third, access to particular intellectual property rights or critical human capital that is important for further R&D could be important. Fourth, the acquirer might eliminate redundancies and reduce the number of parallel paths being pursued.

[9] The antitrust agencies used to focus on predicting outcomes in the two years following a merger in their evaluations. The most recent Horizontal Merger Guidelines do not mention a particular time horizon, but we assume that two years is still a reasonable horizon to examine. In the presence of dynamic competition, at some point it becomes questionable whether post-merger events can be attributed to the merger.

[10] See DiMasi, Hansen and Grabowski (2003) and DiMasi and Grabowski (2007) for evidence on R&D lags and attrition rates.

III. Data

To assemble a set of mergers to analyze (we use "merger" to describe both mergers and acquisitions), we begin by collecting all announcements in Thomson ONE during 2003-2010 where either party's primary 4-digit NAICS code involves pharmaceutical manufacturing (3254) and the value of the transaction is at least $500M.[11] We restrict attention to cases where the acquirer lacks a majority interest prior to the merger but obtains one after the merger, so our mergers involve changes in control. We then refine the set to include only those mergers in which the acquirer produces a drug listed in Verispan's *Top 200 Drugs by Sales* in the year of the merger or the prior year. This along with the transaction-size cutoff ensures that we focus on mergers in which the acquirers are large and important in particular market segments at the time the merger is announced (as discussed further below, the pharmaceutical industry is composed of several market segments; each focuses on particular diseases and conditions). Such mergers that involve changes in control are the ones most likely to impact rival firms and the ones most likely to warrant scrutiny by the agencies. The result is 120 mergers.

The Verispan rankings are available annually 2003-2010 and are provided online by *drugs.com/top200.html*).[12] We employ a competing top 200 list generated by IMS Health and published annually in *Pharmacy Times* 2003-2010 to check the accuracy of the listed manufacturer. Most conflicts are because the Verispan list tends to favor the manufacturer/marketer (particularly the U.S. manufacturer/marketer) and the IMS list tends to favor the original developer (which might retain manufacturing/marketing rights in some

[11] We select high-value mergers to focus on the mergers most likely to attract the attention of the agencies. We exclude transactions where a firm repurchases some of its own shares (Thomson ONE uses a broad definition of "acquisition" that includes share repurchases).

[12] The top 200 drugs account for the bulk of industry revenues. During the years 2003-2008, Verispan provides the total revenue generated by drugs outside of the top 200. Using these numbers, top 200 drugs account for 82-84% of total prescription drug sales each year 2003-2008.

markets). In the case of such conflicts we keep the Verispan firm, which seems appropriate given our focus on product market rivalry and U.S. antitrust policy. In cases where the Verispan name is incorrect for the particular year, we replace it with the IMS Health name. We then examine all Thomson mergers involving pharmaceutical firms (regardless of size) to check for mid-year transitions in ownership of particular drugs or entire firms and make appropriate changes.

Next we check for cases where multiple announcements occur on or around the same day. One of the standard problems with event studies is that if multiple events occur on or around the same day, it is typically not possible to sort out the impacts of each event separately in a robust way. We consider a merger announcement to be a potential problem if it occurs within 3 trading days of another merger announcement. In such cases, if one merger has a much larger transaction value than the other, we drop the smaller merger, and if multiple mergers have roughly the same transaction value, we drop all. This reduces the sample to 100 mergers.

As a final step, we eliminate cases where the acquirer is not publicly traded, the merger is not completed, and/or data on pre-announcement and post-completion acquirer R&D and sales are not available for other reasons (as discussed below, we use this data to assess the impact of the merger on R&D intensity).[13] This step reduces the sample to 75 mergers.

Measures of Relatedness and the Set of Rivals

The broadest set of potential rivals we employ consists of all publicly traded firms that produce at least one drug in the top 200 in the year of the merger announcement or the prior year. To create this set, we allow for mid-year changes in the ownership of particular drugs (in this sense, each merger has its own list of top 200 drug manufacturers where the listed firms depend on the timing of the merger relative to the timing in changes in ownership of particular drugs). We also

[13] We do not require completed mergers initially because for eliminating mergers that occur on or around the same day it is appropriate to consider all announcements; market participants cannot know for sure which ones will ultimately be completed.

consider alternative sets of rivals by examining overlap in particular market segments. We consider the second level of the Anatomical Therapeutic Chemical Code (ATC code) to define a market segment.[14] We obtain most ATC codes by obtaining the generic name of the drug from drugs.com and then using the searchable index provided by World Health Organization: www.whocc.no/atc_ddd_index. In a small fraction of cases we obtain codes from Wikipedia. For each merger, we focus on ATC codes in which the acquirer has a top 200 drug in the current or previous year (including the previous year allows for mid-year declines in sales). We then add up each rival's annual sales in those ATC codes (computed using top 200 drugs only) and divide by the rival's total annual revenue (from Compustat). Thus, we estimate the fraction of revenue of each rival that can be attributed to ATC codes in which the acquirer has a top 200 drug. Below, we construct portfolios using different cutoffs of these fractions of revenue. Requiring that the fraction is positive is the most basic cutoff that narrows the set of rivals.

Measuring R&D Intensity

We use Compustat data to measure the acquirer's R&D and sales in the four quarters prior to the merger announcement and the four quarters (or eight quarters) after completion. We use four or eight quarters to measure a full year's worth (or two years) of outcomes, which allows for any systematic tendency of a firm to experience R&D or sales spikes in particular quarters. In each case, we aggregate R&D for the quarters in question, aggregate sales, and then divide the aggregated R&D by aggregated sales to construct a single pre-merger R&D intensity and a single post-merger R&D intensity. Our analysis focuses on difference in R&D intensity.

[14] For a discussion of how ATC Codes are determined, see the WHO Collaborating Centre for Drug Statistics Methodology at http://www.whocc.no/atc/structure_and_principles/. The first level defines an anatomical main group, the second level a therapeutic subgroup, the third level a pharmacological subgroup, the fourth a chemical subgroup, and the fifth a chemical substance.

We deduct expenses associated with in-process R&D (IPR&D) from Compustat's R&D variable to address an accounting issue that prior work seems to have overlooked.[15] IPR&D measures the acquirer's valuation of the target's intermediate outputs from their R&D efforts (not those that yielded patents or other assets that could be valued separately). Prior to December 15, 2008, the acquirer would expense IPR&D immediately after merger completion. After a rule change that went into effect December 15, 2008, the acquirer could capitalize the target's IPR&D instead of expensing it and then either keep it on the balance sheet until project completion (if it continued to be valuable; annual tests for impairment are required), write it off over its useful life, or expense it immediately if the target's R&D projects were abandoned. Compustat's R&D variable includes expenses associated with IPR&D, but these expenses are also reported as a separate variable; we subtract them to avoid counting what amount to sunk costs in our R&D measure.[16] Given that the accounting treatment of IPR&D changed during our sample period it is particularly critical to do so, but it would be appropriate to do so in any case. Expenses associated with IPR&D account for a substantial fraction of Compustat's R&D expenses when targets are relatively large, R&D-intensive firms, and including them clearly biases results toward a conclusion that mergers increase R&D intensity.[17]

Control Variables

We consider several control variables that might impact the change in the acquirer's R&D intensity. Summary statistics are provided in Table 1. In most cases we lack clear directional predictions of the impacts of these variables comparable to what we have for rival CARs. In

[15] Prior studies of the impact of mergers on R&D do not mention this issue. We thank our accounting colleagues Josh Rosett, George Batta, and Matt Magilke for alerting us to the issue and discussing how to address it. Mulford and Yang (2008) and PricewaterhouseCoopers (2013) provide an expanded discussion of the 2008 rule change.
[16] We examined Compustat's variable definitions as well as acquirer financial statements in a small subset of cases to confirm that IPR&D expenses are included in Compustat's R&D measure.
[17] The adjustment has a substantial impact on our results, and we expect it would also lead to substantial revisions in other studies of the impacts of mergers on R&D. For example, the magnitudes of the effects of rival CARs in Tables 3-4 are approximately twice as large (suggesting much stronger results) if we do not deduct IPR&D.

some cases prior empirical findings in the literature suggest the likely sign of the effect. We include a dummy for whether the headquarters nation of the merging firms differs. Some prior literature has suggested that cross-border mergers have more positive impacts on R&D than within-country mergers (Bertrand and Zuniga (2005)). We include a dummy for whether the acquirer has an equity stake in the target prior to the merger announcement. Prior work by Filson and Morales (2006) suggests that equity stakes promote learning, which might impact how effectively the target's R&D operation and other operations can be integrated into the acquiring firm. We also include dummies for whether the target is a biotech (biotechs might be expected to be more focused on R&D) and whether the target is not a biotech firm or a pharmaceutical firm (the target could be a device manufacturer or a service provider, for example). We include the natural log of the dollar value of the transaction to account for any systematic impacts that transaction size might have on R&D intensity. We include the acquirer's pre-announcement R&D intensity partly because it is likely more difficult for a firm to increase its R&D intensity when its R&D intensity is already high. However, other factors could create different relationships between the acquirer's pre-merger R&D intensity and our outcome variable. For example, it could be the case that firms with high R&D intensities are more likely to pursue mergers with the goal of increasing their R&D intensity further because their R&D capabilities are their key source of competitive advantage. We include the year-to-year change in the acquirer's R&D intensity partly to allow for the possibility of mean reversion in the firm's R&D intensity. For example, a year-to-year drop (comparing the R&D intensity based on 8-5 quarters prior to the merger announcement to the R&D intensity based on 4-1 quarters prior to the announcement) might suggest the post-merger R&D intensity is likely to rise toward its long-run level. Alternatively, a year-to-year drop might suggest the firm is abandoning a focus on R&D

and that the trend is likely to continue. We include the natural log of the acquirer's sales as a proxy for the acquirer's size. We include the year-to-year change in sales to allow for the possibility of mean reversion or trends in sales that could impact the change in R&D intensity. Such firms might react to a drop in sales by increasing their R&D intensity. We include the acquirer's profit margin and ratio of liquid assets (cash and equivalents) to assets as proxies of the ease of access to external and internal financing for new R&D projects. We include the year-to-year change in the acquirer's value as a proxy for the sort of acquirer decline that Higgins and Rodriguez (2006) emphasize. Higgins and Rodriguez (2006) find that pharmaceutical firms with imminent patent expirations and a lack of replacement drugs in the R&D pipeline pursue acquisitions with the goal of replenishing their pipeline (the year-to-year change in sales might also pick up the effect of patent expirations). Finally, we include the natural log of the acquirer's average Herfindahl-Hirshmann Index (HHI) as a measure of product market concentration. The HHI in each ATC-code-based segment is computed using the top 200 drugs in that segment, and the acquirer's relative sales of top 200 drugs in each segment are used to compute a weighted average of the segment-level HHIs.

IV. Results

For each portfolio of rivals in each merger, we estimate a standard four-factor model of returns using a period of up to 250 trading days (a year's worth) that ends 21 trading days prior to the merger announcement (stopping the estimation window well prior to the announcement helps ensure that any early information leakage does not contaminate the model of normal returns):

$$R_{it} - R_{ft} = \alpha_i + \beta_i (R_{mt} - R_{ft}) + \gamma_{i1} SMB_t + \gamma_{i2} HML_t + \gamma_{i3} UMD_t + \varepsilon_{it} \quad (3)$$

where R_{it} is portfolio i's return on day t, R_{ft} is the risk-free return on day t (measured using the 1-month U.S. Treasury Bill), α_i, β_i, γ_{i1}, γ_{i2} and γ_{i3} are parameters, R_{mt} is the return on the

value-weighted market index on day t, SMB_t and HML_t are the Fama-French factors (Fama and French (1993), (1996)), UMD_t is the momentum factor (Carhart (1997)), and ε_{it} is the residual (the abnormal return).[18] Firm returns are from the Center for Research in Security Prices. The risk-free return and the factors are from Wharton Research Data Services.

We use the estimated factor models and the data surrounding the announcement to compute the cumulative abnormal return (the summed OLS residuals) for each portfolio of rivals for each merger. Following Andrade, Mitchell and Stafford (2001), we focus on the CAR[-1,1], which sums the abnormal returns in the 3 trading days surrounding the announcement. The CAR[-1,1] allows for some information leakage prior to the announcement day and for the possibility that the announcement does not impact returns until the following day because it was made after trading closed. To some extent, a tight window is dictated by our focus on merger evaluation; agencies cannot wait for several weeks or months of stock returns before making a decision. It is also consistent with semi-strong form efficiency: market participants react quickly to new information and profit opportunities from trading do not persist, so a short window is sufficient to assess whether a merger announcement helps or hurts rival firms. An added benefit of working with short windows is that the conclusions from the event study are not very sensitive to the model of normal returns employed.

In this section we present several results on the empirical relationship between rival CARs and changes in the acquirer's R&D intensity. Throughout the section, we attempt to assess the robustness of the results to alternative ways of measuring rivals and alternative ways of using the CARs. Above we discussed how we use ATC codes to construct alternative portfolios of rivals for each merger. With respect to CARs, we might trust directional impacts (positive CARs

[18] We use the four-factor model instead of the simpler market model (that drops the last three factors) because it should do a better job of isolating abnormal returns.

vs. negative CARs) more than the magnitudes. The precise magnitudes are more sensitive to the specification of the model of normal returns and to other news that arrives around the same time as the merger announcement. For similar reasons, we might doubt CARs that are very small in absolute value; changing the model of normal returns in reasonable ways might change the sign of the CAR. We also anticipate a potential concern that outliers in R&D intensity might distort results that relate rival CARs to changes in R&D intensity. This motivates our initial focus on whether R&D intensity rises or falls without consideration of the magnitude of the change.

A related issue is that it is unlikely that the CARs capture the entire impact of the merger on rival firms. One reason is that information about the merger could leak out more than 1 day in advance of the announcement. Beyond this issue (which could potentially be addressed by using a wider event window), several authors present evidence that investors often anticipate that acquirers will announce mergers well in advance of the announcement (contributions include Malatesta and Thompson (1985), Akhigbe, Borde and Whyte (2000), Song and Walkling (2000) and Cai, Song and Walkling (2011)). Some firms announce acquisition programs that take years to complete, and in other cases one major merger prompts others in the same industry many months later. Given that anticipation effects associated with such events are relevant for acquirers, it is plausible that they are also relevant for rivals of the acquirers.[19] Despite this concern, it remains of interest to determine whether short-horizon CARs are useful for forecasting changes in R&D intensity. However, this is clearly one more reason we might be reluctant to rely too much on the precise magnitude of the CAR.

[19] In our sample we lack straightforward ways to distinguish more anticipated mergers from less anticipated ones. The strategy used by Cai, Song and Walkling (2011), for example, requires long periods in the market with no mergers to distinguish surprising ones (those that occur after a long gap) from those that are less surprising. In our data, there are essentially no gaps; pharmaceutical mergers occur throughout our sample period.

Given our concerns, our first set of results just focuses on whether R&D intensity rises or falls and whether CARs are above or below some cutoff without considering the magnitudes. Results that follow consider magnitudes. Tables 2a and 2b compare cases with CARs above a specified cutoff C to those with CARs below $-C$ using our alternative definitions of a rival and focusing on whether R&D rises or falls. Proportions in the table are the proportion of cases for which R&D intensity rises. Both tables use R&D intensity in the 4 quarters prior to the merger announcement as the base, and Table 2a computes the difference in R&D intensity using the 4 quarters after merger completion while Table 2b uses the 8 quarters after merger completion.

Tables 2a and 2b yield several conclusions. First, the definition of a rival matters. Results are relatively weak when we consider all top 200 firms to be rivals. While the point estimates associated with high and low CARs (columns 2 and 3) differ from the overall sample proportions (.52 for Table 2a and .55 for Table 2b) in the expected direction, few of the effects are statistically significant when all top 200 firms are used. The results become stronger as the ATC overlap cutoff rises. However, there is a tradeoff associated with increasing the ATC overlap cutoff, because as the cutoff rises, each portfolio contains fewer firms (fewer firms satisfy the overlap criteria). The number of mergers we can analyze does not change much, but the reliability of the portfolio eventually diminishes because the idiosyncratic shocks of one or a few firms has a much more substantial impact on the results. In our sample, this explains the slight deterioration of the results when the ATC overlap cutoff exceeds 10%. In unreported results we confirmed that using even higher cutoffs results in further deterioration. Interestingly, these results suggest it is not desirable to examine only the very closest rivals: the tradeoff between the number of rivals used to construct the portfolio and the closeness of those rivals to the acquirer must be taken into account. Ideally, one would like to have a large number of close rivals, so that

idiosyncratic noise gets cancelled out and what remains is a clear indication of the impact of the merger announcement. In practice, where there might not be a large number of close rivals, intermediate definitions of rivalry avoid the problem associated with including "rivals" that are not really competitors of the merging firms, and they also avoid an excessive reliance on the abnormal returns of one or a few firms. Second, the CAR cutoff also involves a tradeoff. We would like a low cutoff (so the CAR is useful in more cases) but not so low that it is uninformative. The results in the tables show that increasing C yields stronger results, but once C reaches .01 the results tend to deteriorate. This is because the number of mergers that have rival CARs that meet the criteria becomes too low. Thus, the effect of the number of mergers falling outweighs the benefit of have clearer impacts on rivals. Third, the results using the two different time horizons are very similar. In the tables that follow, we report only the results for the one-year horizon. In unreported results, we confirmed that results are essentially the same using the two-year horizon.

Table 3 goes beyond considering whether R&D intensity rises or falls by examining how the magnitude of the change in R&D intensity depends on whether the rival CAR is positive. Tables 2a and 2b suggest that R&D intensity is more likely to be lower if the CAR is positive; Table 3 quantifies how much lower. In all of the results that follow, we focus on the intermediate definitions of a rival from Tables 2a and 2b. Columns 2, 4 and 6 regress the change in R&D intensity on a dummy variable for whether the rival CAR is positive. The point estimate of the slope coefficient ranges from $-.011$ to $-.022$; the models estimate that R&D intensity is from 1.1 to 2.2 percentage points lower in the year after merger completion if the rival CAR is positive. Given that the average post-merger acquirer R&D intensity is approximately 15% (see Table 1), this is a substantial drop (if sales could be held constant, 1.1-2.2 percentage points

would represent a reduction in R&D spending ranging from 7-15%). Columns 3, 5 and 7 introduce several control variables that might impact the change in R&D intensity. Few of these variables are statistically significant (confirming how difficult it is to forecast changes in R&D intensity), and the coefficients on the rival CAR effects are either unchanged or become stronger. The main control variable that appears relevant is the change in the acquirer's R&D intensity in the year prior to the merger announcement, which has a significantly negative impact in all models. This suggests mean reversion in R&D intensity.

Table 4 considers how the magnitude of the change in R&D intensity depends on the magnitude of the change in the CAR. The CAR has a statistically significant negative effect in all models. The standard deviation of the CAR is approximately .012 and the magnitude of the CAR effects in Tables 4a and 4b range from -.37 to -.69, so increasing the CAR by a standard deviation reduces the R&D intensity from .4 to .8 percentage points. Including controls in the models strengthens the CAR effect, and as in Table 3 the only control variable that has a consistently significant impact is the pre-announcement change in the acquirer's R&D intensity.

Robustness

One potential concern is that industry or economy-wide changes that occur around each merger account for the observed changes in R&D intensity. We include year-of-announcement effects among the control variables, but these might be inadequate because the timing of each merger's completion varies. In unreported regressions we confirmed that the results in Tables 3-4 remain essentially unchanged if we use the deviation from the median change in R&D intensity in the announcement-to-completion period as the dependent variable, where the median change is computed using only those firms not involved in any merger announcement during the

announcement quarter. The median change in R&D intensity should capture any industry or economy-wide impacts that could impact changes in the acquirer's R&D intensity.

Another potential concern is that the change in R&D intensity might be simple to predict by dividing the pre-merger sum of the merging firms' R&D expenditures by the pre-merger sum of their sales to project what the R&D intensity of the merged firm would be and then subtracting the pre-merger R&D intensity of the acquirer to project the change in the acquirer's R&D intensity. In such a case, forecasting would not require metrics like rival CARs. We cannot construct the simple projection in most of our cases because we lack sufficient data on the target firms, but in unreported results we re-estimated the models in Tables 3-4 using the simple projection as one of the independent variables. The simple projection is extremely insignificant in every model. This suggests that synergies in R&D and other factors discussed in Section 2 cause the acquirer to adjust its R&D intensity post-merger, which makes other metrics useful.

It seems unlikely that the results we obtain on rival CARs are due to selection or endogeneity effects. Rival CARs are not a choice variable of the acquiring firm, and it is implausible that an acquirer would adjust its post-completion R&D intensity in response to how rival firm values responded to the merger announcement. However, it is still worth confirming that the mergers impact R&D intensity. It is possible that an acquirer would already have a plan to change the R&D intensity whether the merger occurs or not, and the change in R&D intensity we observe is not actually attributable to the merger. It would be hard to account for the statistical relationships we find in Tables 2a-4 in such a case, but we attempt to construct a test. To do this we match acquirers to comparable firms and compare changes in R&D intensity.

Table 5 presents nearest-neighbor matching analyses. Each acquirer is matched to a single nearest neighbor using the quarter of the announcement and a vector of firm

characteristics: the pre-announcement 4-quarter R&D intensity, the change in the R&D intensity and the change in sales from 5-8 quarters ago to the most recent 1-4 quarters prior to the announcement, the profit margin (net income/sales), a measure of available liquidity (cash and near-cash/assets), the change in the firm's value over the prior year, the natural logs of sales and firm value, and dummy variables for non-U.S. firm, biotech, and non-pharm/non-biotech. The results suggest that the merger does not have much impact on the change in the acquirer's R&D intensity when the CAR is positive, but the change in the acquirer's R&D intensity is significantly higher than the neighbor's when the rival CAR is below $-C$. On the whole, our results suggest that the changes in R&D intensity that we observe can be attributed to the mergers, particularly when the CARs are negative.

V. Conclusion

Ideally we would like to assess the incremental contribution that rival CARs could make to agency decision making and/or any cost efficiencies that might be generated if using rival CARs could replace more costly evaluation procedures. If rival CARs would never impact decisions or costs, there would be no point in including them in the agency's toolkit. Unfortunately, we lack a way to assess these impacts. It would be necessary to have a detailed understanding of the information and procedures the agencies employed in each individual case and then determine how considering rival CARs might have impacted the process and outcomes. We do know that innovation effects have become increasingly important in merger analyses over time. According to Gilbert (2006), the agencies alleged adverse impacts to innovation in approximately 3% of merger challenges in 1990-94, but this percentage rose to 18% in 1995-99 and 38% in 2000-03. By 2003, the agencies always considered innovation effects when the merger involved R&D intensive firms. However, Gilbert (2006) also notes that innovation was rarely central to the

enforcement decision, and most challenges were due to projected impacts on prices.[20] Gilbert and Tom (2001) suggest that considering innovation has impacted the agencies' analysis and discussion more than the outcomes of cases, and it seems likely that rival CARs could have a similar impact. Further, Katz and Shelanski (2007) emphasize that most cases have focused on innovations that were essentially complete. In such cases, the innovations will impact product market competition fairly soon, so the analysis can focus on the impact on the product market outcomes. In contrast, the R&D intensities that we focus on would be expected to have long-run impacts on market outcomes but essentially no short-run impacts on product market competition. This could be useful if it allows the agencies to consider an impact that has been underemphasized in their analyses.

[20] Gilbert (2006) focuses on adverse effects on innovation, and Gilbert and Tom (2001) also present evidence that considering innovation either has no impact or leads to challenges in more markets and broader remedies. In principle, considering innovation could sometimes result in leniency: it could be desirable to tolerate higher prices if doing so encourages innovation (Filson and Gretz (2004) provide a formal treatment).

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Table 1. Summary Statistics. 75 observations except where noted. For dummy variables, the table entry is the proportion of cases for which the variable takes the value 1.

Variable	Mean	Standard Deviation	Median	Min	Max
Pre-merger acquirer R&D intensity	.15	.062	.15	.025	.42
Post-merger acquirer R&D intensity (using 4 quarters)	.15	.062	.15	.029	.40
Post-merger acquirer R&D intensity (using 8 quarters) (73 obs)	.15	.063	.15	.026	.34
Change in R&D intensity using 4 quarters	.0020	.025	.0015	-.10	.097
Change in R&D intensity is positive (using 4 quarters)	.52				
Change in R&D intensity using 8 quarters (73 obs)	.0013	.022	.0044	-.11	.069
Change in R&D intensity is positive (using 8 quarters) (73 obs)	.55				
CAR[-1,1]	.00059	.012	.00092	-.030	.035
CAR[-1,1] is positive	.53				
Nations differ	.39				
Initial share in the target is positive	.067				
Target is a biotech	.24				
Target is other (not a pharma or biotech firm)	.12				
Value of the transaction ($M)	5,048	9,897	1,459	500	67,286
Pre-announcement change in R&D intensity	-.00059	.028	-.0011	-.11	.14
Acquirer sales ($M)	21,999	18,402	22,288	442	66,205
Pre-announcement change in sales	.13	.18	.11	-.32	.64
Acquirer profit margin	.19	.092	.18	-.049	.55
Acquirer liquid assets to assets	.22	.14	.19	.032	.75
Acquirer value change	.085	.28	.090	-.60	1.18
Acquirer HHI	3,500	1,625	3,413	1,308	10,000
Year:					
2003	.11				
2004	.08				
2005	.15				
2006	.16				
2007	.08				
2008	.09				
2009	.17				
2010	.16				

*, ** and *** indicate statistical significance at the 10, 5 and 1% levels.

Table 2a. Directional Impacts Using 4 Quarters Post-Completion. The table entry is the proportion of cases in which the R&D intensity computed using the 4 quarters after merger completion is higher than the R&D intensity computed using the 4 quarters prior to the merger announcement.

	Proportion if the CAR exceeds C (number of cases)	Proportion if the CAR is below –C (number of cases)	Significance levels of the test of equality of the two proportions
All rivals:			
C = 0	.43 (40)	.63 (35)	10
C = .001	.39* (36)	.64 (33)	5
C = .005	.46 (24)	.64 (22)	-
C = .01	.45 (11)	.83** (12)	10
Rivals with ATC overlap > 0			
C = 0	.32*** (38)	.76*** (34)	1
C = .001	.30*** (33)	.79*** (29)	1
C = .005	.43 (21)	.80*** (20)	5
C = .01	.50 (14)	.80* (10)	No test
Rivals with ATC overlap > 1%			
C = 0	.34** (38)	.74*** (34)	1
C = .001	.29*** (34)	.77*** (30)	1
C = .005	.38 (21)	.85*** (20)	1
C = .01	.58 (12)	.80* (10)	No test
Rivals with ATC overlap > 5%			
C = 0	.33*** (40)	.78*** (32)	1
C = .001	.32** (37)	.77*** (31)	1
C = .005	.32** (25)	.76** (21)	1
C = .01	.55 (11)	.81** (16)	10
Rivals with ATC overlap > 10%			
C = 0	.37* (35)	.69** (29)	5
C = .001	.33** (33)	.69* (26)	1
C = .005	.27*** (26)	.73** (22)	1
C = .01	.38 (13)	.80** (15)	5

*, ** and *** indicate statistical significance at the 10, 5 and 1% levels. In columns 2 and 3, the significance test compares the proportion of cases in which R&D intensity rises to the overall sample proportion (.52). These tests are based on the exact binomial distribution so they are robust to small sample sizes. The tests in column 4 use the normal approximation to the binomial distribution. For this approximation to be valid, np and n(1-p) must be at least 5 in both subsamples under the null hypothesis of no difference; the entry in column 4 is "No test" when this condition is not satisfied.

Table 2b. Directional Impacts Using 8 Quarters Post-Completion. The table entry is the proportion of cases in which the R&D intensity computed using the 8 quarters after merger completion is higher than the R&D intensity computed using the 4 quarters prior to the merger announcement.

	Proportion if the CAR exceeds C (number of cases)	Proportion if the CAR is below –C (number of cases)	Significance levels of the test of equality of the two proportions
All rivals:			
C = 0	.51 (39)	.59 (34)	-
C = .001	.47 (36)	.59 (32)	-
C = .005	.46 (24)	.64 (22)	-
C = .01	.45 (11)	.83** (12)	No test
Rivals with ATC overlap > 0			
C = 0	.36** (36)	.76*** (34)	1
C = .001	.35** (31)	.76** (29)	1
C = .005	.40 (20)	.80** (20)	1
C = .01	.43 (14)	.90** (10)	No test
Rivals with ATC overlap > 1%			
C = 0	.42* (36)	.71** (34)	5
C = .001	.38** (32)	.73** (30)	1
C = .005	.40 (20)	.85*** (20)	1
C = .01	.50 (12)	.90** (10)	No test
Rivals with ATC overlap > 5%			
C = 0	.41* (39)	.74** (31)	1
C = .001	.42* (36)	.73** (30)	1
C = .005	.38* (24)	.80** (20)	1
C = .01	.45 (11)	.87** (15)	No test
Rivals with ATC overlap > 10%			
C = 0	.44 (34)	.68 (28)	10
C = .001	.41* (32)	.68 (25)	5
C = .005	.32** (25)	.71* (21)	1
C = .01	.38 (13)	.71 (14)	No test

*, ** and *** indicate statistical significance at the 10, 5 and 1% levels. In columns 2 and 3, the significance test compares the proportion of cases in which R&D intensity rises to the overall sample proportion (.55). These tests are based on the exact binomial distribution so they are robust to small sample sizes. The tests in column 4 use the normal approximation to the binomial distribution. For this approximation to be valid, np and n(1-p) must be at least 5 in both subsamples; the entry in column 4 is “No test” when this condition is not satisfied.

Table 3. Regression Analysis. Dependent variable is the difference in R&D intensity comparing the 4 quarters after completion to the 4 quarters prior to the announcement. White standard errors are in parentheses.

	ATC overlap > 0	ATC overlap > 0	ATC overlap > 1%	ATC overlap > 1%	ATC overlap > 5%	ATC overlap > 5%
CAR is positive	-.015** (.0060)	-.022*** (.0048)	-.011* (.0061)	-.015*** (.0055)	-.018*** (.0058)	-.020*** (.0051)
Nations differ		9.7e-06 (.0047)		.0020 (.0048)		.0059 (.0046)
Initial share positive		.011 (.0074)		.0063 (.0080)		.0030 (.0088)
Target is a biotech		-.0022 (.0058)		-.0045 (.0066)		-.0040 (.0060)
Target is other		.00021 (.0054)		-.00020 (.0063)		-.0013 (.0059)
Ln(value)		-.00069 (.0018)		-.00055 (.0018)		-.0014 (.0018)
R&D Intensity Pre-announcement		-.072 (.071)		-.044 (.073)		-.026 (.069)
R&D change		-.47*** (.17)		-.45*** (.17)		-.42*** (.16)
Ln(sales)		.0036 (.0031)		.0029 (.0032)		.0027 (.0031)
Sales change pre-announcement		.013 (.019)		.014 (.019)		.021 (.018)
Profit margin		.031 (.032)		.026 (.036)		.031 (.032)
Liquid assets to assets		.042 (.038)		.041 (.040)		.039 (.038)
Acquiror value change		.00074 (.012)		.0026 (.012)		.00081 (.012)
Ln(Acquiror HHI)		-.0051 (.012)		-.00040 (.012)		.00082 (.012)
Constant	.010* (.0056)	.028 (.10)	.0076 (.0055)	-.0085 (.11)	.012** (.0046)	-.014 (.10)
Year Effects Included	No	Yes	No	Yes	No	Yes
R-squared	.090	.58	.044	.52	.12	.57
Number of observations	72	70	72	70	72	70

*, **, *** indicate significance at the 10%, 5% and 1% levels

Table 4. Regression Analysis. Dependent variable is the difference in R&D intensity comparing the 4 quarters after completion to the 4 quarters prior to the announcement. White standard errors are in parentheses.

	ATC overlap > 0	ATC overlap > 0	ATC overlap > 1%	ATC overlap > 1%	ATC overlap > 5%	ATC overlap > 5%
CAR	-.38** (.18)	-.60*** (.15)	-.44** (.20)	-.69*** (.17)	-.37* (.22)	-.56*** (.18)
Nations differ		.0018 (.0052)		.0031 (.0052)		.0030 (.0053)
Initial share positive		.0081 (.0088)		.010 (.0088)		.0068 (.0090)
Target is a biotech		-.0033 (.0062)		-.0033 (.0062)		-.0033 (.0060)
Target is other		-.0028 (.0068)		-.0016 (.0070)		-.0017 (.0070)
Ln(value)		-.0021 (.0019)		-.0020 (.0019)		-.0024 (.0018)
R&D Intensity Pre-announcement		-.063 (.072)		-.057 (.070)		-.064 (.070)
R&D change		-.41*** (.14)		-.41*** (.15)		-.38*** (.14)
Ln(sales)		.0035 (.0033)		.0037 (.0033)		.0032 (.0032)
Sales change pre-announcement		.021 (.019)		.019 (.018)		.023 (.018)
Profit margin		.031 (.034)		.021 (.035)		.033 (.033)
Liquid assets to assets		.044 (.041)		.047 (.040)		.043 (.038)
Acquiror value change		.0066 (.014)		.0066 (.013)		-.00066 (.013)
Ln(Acquiror HHI)		-.00035 (.012)		.00085 (.012)		.0018 (.011)
Constant	.0027 (.0031)	-.0097 (.10)	.0026 (.0030)	-.023 (.10)	.0025 (.0030)	-.022 (.097)
Year Effects Included	No	Yes	No	Yes	No	Yes
R-squared	.041	.52	.047	.54	.055	.54
Number of observations	72	70	72	70	72	70

*, **, *** indicate significance at the 10%, 5% and 1% levels

Table 5. Nearest Neighbor Matching Tests. The table entry is the average treatment effect on the treated (ATET). The results compare the change in R&D intensity of the acquirers to that of the neighbors. The change in R&D intensity is computed by comparing the 4 quarters after merger completion to the 4 quarters prior to the merger announcement. Matching employs a vector of firm characteristics in addition to the quarter of the merger announcement to select a single nearest neighbor for each merger. Robust standard errors are in parentheses.

	Average difference if the CAR exceeds C (matching on the quarter and a vector of firm characteristics)	Average difference if the CAR is below –C (matching on the quarter and a vector of firm characteristics)
Rivals with ATC overlap > 0		
C = 0	.000040 (.0034)	.014* (.0080)
C = .001	-.0013 (.0037)	.014 (.0088)
C = .005	.0018 (.0040)	.020* (.011)
C = .01	.0059 (.0052)	.014 (.011)
Rivals with ATC overlap > 1%		
C = 0	.0021 (.0041)	.011 (.0077)
C = .001	-.00082 (.0036)	.016** (.0081)
C = .005	.0015 (.0054)	.020* (.011)
C = .01	.0065 (.0056)	.015 (.011)
Rivals with ATC overlap > 5%		
C = 0	.00021 (.0043)	.012 (.0081)
C = .001	-.0035 (.0037)	.012 (.0084)
C = .005	-.0038 (.0043)	.020** (.010)
C = .01	-.00030 (.0044)	.027** (.012)

*, ** and *** indicate statistical significance at the 10, 5 and 1% levels.