

Mergers and Acquisitions in the Pharmaceutical and Biotech Industries

Patricia M. Danzon^{a,*}, Andrew Epstein^b and Sean Nicholson^c

^aUniversity of Pennsylvania, USA

^bYale University, USA

^cCornell University, USA

We examine the determinants and effects of M&A activity in the pharmaceutical/biotechnology industry using SDC data on 383 firms from 1988 to 2001. For large firms, mergers are a response to expected excess capacity due to patent expirations and gaps in a firm's product pipeline. For small firms, mergers are primarily an exit strategy in response to financial trouble (low Tobin's q , few marketed products, low cash–sales ratios). In estimating effects of mergers, we use a propensity score to control for selection based on observed characteristics. Controlling for merger propensity, large firms that merged experienced a similar change in enterprise value, sales, employees, and R&D, and had slower growth in operating profit, compared with similar firms that did not merge. Thus mergers may be a response to trouble, but they are not a solution. Copyright © 2007 John Wiley & Sons, Ltd.

INTRODUCTION

A significant body of economic research has examined the reasons for mergers and their effects—whether mergers add, destroy or merely redistribute value. Economic theory suggests several, not mutually exclusive reasons for mergers, including economies of scale and scope, acquisition of specific assets, and the market for corporate control. These general theories have difficulty explaining the fact that mergers have historically occurred in industry-specific waves. To explain these waves, several authors have suggested shocks, due to such factors as technological advances or deregulation, that are often industry specific and create excess capacity or other inefficiencies in the current configuration of resources, which leads to within-industry correla-

tion in merger activity (for example, Jensen, 1993; Mitchell and Mulherin, 1996; Hall, 1999; Andrade and Stafford, 2004). These studies shed some light on cross-industry variation in merger activity but they do not address within-industry variation.

Assuming that mergers are intended to create value, there is no consensus on whether expectations at the time of merger are actually realized in the longer term and, if so, how this value is created. In their review of empirical evidence on mergers, Andrade *et al.* (2001) report a quasi difference-in-differences estimate of operating margin before and after merger, for merged firms versus the industry average. They conclude that ‘mergers improve efficiency and that the gains to shareholders at announcement accurately reflect improved expectations of future cash flow performance. ... (But) the underlying sources of gains from mergers have not been identified.’

In this paper, we examine the determinants and effects of M&A activity in the pharmaceutical–biotechnology industry during 1988–2001. The value of M&A during this period exceeded \$500

*Correspondence to: Patricia M. Danzon, Celia Moh Professor, Health Care Department, The Wharton School, University of Pennsylvania, 207 Colonial Penn Center, 3641 Locust Walk, Philadelphia, PA 19104, USA.

billion, which led to a significant increase in the 10-firm share of global sales, from 20% in 1985 to 48% in 2002. Pharmaceutical mergers are often rationalized by claims of economies of scale and scope in R&D and marketing. The pharmaceutical industry is research-intensive, with an average R&D to sales ratio of 18%, compared to 4% for US manufacturing industry overall (Pharmaceutical Researchers and Manufacturers of America, 2003). However, despite rising R&D spending, the number of compounds approved per year by the Food and Drug Administration (FDA) has deteriorated since 1996, and the share of these compounds originated by large firms has decreased. This evidence of apparently declining R&D productivity, particularly for large firms, casts doubt on the effectiveness of mergers and the economies of scale hypothesis more generally.

Two recent event studies of pharmaceutical mergers found mixed evidence of abnormal stock returns at the time of merger announcement. Ravenscraft and Long (2000) performed an event study of 65 pharmaceutical mergers between 1985 and 1996. They found abnormal stock returns around the announcement date of 13.3% for the target firm, -2.1% for the bidding firm, but effects not significantly different from zero for the combined firm. For large horizontal mergers and cross-border mergers, however, the combined abnormal returns were positive.¹ Ravenscraft and Long show that target firms experienced negative cumulative stock return in the 18 months prior to merger, compared to an index of non-merging pharmaceutical firms; however, they do not analyze the firm-specific determinants of mergers nor whether the positive expectations at announcement are actually realized in the longer term and, if so, how shareholder value is created.

Higgins and Rodriguez (2005) focus on mergers as a means to outsource R&D in a sample of about 60 public firms that formed at least one strategic alliance between 1994 and 2001. In this selected sample, they find that firms with a high 'desperation index' (expected years of patent life, including marketed and pipeline products) were more likely to acquire another firm. Among 160 acquisitions that were selected as being R&D-related, they find positive announcement period abnormal returns to both the acquirer (3.9%) and to the target firm (16.0%), and that these returns are positively correlated with prior alliances between the parties. Higgins and Rodriguez also find that 71% of

acquirers maintained or improved their product pipelines in the first year post-merger. They conclude that pre-merger alliances are a means of reducing information asymmetries and hence increasing the value of M&A undertaken to outsource R&D. While this analysis provides insights for a selected subset of pharma-biotech mergers, it does not address the longer term effects of these mergers, the broader set of mergers that are not included in the study, and does not control firm characteristics that affect the probability of merging.

We study a more comprehensive sample of pharma-biotech mergers and use a two-part estimation strategy. The first stage tests various hypothesized determinants of M&A activity. The second stage measures the effects of merger on firm performance, using a propensity score to control for probability that each firm would merge. Specifically, our sample includes 383 firms in the pharma-biotech industry and 165 'transforming mergers', defined as transactions that are sufficiently large that post-merger integration will require reorganization and potentially have an observable impact on accounting measures of performance. The analysis distinguishes between small biotech firms and large pharmaceutical firms, because small firms, which account for almost half the firms in our sample, face very different production and cost functions.

Our analysis is designed to test several hypotheses to explain mergers based on existing literature (for example, Jensen, 1986; Holmstrom and Kaplan, 2001), including: economies of scale or scope; specific assets or capacities (for example, foreign subsidiaries) that can be acquired more efficiently than through internal growth; imperfect agency controls that permit acquisitions by managers with excess cash; and the market for corporate control, in which acquisition is a mechanism to transfer assets to more efficient uses and/or management.

We also test a variant of the excess capacity theory of mergers as applied to large pharmaceutical firms. Previous literature has suggested that excess capacity is a rationale for merger to restructure assets in industries that experience shocks due to technological change or deregulation (Jensen, 1993; Mitchell and Mulherin, 1996; Hall, 1999; Andrade and Stafford, 2004). We argue that an analogous but firm-specific capacity-adjustment motive for merging occurs when a pharmaceutical firm experiences patent expirations and gaps in its pipeline of new drugs that make

current levels of human and physical capital potentially excessive. Essentially, a fully-integrated pharmaceutical firm has two production activities. The first is R&D, which uses labor, capital, and various technologies to discover new compounds and obtain regulatory approval.² R&D investment by itself generates no revenue, and is characterized by a high degree of *ex ante* uncertainty regarding the ultimate scientific and market potential of new compounds. The second activity is production, marketing and sales, for which approved compounds, obtained from internal R&D, in-licensing or acquisition, are an essential input. Patent protection on new drugs on average lasts for roughly 12 years after market approval. Once the patent expires, in the US generic competitors usually rapidly erode the originator firm's sales.³ Since a few blockbuster drugs often account for 50% or more of a firm's revenues, patent expiration on one or more of these compounds can decimate the firm's revenues within a few months, unless the firm can replace the patent-expired compounds with new compounds. Thus, if a firm is faced with patent expirations and has failed to generate or in-license new compounds to replace them, its investment in specialized labor and capital in sales and marketing becomes unproductive. Since large firms finance their R&D almost exclusively from current earnings (Vernon, 2005), patent expirations may also disrupt the funding of R&D.

For an integrated pharmaceutical company that faces patent expirations and gaps in its pipeline, merging with a firm that has pipeline drugs but lacks adequate marketing and sales capacity to optimally launch these drugs may create value.⁴ Merger may also permit elimination of duplicative functions, thereby offering cost savings in the short term to offset the negative effect of declining revenues on net profits and generating economies of scale in the longer run. Although a pharmaceutical firm that faces excess capacity due to lack of compounds could reduce staff and sell assets without merging, this may entail loss of quasi-rents on investments in firm-specific human and physical capital, if this capital has specialized skills and the compound shortfall is expected to be transitory (Oi, 1962). The loss of quasi-rents may be reduced if the cuts are made in the context of a merger that brings in new compounds and facilitates restructuring that permits the elimination of duplicative functions and selection of the best people for those jobs remain.⁵

Our analysis of determinants of M&A uses a multinomial logit to distinguish being an acquirer, a target or involved in a pooling of equals. For large pharmaceutical firms, we find evidence supporting the hypothesis that mergers are, in part, a response to expectations of excess capacity that will decrease future productivity. Large firms with a relatively low Tobin's q (the ratio of the market to book value of a firm's assets), and thus firms with a low expected growth rate of cash flows, are more likely to acquire other firms. Andrade and Stafford (2004), on the other hand, find that over the 1970–1994 period firms (from the pharma–biotech as well as other industries) with a high Tobin's q were more likely to undertake both mergers and non-merger investment. Controlling for the age of a firm's portfolio of drugs, which is a more direct measure of expected excess capacity than the Tobin's q , the coefficient on the 'drug age' variable is positive and significant and the Tobin's q coefficient remains negative but is insignificant. This is consistent with the hypothesis that the anticipation of patent expirations and the associated shock to revenues and excess labor capacity is a significant motive for acquisitions. Relatively large firms, as measured by market value, are more likely to acquire another firm, be acquired, and be involved in a pooling merger. This suggests that if achieving economies of scale is a rationale for merging, firms perceive that optimum scale exceeds the mean size in our large-firm sample. Firms that experienced a relatively large increase in operating expenses in the prior three years were more likely to be involved in a pooling merger, suggesting that merging may be a useful context for eliminating excess costs and/or that mergers transfer assets to firms with (more) competent management.⁶

For relatively small firms (firms with at least \$20 million in sales for at least one year between 1988 and 2000 but with an enterprise value always less than \$1 billion), our results suggest that firms that are financially weak are at risk of being acquired. Financially strong firms (as measured by relatively high Tobin's q , number of marketed drugs and high ratio of cash to sales) are more likely not to engage in M&A at all.

Our analysis of post-merger performance tests for effects on growth in inputs (employment and R&D investment) and accounting performance (growth in sales, operating profit and market value) for up to four years after the event.

We use accounting data rather than an event study to examine post-merger performance for two reasons. First, almost three-quarters of the mergers in our sample involve a private firm or a subsidiary of a public firm. Analysis based on accounting data can include these mergers, whereas an event study would be restricted to transactions between public firms, or subsidiaries of public firms that report a separate stock price. Second, we are interested in measuring long term performance effects of mergers, and identifying the factors that contribute to performance changes, if any, whereas event studies at best capture expectations of future net revenue growth, measured at the time of merger announcement.

The results strongly confirm the importance of controlling for pre-merger firm characteristics. If we assume mergers are exogenous, we would conclude that merged firms have low growth rates of sales and R&D expenditures in the first year following a merger, relative to firms that do not merge. However, firms with a high merger propensity experience low growth of sales, employees, and R&D expenditures in the subsequent one, two, and three years, regardless of whether they actually merge. Controlling for the merger propensity, mergers have very little effect on a firm's subsequent growth in sales, employees, R&D expenditures, and enterprise value for large firms. For a large firm with the mean merger propensity, however, a merger is predicted to reduce operating profit by 52.3% in the third year following a merger relative to an otherwise similar firm that did not merge. This suggests that post-merger integration may absorb more resources and managerial effort than anticipated by most managers.

In the small firm sample, firms with a high merger propensity experienced relatively low growth in employees and R&D regardless of whether they merged, consistent with the earlier finding that strong firms tend not to engage in M&A. Merger was not an effective growth strategy for a firm with the mean propensity of merging. For such a firm, we predict that a merger would result in a 29% reduction in R&D in the first full year following a merger relative to an otherwise similar firm that did not merge. This suggests that resources may be diverted from R&D immediately post-merger. Conversely, for firms with a very high merger propensity, merging is predicted to increase employees and R&D investments by 21 and 30%, respectively, in the first full year following a

merger, compared to similar firms that did not merge. Thus, small firms that faced the greatest distress appeared to increase inputs following a merger, possibly because the merger provided access to resources that these small firms lacked. There is no evidence of improved performance, however, at least by the measures and time frame included in this study.

BACKGROUND AND RELATED RESEARCH

Previous studies of pharmaceutical mergers by Ravenscraft and Long (2000) and Higgins and Rodriguez (2006) were described earlier. Both analyze a more limited sample of mergers and use an event study of abnormal returns to measure expected merger impact at the time of merger announcement, rather than measuring long term performance controlling for selection bias. Moreover, neither study tests alternative hypotheses of determinants of mergers.

Most similar to our study is Hall's (1999) analysis of the determinants of mergers and the real effects of mergers for a large, multi-industry sample of manufacturing firms between 1957 and 1995, using a propensity score to control for pre-merger characteristics when estimating the effects of merger. She uses a Cox proportional hazards model, treating merger, going private and bankruptcy as competing methods of exit, and separate logit models for probability of acquiring or being acquired. She finds that in general firms that were acquired by other public firms do not differ significantly from firms that remained independent. For the sample as a whole, there is no significant effect of merger on R&D investment, but for firms with the highest propensity to merge, those that did merge experienced more rapid post-merger growth in R&D than those that did not merge.⁷ By contrast, in previous work on an earlier sample without controlling for pre-merger characteristics (propensity to merge), Hall (1988) found little effect of mergers on R&D, which she interpreted as evidence against economies of scale in R&D. Like many other industries, the pharmaceutical industry experienced a high rate of M&A activity in the 1980s and 1990s. Only three of the top 10 US companies have not been involved in a major horizontal acquisition during the last 15 years. However, Hall (1999) cites the pharmaceutical industry as an exception to the norm of

restructuring driven by excess capacity and low market value-to-book value ratios (Tobin's q), but does not offer other reasons for pharmaceutical mergers.

Several studies have addressed the issue of self-selection and endogeneity of the decision to change corporate structure when measuring the effects of such changes. Similar to Hall (1999), Dranove and Lindrooth (2003) use a propensity score approach to control for self-selection when estimating the effects of hospital mergers. In a multi-industry study of returns to firm diversification, Campa and Kedia (2002) use instrumental variables, firm fixed effects and a Heckman selection correction as alternative econometric techniques to control for endogeneity of the decision to diversify. They show that controlling for self-selection reduces estimates of the discount on diversified firms that are found in studies that fail to control for selection. Similarly, Villalonga (2004) finds that using a propensity score to control for *ex ante* firm characteristics eliminates evidence of a diversification discount.

Our study contributes to the evidence on determinants of mergers by testing several competing hypotheses to explain a broad sample of pharmaceutical and biotechnology mergers. We

also restate the excess capacity hypothesis for the context of large pharmaceutical firms and find consistent supporting evidence. We estimate the effects of mergers on several measures of inputs and financial performance over a three-year period post merger, controlling for *ex ante* observable characteristics using a propensity score. We find no evidence that merger improves firm performance but we do show that failure to control for *ex ante* conditions leads to overestimates of the negative effects of mergers.

EVIDENCE AND HYPOTHESES FOR PHARMACEUTICAL MERGERS

Table 1 reports the number of unique transforming mergers by year between 1998 and 2000 for our sample of biotech and pharmaceutical firms.⁸ There were a total of 165 transforming mergers, defined as mergers of \$500 million or more, or transactions that represent 20% or more of a firm's pre-merger enterprise value.⁹ These acquisitions accounted for over \$500 billion dollars (in 1999 dollars). The number of transforming mergers and the market value of the mergers increased throughout the 1990s. Six percent of firms were

Table 1. Merger and Acquisition Activity by Year

Year	Number of firms in sample	Number of unique transforming mergers	percent of firms involved in transforming merger (%)	Total market value of mergers (\$ million)	Merger value as a percent of industry's market value (%)	Mean merger value as percent of acquiring firm's value (%)	Mean merger value as percent of target firm's value (%)
1988	121	3	2.5	1309	0.6	33.2	n/a
1989	125	12	7.2	27 971	11.8	44.7	121.0
1990	134	9	5.2	15 843	5.1	28.8	60.6
1991	190	6	4.2	1924	0.4	16.7	112.0
1992	196	3	2.6	1325	0.2	32.5	92.2
1993	212	5	1.9	8385	1.2	16.7	n/a
1994	216	18	9.7	37 174	5.9	22.8	110.0
1995	243	12	6.2	36 732	5.2	19.4	n/a
1996	267	13	5.2	36 714	4.0	29.4	88.4
1997	286	16	5.2	20 492	1.7	35.7	54.0
1998	288	21	8.3	67 741	4.5	27.3	79.1
1999	302	25	9.6	157 708	7.7	38.7	118.0
2000	228	22	10.8	100 750	5.0	37.2	124.0
Total/average		165	6.5	514 068	4.4	29.1	96.9

Note: We define a transforming merger as one where the price exceeded \$500 million or represented at least 20% of the buying and/or selling firm's market value. If a merger involves two firms in the sample, we record it in this table as a single unique merger, but in the regression analysis as a merger for both firms. The market value of a firm is defined as the market value of its equity plus the book value of its long-term debt. 'n/a', or not available, indicates the data are missing. The number of firms involved in transforming merger can differ from the number of unique mergers if two firms from the sample were involved in a merger and/or if a single firm was involved in multiple mergers in a particular year.

involved in a merger in a year, on average, and the value of the acquisition represented 29% of the acquirer's market value.

Several standard economic hypotheses are relevant to understanding the pharmaceutical–biotech merger experience. Pharmaceutical acquisitions of biotech companies are consistent with an asset-specific motive, as are cross-national acquisitions, assuming that it is cheaper, quicker and more effective to buy a local company with established connections than to build a foreign subsidiary. The horizontal mergers between large pharmaceutical companies are often rationalized by economies of scale and scope but the validity of these claims remains questionable, given the growing share of new compounds produced by smaller companies and the recent relatively high valuations of these smaller firms compared to larger pharmaceutical companies. The market power hypothesis is implausible, given the low overall level of concentration in this industry; although concentration is higher at the therapeutic category level (e.g. cardiovascular), the US and European Union competition authorities frequently require divestiture of compounds in therapeutic areas where the merger might significantly lessen competition. Thus, these theories seem inadequate to explain the horizontal mergers between large pharmaceutical firms.

An alternative hypothesis to explain these larger pharmaceutical mergers is the threat of excess capacity due to patent expirations and gaps in the firm's pipeline of compounds, which makes current levels of human and physical capital potentially excessive. This hypothesis is analogous to the excess capacity hypothesis proposed by Hall (1999, citing Blair, Shary and others), except that the causes of excess capacity in the pharmaceutical industry are firm-specific and reflect the atypically critical role of patents in defining product life-cycles and particularly end of economic life for pharmaceutical products. Hall argues that firms in the 1980s engaged in various forms of restructuring as a response to finding their existing capital stock excessive relative to the returns it could generate, as measured by values of Tobin's q less than one. The precipitating factors for the industries studied by Hall—increased foreign competition and high real interest rates—cannot explain pharmaceutical mergers.

Excess capacity due to looming patent expirations is less relevant for small biotech firms, which

typically specialize in R&D devoted to either drug discovery or discovery-related technologies that may be of value to larger firms. The small firms raise capital through external offerings of private or public equity or alliances with larger companies, since they often have no products to generate retained earnings. For those firms that experience shocks that undermine their ability to raise cash, selling the firm and its technologies may be an attractive exit strategy for the seller and an efficient growth strategy for the acquirer. By the mid 1990s, the more mature biotech firms no longer specialized in discovery but had become fully integrated, manufacturing and marketing their own products, hence they faced the same pipeline issues as large pharmaceutical companies.

DATA

Our analysis draws on a number of different data sets. We define an initial universe of pharmaceutical and biotech firms as any company in the Standard & Poor's Compustat or Global Vantage databases with a primary biotechnology or pharmaceutical SIC code (2834, 2835, or 2836). We then added firms listed in the Merrill Lynch Pharma Industry Report, which tracks the largest pharmaceutical and biotech firms, in order to include pharmaceutical divisions of conglomerate companies where the company's primary SIC code is outside of the pharmaceutical and biotech industries.¹⁰ After removing firms with missing financial information, we were left with a universe of 896 pharmaceutical and biotech firms.

To limit our sample to firms with significant economic value, we excluded firms that never had net sales of at least \$20 million (1999 dollars) in any year during the sample period and never had an enterprise value of at least \$1 billion. This restriction reduced our universe of firms to 383. We then split these firms into two sub-samples. 'Large' firms are those that reached the \$1 billion enterprise value threshold ($n = 213$) in at least one year during our study period, whereas 'small' firms had sales of at least \$20 million in at least one year but never had an enterprise value of \$1 billion or more ($n = 170$). Financial data are from the Standard & Poor's Compustat Industrial files and GlobalVantage Industrial/Commercial files for 1985–2001.¹¹ Information on the number of drugs a firm is selling and the year the drugs were

Table 2. Sample Means and Standard Deviations

	Large-firm sample (<i>n</i> = 1591 firm years)		Small-firm sample (<i>n</i> = 1492 firm years)	
	Mean	Standard deviation	Mean	Standard deviation
Tobin's <i>q</i> , top-coded at 20	3.17	2.60	2.88	2.82
Indicator for Tobin's <i>q</i> > 20	0.006	0.075	0.014	0.118
Number of marketed drugs	3.53	7.35	0.082	0.442
Indicator for no marketed drugs	0.560	0.497	0.951	0.216
Percent of drugs launched 9–14 years ago	13.3	24.4	1.08	9.95
log(enterprise value), \$millions	7.35	1.92	4.48	1.21
Foreign firm indicator	0.362	0.481	0.209	0.407
Ratio of cash to sales	3.11	8.46	2.68	7.65
Percent change in sales, <i>t</i> – 3 to <i>t</i> – 1	25.7	49.4	25.1	60.6
Indicator: sales data missing	0.151	0.359	0.212	0.409
Percent change in operating expenses, <i>t</i> – 3 to <i>t</i> – 1	25.3	36.6	24.4	44.0
Indicator: operating expenses missing	0.155	0.362	0.199	0.399

Notes: Large firms had an enterprise value (market value of equity plus book value of debt) exceeding \$1 billion at least once during the sample period. Small firms had sales of at least \$20 million at least once during the sample period but never had an enterprise value exceeding \$1 billion.

approved come from five sources: the Food and Drug Administration (FDA), the First DataBank National Drug Data File, the Electronic Product Catalog, the Lehman Brother's Pipeline reports, and Chemdex. Sample means and standard deviation are reported in Table 2, separately for the large-firm and small-firm sub-samples.

We extracted merger transactions data for 1988–2001 from the Securities and Data Corp.'s (SDC) Worldwide Mergers and Acquisitions database. We use information from the SDC database to classify the role that a firm played in a transforming event as one of the following: (1) acquirer: the firm purchased part or all of another firm; (2) target: the firm sold a substantial portion or all of itself to another firm; or (3) partner in a pooling merger: the firm pooled its assets with another firm or merged with another firm of approximately equal size.¹² Because financial data are collected by fiscal year and fiscal years sometimes differ from calendar years, we linked the transaction to the firm's fiscal year based on the transaction announcement date and the firm's fiscal year calendar.

We restrict our formal analysis to 'transforming' mergers—transactions that are sufficiently large that post-merger integration will require reorganization of a firm's research, development, marketing and/or sales processes and potentially have an observable impact on accounting measures of

performance. We consider a transaction to be transforming if the transaction value was \$500 million or more, or if the transaction value represents 20% or more of a firm's pre-merger enterprise value (the value of the firm at the conclusion of the prior fiscal year). In the handful of cases where firms engaged in multiple transforming mergers in the same fiscal year, we recorded the largest transaction only. Of the 202 transforming mergers, 97 were classified as acquisitions, 59 as targets, and 46 as pooling.

Some mergers are recorded as a transforming event for both the seller and the buyer if both firms are in our sample. In a few cases a transaction was not recorded as a transforming merger for the buyer because the transaction represented less than 20% of its enterprise value, but was recorded as transforming event for the seller because it represented more than 20% of its enterprise value. In other cases, it was a transforming event for the buyer but the seller is simply not in our database, because it is either a privately held (usually small) firm or a foreign firm that is not traded in the US and not listed in Global Vantage. This underscores our assumption that an event is 'transforming' with respect to a specific participant; what is transforming to the seller may not necessarily be transforming to the buyer. Thus in our empirical analysis the number of acquirer and target observations is not identical.

Most prior studies of M&A in other industries have focused on outright acquisitions that result in the exit of the target firm. However, outright acquisition is one extreme variant of the range of pharmaceutical-biotech and biotech-biotech relationships, including purchase of a major equity stake (e.g. Roche-Genentech), product-specific drug development alliances and/or marketing alliances. This continuum of activity makes the definition of a merger/acquisition somewhat arbitrary. Our definition of transforming mergers excludes major product licensing deals that were potentially transforming for one of the partners, such as Millenium's portfolio deals with Bayer and Monsanto.¹³

METHODS

Two-stage Model

Our analysis proceeds in two stages. To analyze the determinants of a firm's decision to engage in a transforming merger in each year between 1988 and 2001, we estimate a multinomial logit model with four possible outcomes: the firm acquires another firm in a transforming merger, is acquired by another firm, is involved in a pooling merger, or does not undertake any merger activity. In the second stage we examine the effects of these transforming mergers on several measures of firm investment and performance, using a propensity score to control for *ex ante* observable firm characteristics. Estimating the effect of mergers simply by comparing post-merger performance of merged firms to an industry mean for non-merged firms leads to biased estimates if the decision to engage in acquisition is related to expected future performance, as confirmed by our first-stage results. In particular, if firms that anticipate poor earnings growth, due to patent expirations or other pipeline shocks, are more likely to merge than firms with strong growth prospects, then the subsequent performance of the merged firms may be inferior to that of the non-merged firms, but still better than it would have been in the absence of merger.

Determinants of Merger

The unit of observation for the first stage analysis is a firm-year and the sample size is 3083 firm-years, of which 1591 are in the large-firm sample

and 1492 are in the small-firm sample. We model the probability that a firm will engage in each of the three types of merger activity or not be involved in any merger activity in year t as a function of firm characteristics in years $t-3$, $t-2$, and $t-1$.¹⁴ Our explanatory variables are selected to test a number of hypotheses regarding reasons for merger, as follows:

Excess Capacity due to Pipeline Gaps. The first hypothesis is that for large integrated pharmaceutical/biotech firms, mergers are motivated by the expectation of a gap in the product pipeline. Such gaps cause a decline in the expected growth of future revenue and create expected excess capacity in the firm's marketing, sales, and manufacturing departments. The excess capacity motivation for mergers should be less relevant for small firms that have yet to invest in large sales, marketing, and manufacturing capabilities whose productivity requires a steady stream of compounds to sell.

We use four variables to measure a firm's expected excess capacity: Tobin's q , the lagged percent change in sales, and the percentage of a firm's marketed drugs that are old and therefore likely to lose patent protection in the near future. Tobin's q is the ratio of the market value (the sum of book value of long-term debt and market value of equity) to the book value of a firm's assets at the end of a fiscal year.¹⁵ The market value of a firm's equity will be a function of its current and expected future cash flows, while the book value of assets is a contemporaneous measure. Since the balance sheet records the book value of physical assets, whereas most of a pharmaceutical-biotech firm's assets are associated with patents and other intangible capital, Tobin's q is likely to be very sensitive to fluctuations in the value of this intangible capital. Specifically, a firm with large expected growth opportunities due to a promising pipeline of products will have a large Tobin's q . Conversely, a firm that will soon lose patent protection on key products and/or has few promising products in late-stage clinical trials will have lower expected future cash flows and a lower Tobin's q . The excess capacity hypothesis predicts that acquisitions and pooling mergers are negatively related to (lagged) Tobin's q .

On the other hand, firms with a high Tobin's q should be able to finance an acquisition relatively easily due to their relatively high stock price. If the financing effect of an abnormally high share value

is important to the timing of acquisitions, we expect Tobin's q to be positively associated with being an acquirer. Thus, since Tobin's q may reflect both excess capacity effects and financing effects, the net effect for acquirers (and possibly pooling) will be negative if the excess capacity effect dominates the financing effect. Tobin's q is predicted to be negatively associated with being a target if firms tend to be acquired when the market undervalues them relative to some subjective estimates.

We also include the percentage change in sales between year $t - 3$ and year $t - 1$ since a relatively slow sales growth rate suggests aging of the product portfolio and hence that the productivity of quasi-fixed factors is or soon will be declining. Sales grew by 25%, on average, over a two-year period for both the large and small firms (Table 2), but with considerable variation across firms, as indicated by the high standard deviations. The excess capacity motivation for mergers predicts that acquisitions will be negative related to lagged sales growth.

Our most direct measure of expected excess capacity is the percentage of a firm's drugs that were approved by the FDA between nine and 14 years previously, which is a proxy for the percent of the firm's product portfolio that is approaching patent expiration. Although the normal patent term for drugs marketed during our analysis period was 17–20 years, years of sales under patent protection is usually 9–14, because many years of patent life are typically lost due to clinical trials and regulatory approval.¹⁶ For large firms, 13% of their drugs had been approved between nine and 14 years ago (Table 2), and as before the standard deviation is almost twice as large as the mean. Table 2 indicates that for firms in the large-firm sample the mean number of marketed drugs is only 3.5, with 56% of firm years reporting no marketed drugs. This count reflects only new chemical entities (excluding reformulations, combinations, etc.) and assigns each product to a single firm, whereas in fact reformulations are numerous and many products are shared through licensing agreements. Small firms were marketing an approved drug in only 5% of the firm years, although they may be generating revenue through out-licensed products or technologies and/or services performed for other firms. Thus a firm may have revenues and a high market value despite no reported approved drugs. The excess

capacity motivation for mergers predicts that acquisitions will be positively related to the percent of a firm's drugs approved 9–14 years ago. Both the sales and product portfolio measures are less inclusive than Tobin's q because they do not reflect the future value of pipeline products, licensed products and other revenue sources.

Finally, we include the percentage change in operating expenses between years $t - 3$ and $t - 1$. Under the excess capacity hypothesis, a firm that anticipates patent expirations or experiences a pipeline shock may respond initially by reducing costs, in order to maintain net revenue growth (John *et al.*, 1992). If this strategy is exhausted before the firm's pipeline produces new products, the firm may consider an acquisition as a means to obtain further expense reductions. If so, pharmaceutical firms with relatively low lagged expense growth rates would be more likely to acquire another firm or engage in a pooling merger.

Economies of Scale. If achieving economies of scale is a significant motive for merger in the pharmaceutical/biotech industry, smaller firms are expected to be more active as acquirers than larger firms that are operating at the minimum efficient scale. We measure a firm's size by the logarithm of its enterprise value and by the number of approved drugs that it markets.

Note that the excess capacity and economies of scale motives for mergers are not mutually exclusive and ideally they should be complementary. That is, if a firm faced with pipeline gaps were to engage in acquisition in order to achieve short run cost savings, this would be an extremely short-sighted strategy if in the long run the post-merger scale of operations were less efficient than the pre-merger scale.

The Market for Corporate Control. Another function of M&A is to transfer assets from ineffective to effective managers. A low value of Tobin's q could indicate that a firm's value is below its potential value. This would predict that firms with a low Tobin's q are more likely to be targets. As an alternative measure of managerial performance we include the percentage change in operating expenses and sales, respectively, between year $t - 3$ and year $t - 1$. According to the 'corporate control' hypothesis, firms with relatively high lagged operating expense growth rates and relatively low sales growth rates will be more likely to

be acquired. As discussed above, the excess capacity hypothesis predicts that firms with relatively low lagged expense growth rates would be more likely to acquire another firm or merge through pooling. The mean two-year change in operating expenses is about 25% in both samples, approximately equal to the percentage change in sales (Table 2).

Specific Asset Acquisition. Another explanation for mergers is they are the most sensible way for firms to acquire specific assets. For example, a foreign pharmaceutical firm that wants to establish a presence in the US market may acquire a US firm that already has an established sales force and relationships with customers and with the FDA. We include an indicator variable for foreign firms in order to test the hypothesis that foreign-domiciled firms are more likely to merge to improve their access to the US market. One-third of the large firms and one-fifth of the small firms are foreign (Table 2). However, this is far from the universe of foreign pharmaceutical and biotech firms, because many are not listed in our data sets.

Financing/Agency Issues. Some have argued that mergers occur when managers have aspirations to run a larger company, they have considerable cash, and agency controls are imperfect. We include a variable measuring the ratio of cash to sales. A high ratio of cash to sales would be positively related to acquisitions if either imperfect agency concerns are significant or availability of financing is a significant constraint on mergers that are undertaken for other reasons.

Effects of Mergers

In the second stage we examine the effect of transforming mergers on several measures of firm performance between 1989 and 2000:¹⁷ the annual percentage change in sales, operating profit, and enterprise value.¹⁸ To shed light on mechanisms whereby mergers may affect value, we also examine the effects on annual percentage change in employees and R&D investment. Because post-merger integration takes time and results may not be evident immediately, we examine the impact of a merger in year t on the change in outcomes from $t + 1$ to $t + 2$, $t + 2$ to $t + 3$, and $t + 3$ to $t + 4$. Examining actual changes in a firm's financial and operating performance following a merger, rather

than abnormal returns in stock prices around the merger announcement date, provides insights into the effects that were actually realized in longer term performance, while evidence on inputs provides evidence on the mechanism for any change in performance.

The hypotheses regarding motivations for merger imply related predictions for effects of merger. Under the excess capacity hypothesis, mergers are expected to facilitate restructuring and cost reductions. This would predict that employees (and possibly R&D) should grow less at firms that merged than at firms that did not merge and, assuming that the strategy is successful, operating profit should grow more rapidly than would have been predicted based on the acquiring firm's pre-merger condition. Similarly, if mergers are a means of achieving economies of scale or scope, merged firms should experience relatively slow growth in employees and/or R&D, and improved operating profit. Thus empirically the predicted outcomes of the excess capacity and economies of scale hypotheses are similar, which is not surprising because, as noted earlier, these two motives for mergers are not mutually exclusive and ideally should be complementary; that is, a merger could yield both short and long run cost savings if the post-merger scale of operations is more efficient than the pre-merger scale. As discussed earlier, the first stage estimates may enable us to distinguish between these hypotheses: in particular, if Tobin's q is inversely related to the probability of acquisition, this is consistent with the excess capacity motive but not with simple economies of scale. Both hypotheses would also be consistent with a relatively large growth in sales due to increased productivity of the combined sales forces and/or acquisition of new compounds for the sales force to market. Hall (1999) suggests that merger may actually reduce R&D, due to short-term management distraction and because the funds used to finance an acquisition may be diverted from R&D. This hypothesis predicts that R&D growth will be relatively low for firms that merge. However, this hypothesis is empirically indistinguishable from the economies of scale hypothesis.

Both the specific asset acquisition hypothesis and the market for corporate control predict that merged firms should experience relatively rapid growth of sales and/or operating profit. These two hypotheses are thus indistinguishable at the second stage but not at the first stage.

Note that if firms that merge experience a relatively large (small) subsequent increase in enterprise value, this would imply that the market underestimates (overestimates) the impact of mergers on performance. However, such evidence cannot distinguish whether mergers actually changed profitability or merely changed profitability relative to the expectations at the time of the merger announcement, nor the means by which profitability was changed.

Controlling for Selection. Our goal is to estimate the effect of a merger on various measures of post-merger performance and inputs. Specifically, let Y_{it} be the percentage change from year $t + 1$ to year $t + 2$ for one of the five variables of interest if firm i participated in a transforming merger in year t , and let Y_{i0} be the percentage change if the firm did not merge in year t . The effect of merger (treatment effect) for firms that merge is

$$E(Y_{it}|M_{it} = 1) - E(Y_{i0}|M_{it} = 0), \quad (1)$$

where $M_{it} = 1$ if firm i merged in year t . Since we only observe Y_{i0} for firms that do not merge, the estimated treatment effect from Equation (1) will be biased if Y_{i0} differs systematically for firms that do and do not merge. For example, if firms that anticipate poor earnings growth due to upcoming patent expirations are more likely to merge than firms with strong growth prospects, then the subsequent performance of the merged firms may be inferior to that of the non-merged firms even if there were no mergers. Failure to account for this type of selection would bias downward the estimated effect of a merger on the subsequent change in sales and operating profit. The descriptive data in Table 3 strongly suggest significant differences in observed characteristics between firms that were involved in M&A and those that were not.

Our analysis of effects of mergers controls for selection based on observed characteristics using a propensity score method to identify firms that are expected to have similar outcomes regardless of

Table 3. Differences in the Characteristics of Merging and Non-merging Firms

Panel A: Large-firm sample ($n = 1049$ firm years)

	Mean for firms that merged	Mean for firms that did not merge	t -statistic for difference in means
Tobin's q , top-coded at 20	2.62	2.92	1.24
Indicator for Tobin's $q > 20$	0.00	0.0062	3.01**
Number of marketed drugs	9.72	2.29	4.94**
Indicator: no marketed drugs	0.278	0.586	7.49**
Percent of drugs launched 9–14 years ago	23.4	10.3	3.63**
log(enterprise value), \$ millions	8.60	6.82	5.49**
Foreign firm indicator	0.391	0.359	0.71
Ratio of cash to sales	1.36	3.34	3.56**
Change in sales, $t - 3$ to $t - 1$	23.7	24.2	0.08
Indicator: sales data missing	0.053	0.161	4.97**
Change in operating expenses, $t - 3$ to $t - 1$	23.5	24.6	0.23
Indicator: operating expenses missing	0.068	0.163	4.00**

Panel B: Small-firm sample ($n = 1000$)

	Mean for firms that merged	Mean for firms that did not merge	t -statistic for difference in means
Tobin's q , top-coded at 20	2.34	3.04	1.67*
Indicator for Tobin's $q > 20$	0.00	0.015	4.62**
Number of marketed drugs	0.091	0.070	0.23
Indicator: no marketed drugs	0.900	0.954	1.49
Percent of drugs launched 9–14 years ago	0.00	1.25	3.61**
log(enterprise value), \$ millions	4.11	4.34	1.02
Foreign firm indicator	0.174	0.211	0.78
Ratio of cash to sales	2.13	3.24	1.05
Change in sales, $t - 3$ to $t - 1$	41.9	26.1	1.28
Indicator: sales data missing	0.101	0.218	3.05**
Change in operating expenses, $t - 3$ to $t - 1$	45.1	27.0	1.82*
Indicator: operating expenses missing	0.073	0.205	4.00**

Notes: ** = difference in sample means is significantly different from zero at the 5-percent level. The sample for this table is smaller than for Tables 3 and 4 because we include only firm-year observations that are included in the second stage regressions.

whether or not they actually merged. The propensity score is a summary measure of the likelihood of merging based on a vector of firm characteristics. The propensity to merge, $p(M_i)$, is the probability firm i will merge in year t conditional on observed characteristics X

$$p(M_{it}) = \Pr(M_{it} = 1 | X_{i,t-1}). \quad (2)$$

Rosenbaum and Rubin (1983) show that if the outcomes (Y_{i1} and Y_{i0}) are independent of the assignment to the treatment (merging firm) and control (non-merging firm) groups, conditional on the observed covariates, then classifying observations by their propensity score balances the observed covariates (X); within a subclass with a similar $p(M)$, the distribution of X is the same between the treatment and control groups. The treatment effect of a merger for firms with a specific propensity score is the difference in the mean outcomes between the treatment and control groups

$$E(Y_{i1} | p(M_{it}), M_{it} = 1) - E(Y_{i0} | p(M_{it}), M_{it} = 0), \quad (3)$$

where the expectation is taken with respect to the distribution of $p(M)$. Consider two firms with the same probability of merging in a particular year where one firm merged and the other did not. The firm that did not merge can serve as a control for the firm that did merge since the expected difference in their outcomes is equal to the average treatment effect of a merger.¹⁹

To estimate the propensity score, we estimate Equation (2) using a multinomial logit regression that distinguishes situations where a firm acquires another, is acquired, is involved in a pooling merger, or is not involved in any M&A activity. Although the propensity-generating model is similar in structure and includes all the variables in the model used to report first stage results, in order to achieve balance of the propensities the propensity generating equation also includes year indicators, lagged measures of employees, lagged ratio of R&D expenses to sales, lagged ratio of operating profit to sales, interaction terms between many pairs of variables, and quadratic terms of the continuous variables. We sum the predicted probability that a firm will acquire another company and the probability a firm will be involved in a pooling merger to derive the M&A propensity score. We omit the predicted probability that a firm will be acquired because firms that are acquired generally do not appear in our

second-stage sample. We then sort firm-years by the propensity score and assign them to three separate groups, or tertiles: low, medium, and high merger propensity.²⁰

We use a two-way analysis of variance model to determine if the propensity score balances each covariate between the treatment (merged) and control (did not merge) groups. Each covariate that appears in the multinomial logit model is regressed on indicator variables for the three propensity tertiles, an indicator for whether or not the firm actually merged in that year, and interactions between the propensity and merged indicator variables. We then calculate F -statistics to determine whether the covariates differ between merging and non-merging firms—overall and within each tertile—once we control for the firms' propensity to merge using the tertile indicator variables. In fact, once we control for a firm's merger propensity, none of the covariates from the first stage model differ significantly between firms that do and do not merge. For example, although firms in the large-firm sample that merge have considerably more marketed drugs than firms that do not merge, within each of the three propensity tertiles there is no statistical difference in this variable between merging and non-merging firms.²¹

Our second stage estimates regress Y_i , the percentage change in a firm performance measure from $t + 1$ to $t + 2$, on a firm's propensity score for year t , an indicator that equals one if the firm merged in year t , year indicators, and an indicator for foreign firms.²² We also include an interaction between the propensity score and the merger indicator to test whether the effect of a merger differs according to the firm's propensity to merge.²³ A firm facing a substantial loss of sales due to patent expiration, for example, may have a high propensity score and may reduce employees substantially if it were to acquire another firm, whereas a firm that was less distressed might alter staffing less aggressively if it were to merge. Since post-merger integration takes time and results may not be evident immediately, we report three second-stage regressions to measure the impact of mergers on firm performance one, two, and three years following a merger. That is, we define Y_i as the percentage change in a firm's performance from $t + 1$ to $t + 2$, from $t + 2$ to $t + 3$, and from $t + 3$ to $t + 4$ (where the merger of interest occurred in year t).

As a robustness check, we also estimate a second-stage model based on the approach suggested by Hirano *et al.* (2000). Rather than including the propensity score as a regressor in the second stage regression, we perform weighted ordinary least squares where the weights for firms that merged are $1/p_i$, and the weights for firms that did not merge are $1/(1 - p_i)$.²⁴ Thus firms that did not merge are given a greater weight if they had a high propensity score (i.e. they appeared similar to firms that did merge based on observables), and firms that did merge are given a greater weight if they have a low propensity score (i.e. they appear similar to firms that did not merge). The results using this method are qualitatively similar to those reported in Tables 6 and 7.²⁵

The propensity score method controls for selection based on observed firm characteristics, including the number and age of approved drugs, enterprise value and Tobin's q , which should capture many factors affecting the expected growth of a firm's cash flow based on pre-merger conditions. Using growth rates in the second stage controls for unobserved fixed firm characteristics that might affect performance levels in both the pre- and post-merger periods. However, if mergers are systematically related to unobserved characteristics that also affect post-merger growth, our estimate of the impact of a merger may be biased.

RESULTS

Characteristics of Merging and Non-Merging Firms

Table 3 reports the means of the firm characteristics separately for firms that did and did not merge, as well as two-sample t -statistics of the differences in the means. Among the 1049 firm-years in the large-firm sample (panel A), firms that actually merged were marketing more drugs, were less likely to have no approved drugs, had a greater percentage of drugs at risk of patent expiration, had a larger enterprise value, a lower cash-to-sales ratio, and were less likely to have a top-coded Tobin's q (our outlier control) and missing sales data relative to firms that did not merge.²⁶ Among the 1000 firm-years in the small-firm sample (panel B of Table 3), firms that merged had a lower Tobin's q , had fewer drugs at risk of patent expiration, experienced a relatively large increase in operating expenses in the

prior two years, and were less likely to have a top-coded Tobin's q , missing sales data, and missing expense data relative to firms that did not merge.

Multinomial Logit Analysis of M&A Activity

Tables 4 and 5 report marginal effects of the four distinct outcomes for the large-firm sample and the small-firm sample, respectively. The marginal effects, which are the change in the probability of an event (e.g. the probability a firm acquires another) associated with a unit increase in the independent variable, are calculated at the means of the independent variables and sum to zero for each independent variable across all four possible outcomes. We report robust standard errors adjusted for clustering within firm over time.

Focusing first on acquisitions, the results in Table 4 support the hypothesis that large pharmaceutical-biotech firms that expect to have relatively high excess productive capacity are more likely to engage in acquisition. Recall that we use four different variables to measure expected excess capacity: Tobin's q , which is the most comprehensive; the percentage of a firm's drugs that were launched 9–14 years previously (and are thus approaching patent expiration); lagged change in sales; and lagged change in operating expense. When the number and age profile of a firm's marketed drugs are omitted (regressions not reported here), firms with a relatively low Tobin's q are significantly more likely to acquire other firms. This is consistent with the hypothesis that firms with relatively low expected earnings growth rates (as reflected in a low market value relative to book value of assets) use acquisition as a source of either cost reductions and/or new compounds to apply to their pipeline.

When the number and age profile of the firm's products are included, to provide a more direct measure of expected excess capacity (Table 4), the marginal effect of a change in Tobin's q on the likelihood of acquiring another firm is still negative but is no longer significant. However, firms with a relatively old portfolio of drugs are more likely to acquire another firm, as predicted, and this marginal effect is concave. A one standard deviation increase in the percentage of a firm's drugs that are between 9 and 14 years old (from 13.3 to 37.7%) is associated with a 1.8 percentage point increase in the probability a firm will

Table 4. Marginal Effects of the Probability of Participating in M&A Activity: Large-Firm Sample

	Acquirer	Target	Pooling merger	No M&A activity
Tobin's q	-0.276 (0.186)	-0.0027** (0.0012)	0.030 (0.044)	0.248 (0.18)
Number of marketed drugs	-0.0349 (0.047)	-0.00029 (0.00038)	-0.012 (0.020)	0.047 (0.053)
Percent of drugs launched 9-14 years ago	0.104** (0.051)	-0.00033 (0.00028)	0.0012 (0.014)	-0.105** (0.052)
% drugs 9-14, squared	-0.0013** (0.00057)	2.8×10^{-6} (4.6×10^{-6})	-0.000035 (0.00015)	0.0014** (0.00057)
% Change in sales, $t - 3$ to $t - 1$	-0.0042 (0.013)	-0.000022 (0.000085)	-0.0032 (0.0041)	0.0074 (0.014)
Enterprise value (Ln)	1.00** (0.315)	0.0035** (0.0015)	0.321** (0.144)	-1.33* (0.347)
% Change in operating expenses $t - 3$ to $t - 1$	0.0094 (0.017)	0.000066 (0.00011)	0.011** (0.0047)	-0.020 (0.018)
Foreign firm indicator	0.294 (0.815)	-0.0084** (0.0042)	-0.324 (0.296)	0.038 (0.847)
Ratio of cash to sales	0.0035 (0.051)	-0.00036 (0.00030)	-0.069 (0.053)	0.066 (0.071)
Mean of dependent variable (percentage points)	4.65	1.76	1.95	91.6
Observations (firm-years)	74	28	31	1458

Notes: The marginal effects are based on a multinomial logit regression where the dependent variable takes on the value one if a firm was involved in a particular type of merger activity in year t , and zero otherwise. The marginal effects are presented as percentage point changes in the probability of an outcome. The regression also includes indicator variables for firms with missing data on operating expenses and sales, for firms with a Tobin's q above 20, and for firms with no marketed drugs in year $t - 1$.

Table 5. Marginal Effects of the Probability of Participating in M&A Activity: Small-Firm Sample

	Acquirer	Target	Pooling merger	No M&A activity
Tobin's q	-0.079 (0.070)	-0.068** (0.029)	7.4×10^{-6}	0.147* (0.076)
Number of marketed drugs	0.135 (0.206)	-5.02** (1.41)	-1.7×10^{-6} (6.1×10^{-6})	4.89** (1.42)
Percent of drugs launched 9-14 years ago	-1.22** (0.273)	-0.120** (0.037)	1.2×10^{-6} (1.6×10^{-6})	1.34** (0.273)
% drugs 9-14, squared	0.010** (0.0023)	0.00027** (0.00083)	-9.2×10^{-9}	-0.011** (0.0023)
% Change in sales, $t - 3$ to $t - 1$	-0.00021 (0.0025)	-0.00027 (0.0016)	6.9×10^{-8}	0.00049 (0.0029)
Enterprise value (Ln)	-0.077 (0.108)	0.190** (0.053)	5.7×10^{-6} ** (2.4×10^{-6})	-0.113 (0.123)
% Change in operating expenses, $t - 3$ to $t - 1$	0.0046 (0.0028)	-0.00037 (0.0018)	-1.5×10^{-7}	-0.0042 (0.0034)
Foreign firm indicator	0.143 (0.336)	-0.070 (0.129)	-0.385** (0.166)	0.312 (0.403)
Ratio of cash to sales	-0.0069 (0.014)	-0.029** (0.015)	-1.3×10^{-6} (1.8×10^{-6})	0.036* (0.020)
Mean of dependent variable (percentage points)	1.54	2.08	1.01	95.4
Observations (firm-years)	23	31	15	1423

Notes: The marginal effects are based on a multinomial logit regression where the dependent variable takes on the value one if a firm was involved in a particular type of merger activity in year t , and zero otherwise. The marginal effects are presented as percentage point changes in the probability of an outcome. The regression also includes indicator variables for firms with missing data on operating expenses and sales, for firms with a Tobin's q above 20, and for firms with no marketed drugs in year $t - 1$. The standard errors for four of the coefficients in the pooling arm of the multinomial logit are so small that they are reported to be zero by the Stata program. The point estimates for these four coefficients are also very small.

acquire another.²⁷ Since the probability a firm acquires another in a particular year is 0.0465 (bottom row of Table 4), this represents a 38% increase in the likelihood of acquiring another firm. The lagged percent change in sales is negative but insignificant.²⁸

Firms with a relatively low Tobin's q are more likely to be acquired, suggesting that the acquirer values the target's assets more highly than does the market, which is consistent with acquisition being a mechanism to transfer assets to more effective managers. Also consistent with this hypothesis is the finding that firms that experienced relatively rapid growth of operating expenses are more likely to be involved in pooling. However, since this variable is insignificant in the target equation, this interpretation is tentative.

If firms merged in part to achieve economies of scale, smaller firms would be more likely to merge. Contrary to expectations, larger firms, as measured by enterprise value, are more likely to be involved in all three types of merger activity. This suggests that, if economies of scale are a motive for merger, even the firms at the sample mean perceive advantages in growing larger. A 100% increase in a firm's enterprise value (or an increase of one in the log of its enterprise value, which is about one-half of a standard deviation) is associated with a 1.0 and 0.32 percentage point increase in the likelihood of acquiring another firm and being involved in a pooling merger, respectively, which is approximately a 20% increase in the probabilities. Firms with larger enterprise values are also more likely to be targets.

The coefficient on the indicator for foreign firms is positive but insignificant in the acquisition equation, suggesting that foreign firms do not disproportionately engage in merger as means to enter the US market. Our estimates suggest that foreign firms are less likely to be acquired than domestic firms, however this may simply reflect a US-bias in our data set, which may not capture all the acquisitions of foreign firms by other foreign firms. The coefficient on the ratio of cash to sales is insignificant. Thus there is no evidence of imperfect agency, that is, that managers acquire companies merely because they have the means to do so. There is also no evidence that financing is a constraint on M&A.

Table 5 reports the marginal effects from the multinomial regression analysis of determinants of mergers for the small firm sample.²⁹ For these

relatively small firms, our variables have more success predicting the probability of being a target than an acquirer. The results are more consistent with merger being an exit strategy for firms in financial trouble in general, not specifically a response to expected excess capacity associated with patent expirations. This is as expected, since the great majority of these small firms had no marketed drugs, hence were not exposed to patent expirations and the associated risk of underutilized marketing and manufacturing assets. Nevertheless, most of these firms engage in R&D and would be heavily dependent on external financing through public or private equity or alliances with larger firms. If such firms experience R&D setbacks that result in a decline in their Tobin's q and inability to raise additional cash, being acquired may be the best alternative.

We find that small firms with a relatively low Tobin's q , implying a relatively low expected growth rate of earnings, are more likely to be acquired, as in the large firm sample. This is consistent with transfer of underperforming assets to other managers. A one-standard deviation increase in a firm's Tobin's q is associated with a 0.19 percentage point decrease in the predicted probability a firm will be acquired. The mean probability that a small firm will be acquired in a particular year is 0.021 (bottom row of Table 5), so this represents a 9% reduction in the predicted probability. By contrast, small firms with a relatively high value of Tobin's q , large number of drugs, and high ratio of cash to sales are less likely to engage any type of M&A activity. As further evidence that the causes of financial distress are different for small firms, we find that small firms with a large percentage of drugs at risk of losing patent protection are less likely to be involved in M&A activity, whereas the opposite effect was found for larger firms (Table 4).³⁰

Small firms with relatively large enterprise value are more likely to be acquired and be involved in a pooling merger, whereas firm size has no effect on the probability that a small firm is an acquirer, in contrast to the large firm sample. A 100% increase in a small firm's enterprise value (which is slightly smaller than one standard deviation) is associated with a 0.19 percentage point, or 9%, increase in the predicted probability of being acquired. These results are consistent with larger firms being relatively attractive targets, presumably as a means whereby the acquiring firm can achieve economies

of scale in an existing capability or acquire new technologies and expertise.

Although being in financial trouble puts a firm at risk for acquisition, there is no evidence that having the ability to finance a merger tends to precipitate acquisition. Firms with a relatively high cash-to-sales ratio are less likely to be involved in any M&A activity. The finding that small firms with relatively high Tobin's q (an indicator of ability to finance an acquisition through equity) are less likely to engage in M&A provides further evidence that financing is neither a constraint on acquisition nor a precipitating factor. In summary, for small firms the results suggest that financial weakness puts a firm at risk as a target, but financially strong firms (as measured by relatively high Tobin's q , number of marketed drugs and high ratio of cash to sales) are less likely to engage in any M&A.

Effect of Merger on Subsequent Performance

The evidence of means in Table 3 and the analysis of determinants of merger in Tables 4 and 5 demonstrate that merger in the pharmaceutical–biotech industry is not a random event but is related to observable firm characteristics. If post-merger performance is also a function of pre-merger observed characteristics, then estimates of post-merger performance that fail to control for these prior characteristics would produce biased estimates of the effects of mergers. We include the propensity to merge as a summary measure of the firm's likelihood of merging based on its prior observable characteristics (see the Methods section above). Once we control for the firm's merger propensity, none of the covariates in Table 3 differs significantly between firms that do and do not merge. Focusing on growth rates in the second stage allows us to control for unobserved firm fixed effects that may influence the levels of these outcome variables.

Table 6 reports estimates from 30 separate second-stage regressions for the large-firm sample. In the first three rows we regress the percentage change from $t + 1$ to $t + 2$ for each of the five firm performance measures on an indicator variable that equals one if a firm merged in year t , year indicators, and an indicator for foreign firms.³¹ The coefficient on the merger indicator is the impact of a merger if one assumes mergers are exogenous. For each of the five dependent vari-

ables, we then report a second regression that includes the propensity score for the firm-year and an interaction between the merger indicator and the propensity score. This specification tests whether any merger effects are significant after controlling for the merger propensity and whether any effects of a merger differ according to the firm's prior likelihood of engaging in M&A activity. Finally, we repeat these two regressions for each dependent variable, using the percentage changes between $t + 2$ and $t + 3$ (rows 4–6 of Table 6) and $t + 3$ and $t + 4$ (rows 7–9) to examine the impact two and three years after the merger.

For large firms, in the first year post-merger, the merger has no significant effect on employees, operating profit, or enterprise value. The latter result is consistent with investors correctly incorporating, on average, the subsequent impact of a merger into the company's valuation at the announcement date or shortly thereafter. If one were to assume that mergers are exogenous, one would conclude that merger results in slower growth in sales and in R&D expenditures in the first full year after a merger (the first equation for each dependent variable in Table 6). However, the negative and frequently significant coefficient on the propensity score variable in the regressions for growth in sales, employees, and R&D highlights the importance of controlling for prior characteristics that are likely to be associated with future performance. Firms with a relatively high likelihood of merging in a particular year experience relatively small growth in sales, employees, and R&D, on average, over the next three years, regardless of whether or not they actually merge. This supports our hypothesis that many large firms merge to try to improve a bad situation. Firms that don't merge but share similar characteristics as firms that do merge, also perform relatively poorly on the three aforementioned dimensions. It is unsurprising that the propensity score coefficients are insignificant in the enterprise value regressions because a company's current stock price should incorporate expectations of its future performance, and those expectations should include the same firm characteristics as the propensity score.

Controlling for a firm's propensity to merge increases the coefficient on the merger indicator variable in 12 of the 15 regressions in Table 6 and eliminates the finding of significant difference in the growth in sales and R&D expenses between

Table 6. Effect of a Merger on Firm Performance, Large-Firm Sample Change (Percentage Points) Between Year t and $t+1$

	Operating profit		Enterprise value		Sales	Employees		R&D		
<i>1st year after a merger</i>										
Merged in $t-1$	-10.72 (8.20)	-5.36 (12.74)	1.60 (7.75)	10.34 (13.58)	-5.590* (3.07)	0.15 (4.03)	-3.25 (2.75)	1.57 (4.59)	-8.514* (5.01)	-7.39 (7.25)
Merged in $t-1 \times$ propensity score		-12.64		-37.35		-11.78		5.87		32.18
Propensity score, $t-1$		(56.04) -19.31 (28.60)		(39.39) -9.78 (17.23)		(20.02) -20.99 (14.95)		(16.64) -40.64*** (10.77)		(20.47) -40.60*** (11.17)
Mean of dependent variable	4.11	4.11	17.30	17.30	13.80	13.80	9.50	9.50	13.40	13.40
Observations	993	993	996	996	992	992	911	911	967	967
R^2	0.01	0.01	0.13	0.13	0.03	0.03	0.05	0.06	0.04	0.05
<i>2nd year after a merger</i>										
Merged in $t-2$	3.99 (11.71)	21.16 (16.82)	-2.89 (6.64)	-5.66 (10.12)	-6.25 (4.11)	-5.49 (7.21)	-6.107** (2.50)	-5.66 (4.64)	-0.48 (4.15)	2.32 (7.27)
Merged in $t-2 \times$ propensity score		-90.77		12.61		14.33		19.28		0.64
Propensity score, $t-2$		(58.28) -5.77 (20.89)		(37.29) 3.66 (16.02)		(24.01) -25.2* (14.50)		(16.24) -30.2*** (9.49)		(23.77) -21.9* (12.97)
<i>3rd year after a merger</i>										
Merged in $t-3$	-28.01 (17.14)	-60.705** (30.20)	-1.08 (9.32)	-8.874 (15.82)	-4.00 (5.47)	6.36 (5.71)	-8.09 (5.50)	-0.13 (7.87)	-0.65 (5.03)	-0.52 (6.74)
Merged in $t-3 \times$ propensity score		219.43**		57.83		-40.78		-32.71		16.02
Propensity score, $t-3$		(102.69) -40.97 (38.79)		(54.06) -17.19 (18.84)		(30.43) -26.198* (14.27)		(33.88) -18.50* (10.29)		(43.18) -22.97 (14.14)

Notes: The results of 30 separate ordinary least squares regressions are reported in this table. The dependent variable is the change between t and $t+1$ in a firm performance measure, measured in percentage points relative to the midpoint between the two years. The regressions also include a constant, an indicator for foreign firms, and year indicators. Operating profit is sales minus manufacturing, selling, general, and administrative expenses (operating profit is pre-tax and excludes R&D expenses). The means of the dependent variables and the R^2 values are similar for the regressions analyzing the impact of mergers in the second and third year following the merger. There are about 120 and 240 fewer observations for the latter two sets of regressions.

merging and non-merging firms in the first full year following a merger. This confirms that failure to control for pre-merger characteristics leads to biased estimates of the effects of mergers.

The results for the second and third full years following a merger (rows 4–6 and rows 7–9 of Table 6, respectively) are similar to those for the first full year for all of the dependent variables except for employees and operating profit. In the second year post-merger, employee growth appears to be more negative for firms that merged, as expected if mergers facilitate cost reductions through restructuring. However, once we control for the propensity to merge, employee growth is not significantly different between firms that did and did not merge. Thus, firms that were in trouble either cut or slowed the growth of employees within the next two years, regardless of whether or not they merged.

Mergers are associated with relatively low growth in operating profit in the third year after

a merger. Controlling for a firm's propensity to merge, a firm with the sample average propensity (0.038) is predicted to experience a 52.3% reduction in operating profit in the third year following a merger relative to an otherwise similar firm that did not merge.³² This reduction is significantly different from zero at a 6% level. This suggests that post-merger integration may absorb more resources and managerial effort than anticipated by most managers, although not relative to market expectations given the insignificant result for the forward-looking enterprise value measure. However, the positive and significant coefficient of 219 on the merged-propensity score interaction indicates that mergers had a more beneficial effect on operating profit for firms with a relatively high probability of merging. A merger is predicted to increase the operating profit for a firm with a very high propensity score by 10.2% in the third year following a merger relative to an otherwise similar firm that did not

Table 7. Effect of a Merger on Firm Performance, Small-Firm Sample Change (Percentage Points) Between Year t and $t+1$

	Operating profit		Enterprise value		Sales		Employees		R&D	
<i>1st year after a merger</i>										
Merged in $t-1$	-40.49*	-53.87*	2.83	8.35	-4.03	-13.83	-6.08	-15.51	-13.52	-38.32**
	(23.86)	(31.17)	(10.17)	(12.14)	(6.34)	(8.82)	(7.59)	(9.98)	(14.72)	(17.72)
Merged in $t-1 \times$ propensity score		94.97		1.83		116.81**		161.11***		301.30***
Propensity score, $t-1$		(164.37)		(71.71)		(52.53)		(43.52)		(87.86)
		30.72		-70.68		-44.45		-99.22***		-146.04***
		(79.35)		(54.58)		(43.43)		(25.68)		(36.80)
Mean of dependent variable	-19.3	-19.3	5.72	5.72	12.6	12.6	7.49	7.49	8.37	8.37
Observations	930	930	934	934	922	922	887	887	841	841
R^2	0.03	0.03	0.07	0.07	0.02	0.02	0.02	0.06	0.01	0.03
<i>2nd year after a merger</i>										
Merged in $t-2$	-9.27	-8.15	-23.96	-18.69	-4.60	-13.25	4.11	-0.60	-3.26	-7.15
	(22.76)	(27.29)	(15.25)	(21.96)	(10.30)	(15.20)	(5.49)	(8.00)	(7.47)	(11.14)
Merged in $t-2 \times$ propensity score		70.72		-31.21		130.29		87.25**		99.01
Propensity score, $t-2$		(189.31)		(130.87)		(81.81)		(40.74)		(72.98)
		-125.03		-35.11		-62.57		-58.79**		-93.47*
		(88.87)		(55.50)		(40.16)		(28.89)		(51.03)
<i>3rd year after a merger</i>										
Merged in $t-3$	4.61	-6.04	-13.65	-2.09	1.57	7.27	-5.64	-13.14	-3.19	-9.27
	(26.50)	(42.50)	(14.19)	(14.96)	(4.65)	(7.68)	(7.29)	(9.72)	(15.57)	(30.22)
Merged in $t-3 \times$ propensity score		201.82		-217.70*		-61.40		153.55		112.94
Propensity score, $t-3$		(475.00)		(110.32)		(97.04)		(128.55)		(295.18)
		-66.41		69.68		-46.52		-61.38		-53.62
		(97.51)		(59.65)		(62.07)		(46.67)		(44.67)

Notes: The results of 30 separate ordinary least squares regressions are reported in this table. The dependent variable is the change between t and $t+1$ in a firm performance measure, measured in percentage points relative to the midpoint between the two years. The regressions also include a constant, an indicator for foreign firms, and year indicators. Operating profit is sales minus manufacturing, selling, general, and administrative expenses (operating profit is pre-tax and excludes R&D expenses). The means of the dependent variables and the R^2 values are similar for the regressions analyzing the impact of mergers in the second and third year following the merger. There are about 120 and 240 fewer observations for the latter two sets of regressions.

merge, although this effect is not significantly different from zero at conventional levels.³³

Estimates from the same set of second-stage regressions are reported in Table 7 for the sample of small firms. In Table 5 we found that merging is an exit strategy for relatively small biotech firms in financial trouble, whereas strong firms, as measured by high Tobin's q , number of marketed drugs and high ratio of cash to sales, are more likely not to engage in M&A at all. Firms that merged had significantly lower growth in operating profit in the year following the merger, and controlling for the propensity to merge makes this effect more, not less, negative. In subsequent years there was no significant difference in operating profit between firms that did and did not merge, suggesting that post-merger integration is easier for small firms than for large firms, which is not surprising.

Small firms with high propensity scores experienced relatively low growth in employees and

R&D regardless of whether they merged, consistent with the earlier finding that strong firms tend not to engage in M&A. As with the large-firm sample, this highlights the importance of controlling for the likelihood of a firm's expected performance when estimating the impact of mergers. Relative to an otherwise similar firm that did not merge, we predict that a merger reduces the growth rate of sales, employees, and R&D by 10.2, 10.6, and 29.1%, respectively, in the first full year following a merger for a firm with the mean propensity (0.031). Only the change in R&D is statistically significant, which indicates resources may be diverted from R&D immediately post-merger.

As in the operating profit regression discussed above, the positive coefficients on the merged-propensity score interactions for these three regressions indicate that mergers may be a more effective growth strategy for firms with high

propensity scores. A merger is predicted to increase sales, employees, and R&D by 12.8, 21.2, and 30.3%, respectively, in the first full year following a merger for a firm with a very high propensity score relative to an otherwise similar firm that did not merge.³⁴ The results for employees and R&D are significantly different from zero at a 10-percent level, and the predicted effect of a merger is significantly larger for firms with very high propensity scores relative to those with the sample mean propensity score for all three of these dependent variables. Thus, firms that face the greatest distress appear to grow following a merger, possibly because the merger provided access to financial resources that these small firms lacked.

With two exceptions, the insignificant coefficients in most of the second- and third-year regressions indicate that the impact of a merger for small firms appears to be concentrated in the first full year following a merger. For a firm with the sample mean propensity, a merger is predicted to have no statistically significant effect on its employees two years following a merger or its enterprise value three years following a merger. By contrast, for a firm with a very high propensity score, we predict that a merger increases its employees by 16.5% in the second year and reduces its enterprise value by 48.7% in the third year post merger relative to an otherwise similar firm that did not merge.³⁵ This suggests that the long-run impact of merger fell short of investors' expectations for these distressed firms.

CONCLUSIONS

We analyzed the determinants and effects of significant M&A transactions across the entire pharma-biotech industry over the period 1988–2000. Specifically, we used a multinomial logit model to test several competing hypotheses to explain firm-specific merger activity and to generate a measure of each firm's propensity to participate in a merger in each eligible year. Then we measured the effects of mergers on a range of performance measures controlling for the firms' *ex ante* propensity to merge.

Among large firms (over \$20 million in sales and \$1 billion in market value), we find that firms with a low Tobin's q , hence with low expected earnings growth, are more likely to acquire another firm. This effect remains negative but becomes insignif-

icant when we control for the percent of their product portfolio that is approaching patent expiration. Thus for large firms this evidence supports the hypothesis that mergers are frequently the response to expected excess capacity that is triggered by patent expirations and gaps in the product pipeline which render marketing resources unproductive. The excess capacity created by gaps in the pipeline of revenue-generating products creates a motive for merger and restructuring in the research-based pharmaceutical industry that is analogous to the role of technological and regulatory shocks that create a motive for merger and restructuring in other industries. We find that firms with high enterprise value are more likely to engage in merger, confirming that there is a perception of economies of scale in this industry. Whereas Higgins and Rodriguez (2005) find that mergers between firms that had a prior licensing relationship create value, however, in our larger sample that is not restricted to firms with a prior R&D relationship, we find no evidence that mergers create positive long term value. This suggests that mergers that are motivated to address R&D gaps through cost savings and economies of scale are unsuccessful in the long run.

For small firms mergers appear to be primarily an exit strategy for firms that are in financial trouble, as measured by low Tobin's q , few products and low cash-sales ratio. Because most of these small firms do not have marketed products, this financial trouble is more likely caused by unobserved R&D shocks rather than excess capacity due to patent expirations. Conversely, small firms with a relatively high Tobin's q , marketed products and cash/sales ratios are more likely to remain independent and less likely to engage in any M&A activity. We find no evidence that the availability of financing, either cash or relatively high value of equity, raises the probability of acquisitions for large or small firms; thus at least by this measure, we find no evidence that mergers are the result of imperfect agency by managers with cash available.

Our analysis of merger effects strongly confirms the importance of controlling for a firm's prior characteristics, as reflected in the merger propensity. For both the large- and small-firm samples, firms with relatively high merger propensity tend to have slower growth of sales, employees and R&D, consistent with merger being a response to

distress. Controlling for merger propensity, large firms that merged were not significantly different from non-merging firms in growth in enterprise value, sales, employees, and R&D expenses in the three years following a merger. Firms that merged experienced slower operating profit growth in the third year after merger. For small firms, those that merged experienced relatively slow growth of R&D in the first year compared to similar firms that did not merge, suggesting that post-merger integration may absorb the cash that is necessary to finance R&D. Thus, although merger in the pharma–biotech industry is a response to being in trouble for both large and small firms, there is no evidence that it is a solution.

Acknowledgements

This research was supported by a grant from the Merck Company Foundation and a grant from the Huntsman Center at the Wharton School. The opinions expressed are those of the authors and do not necessarily reflect the views of the research sponsors.

NOTES

1. The remaining categories were partial, hostile and vertical acquisition.
2. Compounds must demonstrate safety and efficacy in human clinical trials, in order to obtain marketing approval from the FDA in the US or similar regulatory agencies in other countries. In the US, roughly 4 out of 5 drugs fail in clinical trials, and some are withdrawn post launch if adverse events occur once on the market. Taking a compound through discovery, development and regulatory approval takes on average 12 years.
3. Recent experience is that generics take over 80% of prescription volume within the first year of patent expiration, due to their much lower prices and strong incentives of patients and pharmacists to substitute generics.
4. In-licensing individual drugs from other companies is an alternative to merging. However, for a firm experiencing patent expiration and gaps in its pipeline, including both self-originated and in-licensed products, in-licensing additional late-stage (in phase III clinical trials) or marketed products may be prohibitively costly because there are relatively few late-stage products for sale. The majority of licensing deals involve compounds that have not reached human trials or are in phase I, implying that they still face great uncertainty and many years before approval (Nicholson *et al.*, 2005).
5. According to a survey of US pharmaceutical firms conducted in 2000, 35% of personnel were in marketing, 22% in production and quality control, 21% in R&D, 12% in administration, and 10% in other functions (*Pharmaceutical Industry Profile*, Pharmaceutical Researchers and Manufacturers of America, 2003).
6. In theory, acquisition rather than pooling would be a more effective mechanism for transferring control, since acquisition clearly establishes who is in control. However, pooling may be a preferred means to implement such acquisitions due to the perceived accounting advantages of pooling rather than an outright acquisition at the time of our data.
7. Hall (1999), following Rosenbaum and Rubin (1983), constructs a cohort of merged firms and a matched cohort of firms that did not merge but that were similar in their predicted probability of merging, based on a logit regression (other forms of exit are presumably included in the non-merger group). The difference in differences in R&D growth of these two cohorts is used to estimate the effects of merger. The test is based on medians and other distribution-free tests.
8. To be included in our sample a firm had to have sales in excess of \$20 million or a market value in excess of \$1 billion for at least one year between 1988 and 2000. If two pharmaceutical/biotech firms in our sample merge, we record this in Table 1 as a single unique merger.
9. If firm A acquires 20% or more of firm B, firm A is required to incorporate firm B's results into its financial reporting. By our definitions, if a large firm buys a 50% share in a smaller firm, this may be a transforming acquisition for the small firm but not necessarily for the large firm.
10. We added four additional firms not identified in the two steps described in the text but known to be in the pharmaceutical or biotech sector: American Cyanamid, Warner-Lambert, Pharmacoepia, and Affymetrix, and excluded four firms more appropriately described as outside the pharmaceutical/biotech industry: Dupont, 3M, Procter & Gamble and BASF. Twenty more firms were excluded because they were old entries, *pro forma* entries, Indian subsidiaries, or duplicates.
11. Foreign currency values from the Global Vantage files were converted to US dollars, using monthly exchange rates from Global Vantage. All monetary values were then adjusted for inflation using the U.S. domestic manufacturing Producer Price Index (index year is 1999). To maximize our sample size, we imputed some financial data, but only for observations where other key financial variables were non-missing in order to be certain that the firm was active in that year. Because some firms were listed in both the Compustat and Global Vantage files, we extracted financial data on a firm-by-firm basis from the source that reported more years for a given firm, and we filled in missing data from the otherwise unused source.
12. The SDC database tracks up to three firms on the acquirer side of the transaction and up to three firms on the selling side. Each merger was credited to all of the relevant firms in our sample. Most transactions were credited to a single firm on the acquirer side. For transactions that involve the acquisition of

- a relatively small firm that is not listed in Compustat, we lack financial data on the target firm. However, for some transactions we were able to match both acquirer- and seller-side firms, and for others only seller-side firms. We excluded all divestiture transactions where the pharmaceutical-biotech firm in our sample was selling a division.
13. Our measure of a firm's portfolio of drugs assigns each drug to one firm, hence it omits royalty payments received by originators from licensee firms that market the drugs; it also excludes products in the pipeline, whether self-originated or in-licensed.
 14. In a preliminary analysis not reported here, we tested whether the 4-outcome model, which treats pooling mergers as a separate category, is superior to a 3-outcome model, which includes only being an acquirer, a target and no M&A activity. We rejected the 3-outcome model in favor of the 4-outcome model because the pooling mergers vector of coefficients was significantly different from the other outcomes. Because the sample of pooling mergers is so small, our estimation does not distinguish acquirers and targets within this category, although SDC does designate one firm in a pooling as the acquirer and another as the target.
 15. Book value of long-term debt should be close to its market value.
 16. Firms file for patent protection during the pre-clinical stage, well before the FDA approves a drug.
 17. Because 2001 is the last year of our financial data, 2000 is the last year for which we can calculate an annual percent change.
 18. We calculate percentage changes using an arc formula. Operating profit is defined as sales—cost of goods sold—selling/general and administrative expenses. We exclude R&D expenses since increases in R&D expenses are often perceived to increase the future value of biotech and pharmaceutical firms.
 19. See Imbens (2004) for a review of methods for estimating the treatment effect of a binary treatment when there is selection on observable characteristics.
 20. Cochran (1968) shows that grouping observations into five subclasses according to their propensity score often removes over 90% of the bias due to the covariates. Since mergers are infrequent in our sample (about five percent of the firms merge in a particular year), we would have a small number of mergers in each quintile and therefore use tertiles.
 21. Using the propensity score enables us to include a more complete control for prior characteristics than would be possible if we simply included lagged values in the second stage regression. Given the relatively small number of observations (2000) at the second stage, the model would be over fitted if we included all the covariates that are included in the propensity generating equation.
 22. We cannot compare performance of merged firms, pre- and post-merger, with a matched sample of non-merging firms over the same time period, because we lack pre-merger accounting data for one component of the merged entity for a significant fraction of our mergers. This occurs primarily due to partial acquisitions (where reported data pertains to the entire corporate entity, not just the division acquired), and acquisitions involving foreign firms and private companies that are not covered by Compustat or Global Vantage. We include the acquiring firm's propensity score in the second stage rather than averaging the propensity scores of the two merging firms because some of the target firms are not included in the first stage regression, due to missing accounting data.
 23. We condition on the propensity score in a regression rather than estimating an average treatment effect within propensity score blocks, or strata, for two reasons. First, with a total of only 200 mergers, it would be difficult to estimate precisely the effect of a merger in the low-propensity score strata. Second, the mergers occurred over a 13-year period, and a regression framework allows us to control for year effects that are expected to have a substantial impact on second-stage outcomes. Imbens (2004) and D'Agostino (1998) describe the method of estimating the treatment effect conditional on the propensity score in a regression framework.
 24. Finkelstein (2003) also uses this method in her study of vaccine development.
 25. Results of the weighted least squares regressions are available upon request. In these specifications we do not include an interaction term between the merger indicator variable and the propensity score.
 26. Observations may be included in the analysis of determinants of mergers in Tables 3 and 4 but not in the second stage regressions if mergers occurred in 2000 or 2001, hence are missing data on post-merger performance, or if there are missing values for the second stage dependent variables. Table 5 includes only the firm-year observations that are included in the second stage regressions.
 27. $24.4(0.104) + (24.4)^2(-0.0013) = 1.8$.
 28. In preliminary analyses, we also included an indicator variable for whether the firm formed an alliance or joint venture with another firm in the prior year, or a categorical variable counting the number of such alliances, as a rough test of the hypothesis that alliances may be a substitute for acquisitions. The alliance variables are omitted from the specifications in Tables 4 and 5 because the coefficients were insignificant, possibly because most alliances involve early-stage compounds and the alliance data from SDC were insufficiently precise to control for development stage of in-licensed compounds. Taken at face value, the results are consistent with the expectation that in-licensing is a long-term strategy but not an effective short-term solution to patent expiration problems.
 29. The standard errors for four of the coefficients in the pooling merger arm of the multinomial logit are so small that the Stata software program reports them as zero. These standard errors are omitted in Table 4. The point estimates of these four coefficients are also very small, as is the frequency of pooling mergers in the small-firm sample.

30. The number of marketed drugs is positive for only 4.9% of the firm-year observations in the small-firm sample. However, among these firm-years, there is considerable variation in the number of marketed drugs (ranges from one to four), and the percentage of drugs that were approved 9–14 years ago (ranges from 0 to 100, with a mean of 22).
31. Some of the year indicators were significant, suggesting industry-wide growth trends, but these coefficients are not reported here.
32. $-60.7 + (0.038)(219) = -52.3$.
33. The 10.2% predicted increase in operating profit is based on a firm with a propensity score of 0.323, which is one-standard deviation higher than the mean propensity score for firms that actually merged. The predicted impact of a merger on the operating profit of a firm with the mean propensity versus a firm with a very high propensity is statistically different from one another at a 5% level.
34. These predictions are based on a firm with a propensity score of 0.223, which is one-standard deviation higher than the mean propensity score for firms that actually merged.
35. Both of the predicted effects for firms with very high propensity scores are significantly different from zero at a 5-percent level. The predictions are based on a firm with a propensity score that is one-standard deviation higher than the mean propensity score for firms that actually merged.

REFERENCES

- Andrade G, Mitchell M, Stafford E. 2001. New evidence and perspectives on mergers. *Journal of Economic Perspectives* **15**(2): 103–120.
- Andrade G, Stafford E. 2004. Investigating the economic role of mergers. *Journal of Corporate Finance* **10**(1): 1–36.
- Campa JM, Kedia S. 2002. Explaining the diversification discount. *Journal of Finance* **LVI**(4): 1731–1762.
- Cochrane WG. 1968. The effectiveness of adjustment by subclassification in removing bias in observational studies. *Biometrics* **24**: 295–313.
- D'Agostino RB. 1998. Tutorial in biostatistics: propensity score methods for bias reduction in the comparison of a treatment to a non-randomized control group. *Statistics in Medicine* **17**: 2265–2281.
- Dranove D, Lindrooth R. 2003. Hospital consolidation and costs: another look at the evidence. *Journal of Health Economics* **22**(6): 983–997.
- Finkelstein A. 2003. Health policy and technological change: evidence from the vaccine industry. *NBER Working Paper* 9460.
- Hall BH. 1999. Mergers and R&D revisited. *Working Paper*.
- Hall BH. 1988. The effect of takeover activity on corporate research and development. In *Corporate Takeovers: Causes and Consequences*, Auerbach AJ (ed.). University of Chicago Press: Chicago.
- Higgins MJ, Rodriguez D. 2006. The outsourcing of R&D through acquisition in the pharmaceutical industry. *Journal of Financial Economics* **80**: 351–383.
- Hirano K, Imbens GW, Ridder G. 2000. Efficient estimation of average treatment effects using the estimated propensity score. *NBER Technical Working Paper* 251.
- Holstrom B, Kaplan SN. 2001. Corporate governance and merger activity in the United States: making sense of the 1980s and 1990s. *Journal of Economic Perspectives* **15**(2): 121–144.
- Imbens G. 2004. Nonparametric estimation of average treatment effects under exogeneity: a review. *Review of Economics and Statistics* **86**(1): 4–29.
- Jensen MC. 1986. Agency costs of free cash flow, corporate finance and takeovers. *American Economic Review* **76**: 323–329.
- Jensen MC. 1993. The modern industrial revolution, exit, and control systems. *Journal of Finance* **48**: 831–880.
- John K, Lang LHP, Netter J. 1992. The voluntary restructuring of large firms in response to performance decline. *Journal of Finance* **47**(3): 891–917.
- Mitchell ML, Stafford E. 2000. Managerial decisions and long-term stock price performance. *Journal of Business* **73**(3): 287–329.
- Mitchell M, Mulherin J. 1996. The impact of industry shocks on takeover and restructuring activity. *Journal of Financial Economics* **41**: 193–229.
- Nicholson S, Danzon PM, McCullough J. 2005. Biotech–pharmaceutical alliances as a signal of asset and firm quality. *Journal of Business* **78**(4): 1433–1464.
- Oi WY. 1962. Labor as a quasi-fixed factor. *Journal of Political Economy* **70**(6): 538–555.
- Pautler PA. 2003. Evidence on mergers and acquisitions. *The Antitrust Bulletin* **48**(1): 119–221.
- Pharmaceutical Researchers and Manufacturers of America. 2003. *Pharmaceutical Industry Profile 2003*. Washington, DC: PhRMA, March.
- Ravenscraft DJ, Long WF. 2000. Paths to creating value in pharmaceutical mergers. In *Mergers and Productivity*, Kaplan SN (ed.). NBER Conference Report Series. University of Chicago Press: Chicago.
- Rosenbaum PR, Rubin DB. 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika* **70**(1): 41–55.
- Vernon J. 2005. Examining the link between price regulation and pharmaceutical R&D investment. *Health Economics* **14**(1): 1–17.
- Villalonga B. 2004. Does diversification cause the 'Diversification Discount'? *Financial Management* **33**(2): 5–27.