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R&D and the Incentives from Merger and Acquisition Activity

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We provide a model and empirical tests showing how an active acquisition market affects firm incentives to innovate and conduct R&D. Our model shows that small firms optimally may decide to innovate more when they can sell out to larger firms. Large firms may find it disadvantageous to engage in an "R&D race" with small firms, as they can obtain access to innovation through acquisition. Our model and evidence also show that the R&D responsiveness of firms increases with demand, competition, and industry merger and acquisition activity. All of these effects are stronger for smaller firms than for larger firms. (*JEL* G34, L11, L22, L25, O31, O34)

We examine how the market for mergers and acquisitions affects the decision to conduct research and development (R&D) and innovate. We argue that an active acquisition market encourages innovation, particularly by small firms in an industry. Instead of conducting R&D in-house, large firms can optimally outsource R&D investment to small firms and then acquire those that successfully innovate. Successful innovation makes firms attractive acquisition targets, and exit through strategic sales becomes an important motivation to continue to spend on R&D.

Recent articles describe how acquisitions are often attempts by large firms to grow by buying innovation (Forbes 2008; Bloomberg 2008).[1] This acquisition potential provides stronger incentives for small firms to engage in R&D. A recent prominent example is Google. Google made 48 acquisitions of smaller firms in 2010, six years after it went public, and 60 acquisitions in the previous

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[1] Companies "cited" as buying others for their innovation include Cisco, General Electric, and Microsoft.

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five years, for a combined total of 108 acquisitions in the six years post–initial public offering (IPO).[2] Early in its life, Google bought three smaller search engines for their technology assets and patents. Each of these companies operated search engines with additional features that Google incorporated into its online search capabilities.[3] Another example is Cisco. To extend its networking offerings, Cisco has purchased 16 computer networking companies and five computer security companies since 1999.

We present a model and empirical tests showing how an active acquisition market positively affects both small and large firms' incentives to innovate and conduct R&D. We also show that mergers can be a way to acquire innovation as a substitute strategy for conducting R&D. This motive is distinct from other motives for acquisitions that include neoclassical theories or agency theories of mergers[4] and is closest to recent theories and evidence by Rhodes-Kropf and Robinson (2008) and Hoberg and Phillips (2010b) that emphasize asset complementarities and product market synergies.

Our model shows why large firms optimally may decide to let small firms conduct R&D and then subsequently acquire the companies that have successful innovated. We show that firms' incentives to conduct R&D increase with the probability that they are taken over and how this effect decreases with size. This result is consistent with evidence that post-acquisition larger firms innovate less and with evidence that larger firms conduct less R&D per unit of firm size. Seru (forthcoming) recently finds that patenting goes down post-acquisition and concludes that large conglomerate firms "stifle" innovation, while noting that they are more likely to sign alliances and joint ventures—a fact consistent with the outsourcing of R&D. Our interpretation of the decrease in innovative activity is different. Our model and evidence show that R&D may optimally decline for large firms but increase for small firms with merger activity. Large firms may find it optimal to buy other firms to gain access to successful innovations instead of investing in R&D themselves, while small firms face increased incentives to invest in R&D with an active takeover market. An additional benefit of acquisition results from the ability of the merged entity to apply innovation to both the bidder's and the target's product ranges.

Specifically, the model provides the following predictions. First, the possibility of an acquisition induces attempts to innovate by both small and large firms, but this effect decreases with size as large firms may find it optimal to buy smaller firms that successfully innovate and cannot prevent small firms from attempting to innovate. The possibility of an acquisition amplifies the potential

[2] See "Google Cranks Up M&A Machine," *Wall Street Journal*, March 5, 2011.

[3] These purchases include Outride (see http://www.google.com/press/pressrel/outride.html), Kaltix (see http://en.wikipedia.org/wiki/Kaltix), and Orion (see http://searchengineland.com/google-implements-orion-technology-improving-search-refinements-adds-longer-snippets-17038).

[4] See Maksimovic and Phillips (2001) and Jovanovic and Rousseau (2002) for neoclassical and q theories and Morck, Shleifer, and Vishny (1990) for an agency motivation for mergers. See Maksimovic and Phillips (2008) for how conglomerate firms may relax financial constraints in order to acquire other firms.

gain from successful R&D. Second, we show that larger firms' R&D is less procyclical than smaller firms' R&D. While small firms are always motivated to invest more following a positive demand change, this is not necessarily true for large firms. Unlike small firms, large firms may find it disadvantageous to engage in an "R&D race" with small firms at intermediate states of demand, as they can obtain access to innovation by acquiring a smaller firm that succeeded in its R&D efforts. Thus, a large firm's investment in R&D might actually go down with a moderate increase in demand. The economic intuition for this result is that while the large firm may have a larger benefit from the innovation, it cannot prevent small firms from trying to successfully obtain the innovation first, and it still has an option of buying the innovation from the smaller firm.

Third, greater bargaining power[5] of the small firm leads to more aggressive attempts to innovate by the small firm and to higher likelihood of an acquisition. Having the ability to capture a greater fraction of the acquisition surplus, the small firm will tend to invest in R&D to increase the odds of successful innovation and being acquired by the larger firm. Fourth, we show that market structure and competition are important. A higher number of small firms leads to less innovation by larger firms. The economic intuition for this result is that the large firm has more potential innovators to purchase the innovation from and the increased competition decreases the odds that it will be the successful innovative firm itself.[6]

We empirically examine these predictions of our model. We find that firms' R&D responds to demand changes, measures of industry acquisition activity, and the probability of being an acquisition target, and less so for large firms than small firms. We also find that their R&D increases with competition and with target acquisition excess returns—a measure of bargaining power of small firms in the acquisition market. We find that while R&D responds positively to competition, larger firms in competitive industries conduct less R&D than smaller firms.

In our analysis, we control for the fact that R&D and acquisition activity may be endogenous and both be affected by fundamentals and thus it may be fundamentals that are driving both acquisitions and R&D. We have two strategies to help us identify whether acquisition likelihood increases firm R&D. We first use industry measures of acquisition activity and demand. We use lagged measures of industry merger and acquisition (M&A) activity to proxy for anticipated demand that potential targets face for their assets. We also examine inside-industry M&A activity to examine what a target firm may expect to sell its assets for following Shleifer and Vishny (1992) and Ortiz-Molina and

5 Usually firms engage in negotiations before and/or after there is a public announcement of a bid or an intention to bid. We refer to the ability of a firm management to negotiate favorable terms of the takeover as the firm's (relative) bargaining power.

6 Fulghieri and Sevilir (2009) model how the optimal response of firms to competition may be to choose to fund innovation through corporate venture capital and strategic alliances.

Phillips (forthcoming). Second, we also control for endogenous acquisition probability by estimating the probability of being an acquisition target using an plausibly exogenous instrument, unexpected mutual fund flow into and out of stocks, that can affect persistent firm valuation and thus acquisition activity but not affect firm fundamentals.[7]

Our research adds to the current academic literature in several areas. First, we provide a new theory for the incentive effects of M&A that has not been explored in the literature. The existing literature has emphasized neoclassical models or q-based theories where highly productive firms buy less productive firms and has also emphasized managerial agency theories of mergers. It also adds to the theories that emphasize asset complementarity or product market synergies, by emphasizing that new innovations produced through R&D can be used by existing firms with complementary assets. Our paper directly examines the effect of acquisition probabilities, market structure, and firm size on R&D.

Second, our model and evidence is consistent with large firms optimally reducing innovation, letting small firms innovate, and acquiring them later. We focus on the selection effect and how this potential effect may impact pre-acquisition R&D. Other papers focus on treatment effects and examine R&D or patents post-acquisition. Our evidence is consistent (although the interpretation is different) with other recent papers that examine R&D and patents post-acquisition. Seru (forthcoming) finds conglomerate firms reduce innovation post-acquisition. Hall (1999) finds no effect on R&D expenditures from mergers of public firms, while a reduction in R&D following going-public transactions.[8] A direct implication of our paper is that instead of interpreting low R&D as a sign of managerial inefficiency or myopia, low R&D can be optimal since the firm can instead be intending to acquire innovation. Our paper is consistent with the recent working paper by Bena and Li (2012), who show that large companies with large patent portfolios and low R&D expenses are more likely to be acquirers.

Related literature looks at the relation between competition in product markets and innovation, without paying attention to acquisitions. Vives (2008) provides a detailed overview of theoretical and empirical work. Recently, Fulghieri and Sevilir (2011) theoretically model the ex ante effects of mergers and competition on innovation. They model how a reduction in competition through mergers reduces employee incentives to innovate. The empirical evidence is favorable to the positive effect of competition

[7] See Edmans, Goldstein, and Jiang (2012) for the description of and successful use of this instrument. We thank them for sharing this mutual fund flow instrument with us.

[8] Note that our model and evidence are about small firms optimally deciding to sell out. We do not model agency conflicts nor anti-takeover amendments that are common for larger firms that may be subject to conflicts between managers and shareholders. See Atanassov (2009) and Chemmanur and Tian (2010) for articles that deal with anti-takeover devices or laws. The anti-takeover laws passed in the United States apply more to large firm takeovers in more mature industries as they reduce post-acquisition asset sales and are thus not relevant for acquisitions of smaller innovative firms. Also note that these state-level anti-takeover laws were not passed in California or Texas, two states with a high technology focus.

on innovation, including Baily and Gersbach (1995), Nickell (1996), and Blundell, Griffin, and Van Reenen (1999). However, most of these papers look at productivity rather than R&D. Theoretical work seems to support a negative relation between innovation and competitive pressure. Standard industrial organization theory predicts that innovation should decline with competition, as more competition reduces the monopoly rents that reward successful innovators (Dasgupta and Stiglitz 1980). Other theoretical papers suggest a positive (Aghion et al. 2001) or U-shaped relation (Aghion et al. 2002) between innovation and product market competition. We complement and extend this literature by focusing on the effect of a potential acquisition on firm innovation incentives.[9]

Overall our contribution is to focus on the trade-off for large firms between innovating themselves or acquiring small firms that have successfully innovated. Acquiring firms that have successfully innovated can be a more-efficient path to obtaining innovation than innovating directly oneself. We illustrate this effect in a theoretical model and provide rigorous empirical tests. Second, we generate new empirical predictions regarding procyclicality of R&D investments and their relation to firm size, the effect of potential acquisitions on R&D, the link of R&D to industry structure, and the effect of bargaining power and asset liquidity on small firms' R&D decisions.

1. The Model

We present a model that allows us to draw empirical predictions about the relation between R&D, acquisitions, and firm size. We begin the model with a simple utility function for consumers who value product variety but are willing to substitute between products. In the base version of the model, we assume heterogeneous products and price (Bertrand) competition.[10] We believe this type of competition fits the case of many industries such as computer networking, cell phones, and consumer products, among others, where companies compete based on product differentiation. We define the product space broadly, with specific features that can be patented that represent "local products," which may affect the demand for existing products. Our idea is that *multiple* firms can try for a particular product characteristic ex ante yet only one will obtain the particular product characteristic with a patent. Ex post, one firm innovating does *not* preclude product differentiation across existing or

9 Our paper is also related to the literature that studies the procyclicality of R&D (e.g., Barlevy 2007 and Aghion et al. 2008).

10 In the online appendix we also examine an alternative competition mechanism, Cournot competition, whereby firms produce homogeneous products and innovation results in cost savings, and find similar results. Under Cournot competition with similar competitors, mergers will not take place as rival firms expand output after the merger. This result is a well-known Cournot-merger paradox (Salant, Switzer, and Reynolds 1983). However, the literature (Gaudet and Salant 1992 and Zhou 2008, among others) has shown that under Cournot competition with cost savings mergers will take place. In our setting, if the innovation produces large cost savings, mergers will take place with positive demand shocks.

new products as the patented product/characteristic, when obtained, may affect the demand for other firms' existing products. The rationale is that areas of the product space are large enough to contain subareas with differentiated products, each with their own particular differentiation. Thus ex post competition is characterized by product differentiation. What is required is that the cross-partial price elasticity of demand is not zero and not infinity. Thus, changes in one product's price or characteristic affect the other product's demand but there is not perfect competition.

The previously cited examples of Google purchasing smaller search engines for the different ways they conduct searches and the different features they offer in their search engines fits the assumption of differentiated products. To extend its networking offerings, Cisco has purchased 16 computer networking companies and five computer security companies since 1999. Since 2004, Google has bought many advertising firms (Admeld, Admob) and even the Android software firm, which allows it to develop and extend its advertising business. Note that Admeld and Admob were close competitors of Google and not just supply-chain related. Google had moved into the business selling advertising through display ads, not directly connected to searches, as display ads appear after you visit a firm's Web site. Admeld and Admob were also selling advertising through display ads. From an advertiser's perspective, ads offered through search or display ads on the Internet are differentiated products that they purchase. The pricing for one product affects the demand for the other, but they serve the same function of getting the advertiser's message out to consumers. Admeld and Admob had a different technology for selling display ads and as such had product extensions that were useful to Google and were viewed by many industry participants as competitors with differentiated products.[11]

Our model captures both heterogeneous products and the intensity of product market competition in a simple setting. We believe that this setting provides a realistic background for the issues of interest, as a positive effect of innovation by a small firm is likely to result in a shift in consumers' demands. However, our analysis is robust to the scenario in which innovation results in cost savings and firms compete in quantities (see the online appendix for results). We study one large firm and up to two small firms, but the model can potentially be extended to allow additional firms. We allow each firm to innovate and introduce a new

[11] Admeld's Web site (http://www.admeld.com/about/overview/) highlights the technology and methods that they use to display advertising on Web sites. As their Web site states, "Admeld was first to introduce the private exchange (November 2010), first to optimize mobile (January 2010), and the first to launch an ad monitoring browser plugin (March 2009). Quite simply, our engineers are building things better and faster to keep our clients on the cutting edge." Many articles have discussed the potential for decreased competition post-deal, including one stating, "So what is the Admeld deal really about for Google? The company is seeking to expand its monopoly power in search advertising to other aspects of online advertising, where Google is already the 800 lb. gorilla between its acquisition of DoubleClick in 2008, and Google's multi-billion-dollar annual AdSense business" (http://www.fairsearch.org/acquisitions/approval-for-admeld-deal-could-make-google-another-category-killer/).

product, but they can also choose to purchase other firms instead of innovating themselves.

1.1 General setup

1.1.1 Consumers. We follow Vives (2000, 2008) and Bernile, Lyandres, and Zhdanov (2012) and consider an industry with n ($n \in \{2,3\}$) firms. Initially, each product is produced by a single firm. There is a representative consumer, with a general quadratic utility function that allows for concavity in consumer utility as she consumes more of any given product and also allows for differentiated products captured by the parameter γ, the degree of substitutability among the products:

$$U(\overrightarrow{q}) = \sqrt{x}\sum_{i=1}^{m}\alpha_i q_i - \frac{1}{2}\left[\sum_{i=1}^{m}\beta q_i^2 + 2\sum_{j\neq i}\gamma q_i q_j\right], \tag{1}$$

where $\alpha_i > 0$ represents consumer preferences for product i, β measures the concavity of the utility function, γ represents the degree of substitutability between products i and j, and m is the number of different products in the market. We assume that $\beta > \gamma > 0$,[12] $\alpha_i > \alpha_j$ implies that the consumer prefers product i to product j, but still consumes both products as long as they are imperfect substitutes ($\gamma < \beta$). In (1), q_i is consumption of good i, n is the number of active firms in the industry, and, thus, the number of available products, and x is the stochastic shock to the representative consumer's utility. $\gamma > 0$ ensures that the products are (imperfect) substitutes. The higher the γ, the more alike are the products and the more intense is competition in the industry. Furthermore, we follow Vives (2008) and assume that, in addition to the products above, there is a numeraire good (or money), which represents the rest of the economy, and income is large enough that the income and wealth constraints never bind and all income effects are captured by consumption of the numeraire good. In what follows, we normalize β to 1. (The results are insensitive to this normalization.) In this setting, as γ approaches 1, the consumer becomes indifferent between the products and is better off having a high quantity of the product with the lower price and none of the others.

1.1.2 Production technology. There are n ($n \in \{2,3\}$) firms in the industry. Firms have a similar production technology, but we allow heterogeneity in the size of firms, with each firm initially endowed with capital K_i. The firms' production functions are of the Cobb-Douglas specification with two factors:

$$q_i = \sqrt{K_i L_i}, \tag{2}$$

where q_i is the quantity produced by firm i, and L_i is the amount of the second factor (e.g., labor) employed by firm i.

[12] This assumption ensures that the utility function is concave. For high values of γ, the consumer is better off having a high quantity of one product and none of the other products rather than moderate amounts of all products.

The cost of one unit of labor is denoted p_l. The amount of capital is fixed, hence labor is the only variable input. Given this specification, firm i's cost of producing q_i units is

$$C_i(q_i)=\frac{q_i^2}{K_i}p_l. \tag{3}$$

This specification results in profit functions of the following form:

$$\pi_i=q_i p_i - C_i(q_i). \tag{4}$$

Firms are heterogeneous in the amount of capital. There is one big dominating firm with capital K_1 and one or two small firms with capital $K_{2,(3)}<K_1$ each. In what follows, we assume that $p_l=1$ (the results are insensitive to this assumption).

1.1.3 R&D and innovation. Each firm in the industry has an option to invest in R&D to potentially obtain and develop an innovative technology at a cost of RD_i. If one firm invests in R&D, then it develops the innovation with 100% certainty. If multiple firms invest in R&D, the probability that any individual firm develops the innovation decreases to *1/n*.[13] The innovative technology, once developed, can be brought to the market through commercialization. For the sake of simplicity, we assume that commercialization is costless, but we obtain similar results under the assumption that commercialization requires a certain cost of I_i to be incurred by firm i. Bringing to market the product based on this innovation results in an enhanced product that results in increased consumer utility for the product, as reflected in an increase of the parameter α_i from α_{i1} to α_{i2}, where $\alpha_{i1}<\alpha_{i2}$. For simplicity, we assume that $\alpha_{i1}=\alpha$ and $\alpha_{i2}=\alpha'$, $i\in\{1,2,3\}$.

1.1.4 The acquisition market. The big firm, whether or not it has acquired the innovative technology, has an option to take over one small firm. We assume (for simplicity to focus on innovation) that there are no economies of scale and that the merged firms utilize all the pre-merged firms' capital and do not reallocate capital between their production facilities (or that it is prohibitively costly to do so). Nevertheless, there are two consequences of an acquisition on the profit of the merged entity (and its competitors, if any). First, the two firms are now able to coordinate their pricing strategies, which leads to greater market power and increases equilibrium prices and profits. Second, the merged entity can apply innovation to its entire product line, resulting in an increase of the consumer preference parameter from α to α' for

[13] In section 2 of the online appendix, we also analyze the case in which the probability of innovating successfully does not depend on the number of firms that attempt to innovate and multiple firms can develop the innovation. Our results are robust to this case.

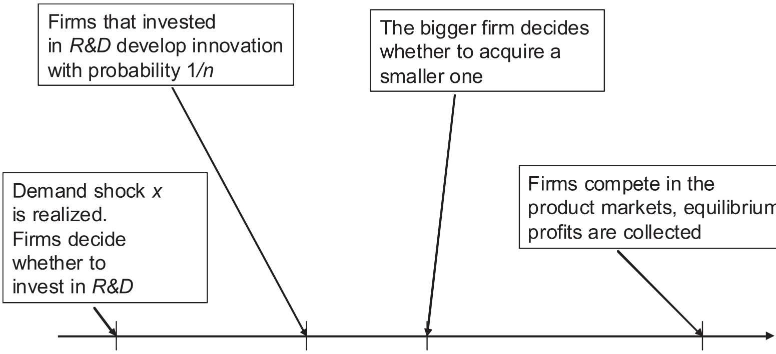

Figure 1
Sequence of events
This figure presents the sequence of events and the nature of the game. Initially, firms observe a realization of the demand shock and decide whether or not they want to invest in R&D. Competition in R&D then results in each participating firm developing innovation with probability $\frac{1}{n}$. The larger firm then decides whether or not to acquire a smaller one (regardless of which firm, if any, has developed innovation). Finally, equilibrium profits are earned by the firms.

all its products.[14] We assume that an acquisition can be implemented at a fixed cost, I_m.

We further assume that the target shareholders get a fraction η of the acquisition surplus; e.g., the price paid to the target shareholders is given by

$$P = V_t^s + \eta(V_m - V_t^s - V_b^s),$$

where V_m is the value of the merged entity if an acquisition is implemented, V_t^s and V_b^s are the "stand-alone" values of the target and the bidder. Parameter η reflects the relative bargaining power of the target (small firm), so $1-\eta$ is the relative bargaining power of the acquirer.

The sequence of events is presented in Figure 1. Initially, firms observe a realization of the demand shock and decide whether or not they want to invest in R&D. Competition in R&D then results in each participating firm developing the innovation with probability $\frac{1}{n}$. The larger firm then decides whether or not to acquire a smaller one (regardless of which firm, if any, has developed the innovation). Finally, equilibrium profits are earned by the firms.

[14] We realize that our assumption that the extension or product that is developed with the R&D can be applied to the entire product line may be viewed as extreme, as the innovation may only apply to part of the acquirer's product line. However, this additional complication of modeling multi-product firms is beyond the scope of our paper. We believe our model does capture the potential for how products may work together or may co-exist separately and how the acquired firm's technology can be used with the acquirer's existing products. An example is Google buying Motorola Holdings, which produces cell phones in addition to having patents that can be used in Google's Android product offerings. Google was previously making cell phones (Nexus One) in addition to providing the Android software.

1.2 Solution

The equilibrium prices and profits of firms in the industry depend on which firm has successfully innovated (if any) and on whether an acquisition occurs. In the following subsections, we allow for a large firm and a small firm with varying degrees of bargaining power. We start with a case when a merger is precluded and then proceed by incorporating a possibility of an acquisition. We also analyze an industry with two small firms and one big firm to illustrate the effect of increasing competition.

Case 1: One small firm and one large firm: No acquisition is possible

To find the equilibrium profits, we first differentiate the utility function with respect to quantities and set the derivatives equal to prices. Solving the resulting system of equations for quantities gives the demand functions

$$q_1 = \frac{\sqrt{x}(\alpha_1 - \alpha_2\gamma) - p_1 + p_2\gamma}{1-\gamma^2}, \tag{5}$$

$$q_2 = \frac{\sqrt{x}(\alpha_2 - \alpha_1\gamma) - p_2 + p_1\gamma}{1-\gamma^2}. \tag{6}$$

The inverse demand functions are linear in prices. We then substitute these functions into profit functions (4), differentiate with respect to prices (firms maximize their profits by setting prices competitively), set the derivatives equal to zero, and solve the resulting system of equations. This produces equilibrium prices, provided in the appendix. We then substitute equilibrium prices back into the inverse demand functions to get equilibrium quantities, then into profit functions (4) to obtain equilibrium profits.

Figure 2 plots the equilibrium profit of a firm as a function of "consumer preferences"; equivalently, this can be thought of as a firm's "product innovation parameter," α_i, for its product, that of its competitor, α_j, the relative size of the two firms, K_1/K_2, and the degree of product differentiation, γ. The comparative statics are based on the following parameter values: $K_1 = 10$, $K_2 = 1$, $\gamma = 0.5$, $\alpha_1 = 10$, $\alpha_2 = 10$. For each graph, we compute the profits with these values but vary one of them as indicated on the x-axis. Consistent with intuition, equilibrium profit of one firm increases in its own product innovation parameter α_i, and decreases with its product substitutability γ, its rival's capitalization K_j, and its rival's product innovation parameter, α_j.

Let us denote the equilibrium profit of firm i by $\pi_i(A_i, A_j)$, where $A_i = NI$ if firm i decides not to invest in R&D and $A_i = I$ if it invests. Lemma 1 establishes certain relations between equilibrium profits in different scenarios. These relations prove useful in the subsequent analysis of the optimal R&D and acquisition policies.

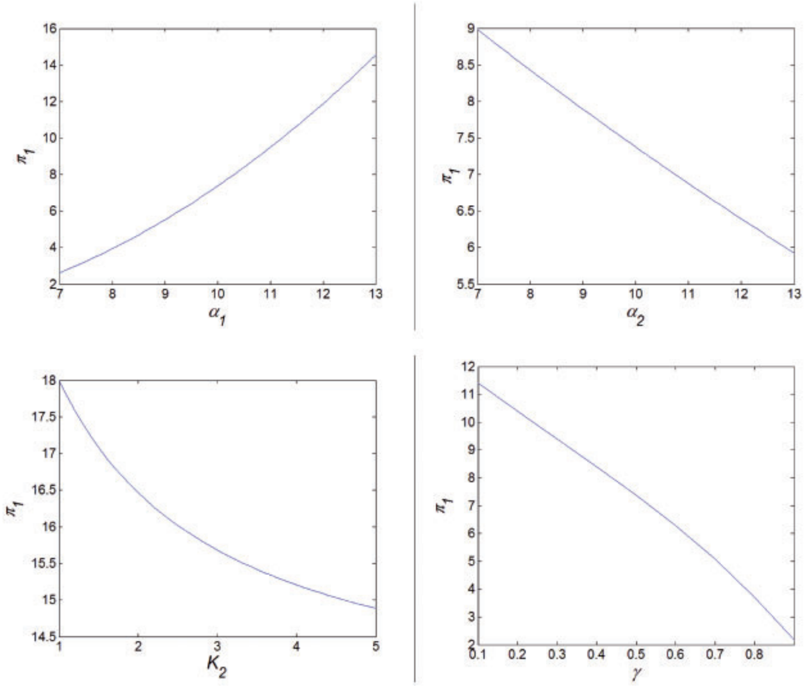

Figure 2
Equilibrium profits: two firms, no acquisition possible
This figure presents the equilibrium profit of a firm as a function of its "innovation parameter," α, the capital ratio of the firms K_1/K_2, and the degree of product differentiation, γ, for the following set of input parameters: $K_1=10$, $K_2=1$, $\gamma=0.5$, $\alpha_1=10, \alpha_2=10$. For each graph, we compute the profits with these values but vary one of them as indicated on the x-axis. Consistent with intuition, equilibrium profit of one firm increases in its own innovation parameter α_i, and decreases with its product substitutability γ, its rival's capitalization K_j, and its innovation parameter α_j.

Lemma 1. Let $K_1 > K_2$ and $I_m=0$.[15] Then, the following inequalities hold:

a) $\pi_1(I,NI) > \pi_1(NI,NI) > \pi_1(NI,I)$.
b) $\pi_2(NI,I) > \pi_2(NI,NI) > \pi_2(I,NI)$.
c) Let $\gamma=0.5$. Then $\pi_1(I,NI)-\pi_1(NI,NI) > \pi_2(NI,I)-\pi_2(NI,NI)$.
d) $\pi_1(I,NI)-\pi_1(NI,I) > \pi_2(NI,I)-\pi_2(I,NI)$.
e) Let $\gamma=0.5$ and $K_2=1$. Then, there exists $\mu>1$ and $\alpha^h >> \alpha$ such that for $K_1/K_2>\mu$ and $\alpha<\alpha_i<\alpha^h$, the following inequality holds:

$$\frac{\pi_1(I,NI)-\pi_1(NI,I)}{2} > \pi_2(NI,I)-\pi_2(NI,NI).$$

15 Our results hold for positive merger cost $I_m>0$. Assuming a positive merger cost is only useful to illustrate the procyclicality of takeovers.

f) Let $\gamma = 0.5$ and $K_2 = 1$. Then, there exists $\mu_1 > 1$ such that for $K_1/K_2 > \mu_1$ the following inequality holds:

$$2(\pi_1(I,NI) - \pi_1(NI,NI)) > \pi_2(NI,I) - \pi_2(I,NI).$$

g) The following relation holds: $\pi_2(NI,I) - 2\pi_2(NI,NI) + \pi_2(I,NI) > 0$.

Proof. See Appendix. ■

Parts a and b of Lemma 1 simply state that the profit of a firm increases if it innovates and decreases if a competitor implements innovation, as shown in Figure 1. Parts c and d state that a successfully implemented innovation has a greater effect on the profit of the larger, more capital-intensive firm. While we impose some parameter restrictions in parts c, e, and f, we also perform numerical simulations to investigate the robustness of our results and find that in general the statements of Lemma 1 hold for a large set of reasonable parameter values, and even when some of these statements are violated, our major predictions still go through. See the online appendix for details.[16]

Let us now introduce the following threshold boundary parameters. These boundary parameters are useful as they define important thresholds that shape firms' equilibrium R&D policies:

$$x_1 = \frac{RD}{\pi_1(I,NI) - \pi_1(NI,NI)}; \qquad x_2 = \frac{RD}{\pi_2(NI,I) - \pi_2(NI,NI)};$$

$$x_3 = \frac{2RD}{\pi_2(NI,I) - \pi_2(I,NI)}; \qquad x_4 = \frac{2RD}{\pi_1(I,NI) - \pi_1(NI,I)}.$$

Note that Lemma 1 a) and b) ensure that all these values are positive, while Lemma 1 e) ensures that $x_4 < x_2$. Lemma 1 c) ensures that $x_1 < x_2$. Lemma 1 d) ensures that $x_4 < x_3$. Lemma 1 f) ensures that $x_1 < x_3$. Lemma 1 g) ensures that $x_2 < x_3$.

The optimal R&D policy of each firm depends on the current state of demand x and on the actions of its opponent. Each firm first decides whether it wants to invest in R&D. If neither firm invests, then neither develops the innovation and the profits of the two firms are given by $\pi_1(NI,NI)$ and $\pi_2(NI,NI)$. If only one firm invests in R&D, then it acquires the new technology with certainty. If both firms invest in R&D, then each of them has a 50% chance of obtaining the patent. The successful firm then commercializes the innovation.

Proposition 2 defines the equilibrium R&D strategies of the two firms in the absence of takeovers.

[16] Lemma 1 part c and Lemma 1 part f hold for a large set of parameter values. For example, both these conditions hold if $K_1 = 10; a = 10;\ 0.1 \leqslant \gamma \leqslant 0.9;\ 1 \leqslant K_2 \leqslant 9;\ 11 \leqslant \alpha' \leqslant 30$. Lemma 1 part e is, however, more restrictive. It holds well when the ratio of the capital stocks of the two firms K_1/K_2 is relatively high. For example, it holds for the following parameter combinations: $K_1 = 10; a = 10;\ 0.25 \leqslant \gamma \leqslant 0.75;\ K_2 \leqslant 1;\ 11 \leqslant \alpha' \leqslant 18$, or $K_1 = 10; a = 10;\ 0.05 \leqslant \gamma \leqslant 0.95;\ K_2 \leqslant 0.5;\ 11 \leqslant \alpha' \leqslant 30$. We believe that our story is more relevant for large firms acquiring much smaller ones, and less for a merger of similar firms. However, numerical analysis suggests that even when lemma 1 part e is violated, our major predictions still obtain.

Proposition 2. Assume that conditions a–f of Lemma 1 hold. Then, there are three Nash equilibria in pure strategies, depending on the value of x. In particular, for $x < x_1$, the only Nash equilibrium is (NI, NI) (no firm invests). For $x_1 < x < x_3$, the only Nash equilibrium is (I, NI) (the big firm invests and the small firm does not). For $x > x_3$, the only equilibrium is (I, I) (both firms invest).

Proof. See Appendix. ■

Figure 3 presents the equilibrium strategies of the two firms in the space (α', x). The results in Figure 3 are based on the following set of parameter values: $K_1 = 10$, $K_2 = 1$, $\gamma = 0.5$, $\alpha = 10$, $\alpha' = 15$, $RD_1 = RD_2 = 15$. There are three regions in Figure 3. For very low states of x, the NPV of investing in R&D for the big firm, NPV_1, is negative, and so is the NPV of investing in R&D for the small firm, NPV_2, so both firms optimally choose not to invest (region I). For sufficiently high values of x, NPV_1 becomes positive and the big firm invests; while NPV_2 is still negative, the benefit of applying innovation to the capital stock of the small firm is less valuable than that of the big firm with more abundant capital (region II). Finally, for even higher states of x, the small firm chooses to join the R&D race with the big firm, as the value of the option to join becomes positive (region III). Regions I and II are separated by threshold x_1, while regions II and III are separated by threshold x_3. As shown in Figure 3, the incentive to invest in innovation for both firms is greater when the benefit of innovation α' is high.

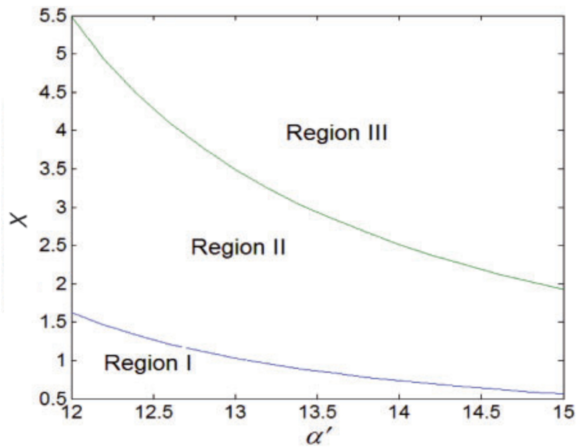

Figure 3
Equilibrium strategies: two firms, no acquisition possible
This figure presents the equilibrium investment thresholds of the two firms in the case when an acquisition is precluded, as functions of the innovation parameter α'. The set of input parameters is as follows: $K_1 = 10$, $K_2 = 1$, $\gamma = 0.5$, $\alpha_1 = \alpha_2 = 10, \alpha' = 15, RD_1 = RD_2 = 15$. No firm invests in Region I, only the big firm invests in Region II, and both firms invest in Region III. Regions I and II are separated by x_1; Regions II and III are separated by x_3.

Case 2: One small firm and one large firm: Acquisitions are possible

We now assume that the big firm has an option to acquire the small one. A successful acquisition results in a single firm in the industry, which sets prices to maximize its total (monopoly) profits. If either the small or the big firm has developed the innovation, then the merged firm will commercialize it. Note that the merged entity still produces two separate products, and demand for each product will be characterized by the parameter $\alpha=\alpha'$. The profit of the merged entity is given in the appendix. We denote by $\pi_m(I)$ the profit of the merged entity if it implements the innovation and by $\pi_m(NI)$ its profit if it does not implement the innovation.

The equilibrium investment choices of firms are found similarly to the previous case by comparing expected firm values in different scenarios. When deciding whether or not to invest in R&D, the big firm now takes into account the possibility of acquiring the small firm if the latter develops the innovation. Likewise, the small firm incorporates the possibility of being acquired by the big firm in its optimization problem.

Proposition 3 establishes the equilibrium R&D strategies of the two firms if an acquisition is possible.

Proposition 3. Assume $\eta=0$ (the big firm captures 100% of the takeover surplus). Also assume that the following conditions hold: $\pi_m(I)-\pi_m(NI)>\pi_1(I,NI)-\pi_1(NI,NI)$[17] and $\pi_2(NI,I)-\pi_2(NI,NI)>\pi_2(NI,NI)-\pi_2(I,NI)$.[18] If takeovers are possible, then the following are the Nash equilibria in pure strategies. If $x<x_{1m}$, where

$$x_{1m}=\frac{RD}{\pi_m(I)-\pi_m(NI)+\pi_2(NI,NI)-\pi_2(I,NI)},$$

then the only Nash equilibrium is (NI,NI) (no firm invests). If $x_{1m}<x<x_2$, then the only Nash equilibrium is (I,NI) (big firm invests). If $x_2<x<x_3$, then there are two pure-strategy Nash equilibria: (NI,I) (small firm invests and big firm does not) and (I,NI) (big firm invests and small firm does not). In addition, there is a mixed-strategy equilibrium in which the big firm invests with probability p_1 and the small firm invests with probability p_2 (these probabilities are determined in the appendix). If $x>x_3$, then the only equilibrium is (I,I) (both firms invest).

[17] This condition stipulates that the acquisition benefit is greater for the merged entity than it is for the big firm (as a stand-alone entity). It is intuitive and holds for a large set of reasonable parameter values.

[18] This condition also holds for a large set of reasonable parameter values. It is also intuitive and implies that the positive effect of its own innovation on the profit of the small firm is greater in absolute value than the negative effect due to the large firm innovating. See the online appendix for details.

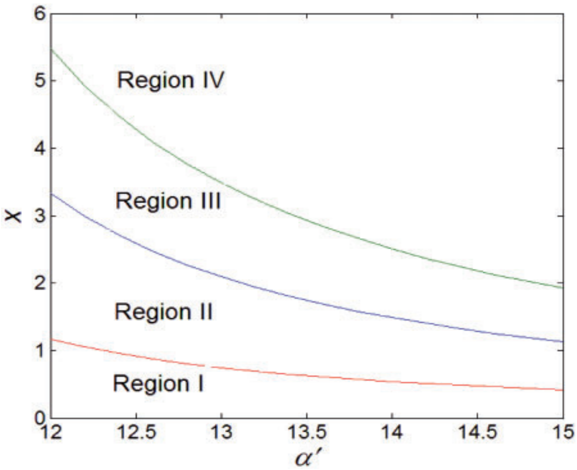

Figure 4
Equilibrium strategies: two firms, an acquisition is possible
This figure presents the equilibrium investment thresholds of the two firms in the case when an acquisition is possible, as functions of the innovation parameter α'. The set of input parameters is as in Figure 3. In addition, the relative bargaining power of target is assumed to be zero ($\eta=0$). At low states of the demand shock x, both firms prefer not to invest in R&D (Region I). In Region II, only the big firm invests. In Region III, there are two pure-strategy Nash equilibria: (small firm invests, big firm does not; big firm invests, small firm does not) and a mixed-strategy equilibrium (the small firm invests with probability ϕ_2 and the big firm invests with probability ϕ_1; ϕ_2 and ϕ_1 are determined in the appendix). Both firms invest in Region IV.

Proof. See Appendix. ■

Figure 4 illustrates the equilibrium innovation strategies of the two firms. There are two important differences between Figures 3 and 4. First, innovation by the big firm starts at a lower state of demand x, because the potential benefit of innovation is greater—the big firm has an option to acquire the small one and apply the innovation to both its capacity and production *and* the production capacity acquired from the non-innovating small firm so x_{1m} is less x_1 (see proof of Proposition 2 in the appendix). Second, there is a region in which there is a pure-strategy equilibrium, in which the small firm innovates while the big firm does not, and another mixed-strategy equilibrium, in which the small firm innovates with a certain probability ϕ_2. (For the set of parameter values used in Figure 4, the state of demand $x=1.5$, and the innovation parameter $\alpha'=12$, the corresponding probabilities are $\phi_1=0.58$ and $\phi_2=0.91$.)

Note that while our modeling framework does not allow us to determine which firm is going to invest in the intermediate region, any advantage in terms of flexibility or speed of reacting to current market conditions would lead to a first-mover advantage and would make the more inert firm less likely to invest. Since it cannot outpace the faster firm, it would be forced not to invest. It is reasonable to think of small firms as being more flexible and able to adapt faster to changes in the market. In this case, by investing first a small firm would rule out the (I,NI) equilibrium and the mixed-strategy equilibrium.

Furthermore, numerical results show that in the mixed-strategy equilibrium, the probability of the small firm investing is typically higher than that of the large firm. On the other hand, for larger, capital-intensive R&D projects, the large firm can potentially commit more capital than the small one and that can give it a competitive edge and result in the (I, NI) outcome.

Overall, by comparing Figures 3 and 4, we conclude that the possibility of takeover intensifies the small firm's R&D investment. Indeed, in region III in Figure 4 there is no equilibrium in which the small firms invest if takeovers are not allowed (Figure 3), while there are multiple equilibria in this region if takeovers are possible (Figure 4). Furthermore, when we analyze below (in extensions of the model) the case where bargaining power of the target may vary, for some values of the bargaining parameter η, there is a region in which (NI,I) is the only equilibrium.

We proceed to analyze the effect of takeover cost I_m on the dynamics of takeovers. A takeover always results in a reduction in the number of firms and therefore in greater market power and increased combined profits for the combined firms, as the firms can now internalize their pricing decisions. Thus, $\pi_m(I) > \pi_1(I,I) + \pi_2(I,I)$. As shown by Proposition 2, at high values of x both firms optimally decide to innovate even if takeovers are precluded, because the benefit of innovation is proportional to x. Given the bargaining power parameter η, the fraction of the surplus captured by the large firm is $\eta(\pi_m(I) - \pi_1(I,I) - \pi_2(I,I))x$ and increasing in x. Clearly, for

$$x > \frac{I_m}{\eta(\pi_m(I) - \pi_1(I,I) - \pi_2(I,I))},$$

the takeover benefit outweighs the cost and the large firm initiates the takeover. On the other hand, for very low x the benefit of the takeover is not enough to compensate for the cost. Thus, if $x < \frac{I_m}{\eta(\pi_m(NI) - \pi_1(NI,NI) - \pi_2(NI,NI))}$, takeover does not occur. This leads to the procyclicality of takeovers. Takeovers always happen at sufficiently high values of x and never happen at low x, as long as the takeover cost I_m is positive. This logic is summarized in Proposition 4 and is illustrated in Figure 5.

Proposition 4. If $I_m > 0$, then takeovers are procyclical.

This result is consistent with the large theoretical literature on acquisitions and capital reallocation (e.g., Lambrecht 2004; Morellec and Zhdanov 2005; Eisfeldt and Rampini 2006) and supported by empirical evidence (Mitchell and Mulherin 1996; Maksimovic and Phillips 2001; Harford 2005). Figure 5 plots the demand threshold, $\overline{x}$, at which the acquisition just becomes profitable, as a function of the acquisition cost I_m. We solve the model numerically for positive values of I_m. Acquisition is optimal for the states of demand exceeding $\overline{x}$. As Figure 5 shows, acquisitions are procyclical and acquisition thresholds increase in the cost of merger I_m. Note that in general there are two acquisition thresholds that divide the space (x, I_m) into three different regions. In the bottom

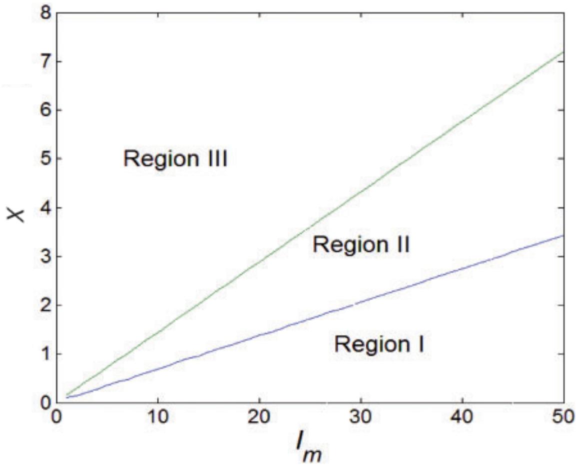

Figure 5
Acquisition thresholds
This figure presents the equilibrium acquisition strategy as a function of the demand shock x and the takeover cost I_m. The set of input parameters is as in Figure 3. Above the higher boundary (Region III), an acquisition occurs with certainty. Between the lower and the upper thresholds (Region II), an acquisition is optimal only if the small firm obtains the innovation. Below the lower threshold (Region I) acquisition never occurs. Thus, the probability of an acquisition is positively related to the state of the demand shock x and acquisitions are procyclical.

region (region I), acquisitions never occur. The cost of merger is too high in that region for an acquisition to be optimal. In the top region (region III), acquisitions occur with probability one. In that region, even if the big firm develops the innovation it still wishes to acquire the small one because it can apply the innovation to its capital stock as well. On the other hand, it will also benefit from reduced industry competition. In the middle region (region II), an acquisition occurs only if the small firm has successfully developed the innovation. Because of the relatively large cost of an acquisition, the big firm does not find it optimal to acquire the small one if the former has accessed the innovation through its own R&D program. It can commercialize without performing an acquisition. By contrast, if the small firm obtains the innovative technology, the big firm has more incentives to initiate an acquisition, because it will also result in gaining access to the innovation. Note that in our model a merger always has a positive effect on the combined profit of the merged entity even if the innovation is not commercialized. This pure market power effect arises because competition becomes less intense following the merger and the equilibrium profits rise. Therefore, even in the absence of innovation, takeovers occur with 100% certainty at very high states of x.

1.3 Extensions of the model

In this section, we allow for varying bargaining power of the small firm and for multiple small firms and analyze the effect of these features on firm incentives to invest in R&D. We start with the analysis of varying bargaining power. For our analysis, it is convenient to introduce the following notations:

$$x_{1\eta}=\frac{RD}{\eta(\pi_1(I,NI)-\pi_1(NI,NI))+(1-\eta)(\pi_m(I)-\pi_m(NI)+\pi_2(NI,NI)-\pi_2(I,NI))}$$

$$x_{5\eta}=\frac{2\,RD}{(1-\eta)[\pi_2(NI,I)-\pi_2(I,NI)]+\eta[\pi_1(I,NI)-\pi_1(NI,I)]}$$

$$x_{2\eta}=\frac{RD}{(1-\eta)(\pi_2(NI,I)-\pi_2(NI,NI))+\eta(\pi_m(I)-\pi_m(NI)+\pi_2(NI,NI)-\pi_2(I,NI))}.$$

Proposition 5 establishes the equilibrium R&D strategies of the two firms if an acquisition is possible and the small firm has positive bargaining power.

Proposition 5. Assume $0<\eta<1$ (the small firm captures a fraction of the takeover surplus). Also assume that the following inequalities hold:[19] $x_{2\eta}<x_{5\eta}$ and $x_{1\eta}<x_{5\eta}$. If takeovers are possible, then the following are the Nash equilibria in pure strategies:

a) If $x_{1\eta}<x_{2\eta}$, then if $x<x_{1\eta}$, the only Nash equilibrium is (NI,NI) (no firm invests). If $x_{1\eta}<x<x_{2\eta}$, the only Nash equilibrium is (I,NI) (only big firm invests). If $x_{2\eta}<x<x_{5\eta}$, then there are two pure-strategy Nash equilibria: (NI,I) (small firm invests and big firm does not) and (I,NI) (big firm invests and small firm does not). In addition, there is a mixed-strategy equilibrium in which the big firm invests with probability p_1 and the small firm invests with probability p_2. If $x>x_{5\eta}$, the only equilibrium is (I,I) (both firms invest).

b) If $x_{2\eta}<x_{1\eta}$, then if $x<x_{2\eta}$, the only Nash equilibrium is (NI,NI) (no firm invests). If $x_{2\eta}<x<x_{1\eta}$, the only Nash equilibrium is (NI,I) (only small firm invests). If $x_{1\eta}<x<x_{5\eta}$, then there are two pure-strategy Nash equilibria: (NI,I) (small firm invests and big firm does not) and (I,NI) (big firm invests and small firm does not). In addition, there is a mixed-strategy equilibrium in which the big firm invests with probability p_1 and the small firm invests with probability p_2. If $x>x_{5\eta}$, the only equilibrium is (I,I) (both firms invest).

Proof. See Appendix. ■

Corollary 6. $x_{5\eta}$ is decreasing in η; furthermore, if $\pi_m(I)-\pi_m(NI)>\pi_1(I,NI)-\pi_1(NI,NI)$, then $x_{1\eta}$ is increasing in η and $x_{2\eta}$ is decreasing in η.

Proof. The first statement follows from Lemma 1 d). The last two statements follow from Lemma 1 a) and b) and the definitions of $x_{1\eta}$ and $x_{2\eta}$. ■

19 These inequalities hold for a large set of reasonable parameter values. See the online appendix for a discussion.

Corollary 6 implies that the small firm invests more aggressively as its bargaining power, η, increases. When η goes up, $x_{2\eta}$ declines. Note that $x_{2\eta}$ is the border of the region in which there are equilibria with the small firm investing, so this region expands downward when η increases. Furthermore, as seen in Figure A.1 of the online appendix, for low enough $\eta, x_{2\eta}$ falls below $x_{1\eta}$ and there appears a region in which the only equilibrium entails the small firm investing. At higher states of demand, the small firm is again more aggressive as $x_{5\eta}$ is decreasing in η. The big firm responds to a greater bargaining power of the small firm in a different way: on one hand, it invests more aggressively at higher states of demand ($x_{5\eta}$ goes down); on the other, it invests less aggressively at low states of demand ($x_{1\eta}$ goes up). Because it has to share the takeover surplus with the small firm, it becomes less motivated to invest when expected profits are low.

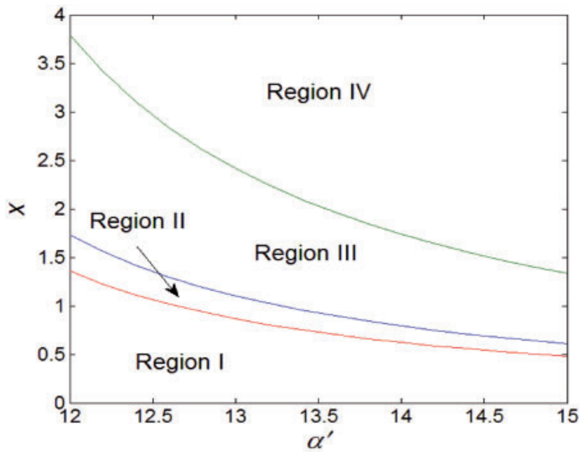

Figure 6
Equilibrium strategies: two firms with target bargaining power
Figure 6 presents the equilibrium investment thresholds of the two firms in the case when an acquisition is possible, as functions of the innovation parameter α'. The set of input parameters is as follows: $K_1=10$, $K_2=1$, $\gamma=0.5$, $\alpha_1=\alpha_2=10, \alpha'=15, RD_1=RD_2=15$. In addition, the relative bargaining power of target shareholders $\eta=0.5$. In Region II, only the big firm invests. In Region III, there are three Nash equilibria: two pure-strategy ones (small firm invests, the big firm does not; big firm invests, small firm does not) and a mixed-strategy equilibrium. Both firms invest in Region IV. It follows from comparing with Figure 4 that greater bargaining power of the potential target (small firm) increases its innovation incentives.

Figure 6 shows the equilibrium R&D strategies of the firms when the small firm has greater bargaining power and captures a fraction of acquisition surplus, $\eta=0.5$.

There are two important differences between Figure 4 ($\eta=0$) and Figure 6 ($\eta=0.5$). First, the intermediate region (region III) is much wider. Since the small firm gets a share of the acquisition benefit, it is more motivated to engage in R&D, so it could sell out to the big firm at a higher price. Because of a high potential payoff in the event of successful innovation and subsequent acquisition, the small firm is motivated to pursue an aggressive R&D strategy. Second, the boundary at which both firms decide to invest in R&D shifts down, consistent with Corollary 6.

In addition, we show in section 2 of the online appendix that further increasing the bargaining power of the small firm gives rise to a new region in which the only equilibrium is the one in which only the small firm invests (and the big firm does not; see Figure A1 in the online appendix).

Finally, we consider the case when there are multiple small firms and one large firm. Due to the complexity of this case, we solve it numerically. We analyze this case in section 3 of the online appendix. Analysis of this case gives us two new results. First, the aggregate investment in R&D is higher when there are two small firms in the industry than when there is only one small firm. Second, and more importantly, a small firm has a stronger motivation to engage in R&D and get a better chance of being acquired by the larger firm. A small firm that does not become a takeover target will face intensified competition with the bigger entity (formed in result of the acquisition of its rival) that also commercializes the new technology. While it faces potential competition in the R&D market with the other small firm, it has a stronger incentive to become a takeover target and to avoid becoming an outsider. On the other hand, the big firm is less motivated to invest when there are two small firms, given more aggressive investment in R&D by the small firms and because it has a lower probability of success facing competition with two firms. Therefore, the big firm prefers to let one of them develop an innovative technology and consequently acquire the innovation through an acquisition. As a consequence, there exists a region that is shown graphically in which in the only pure-strategy equilibrium, both small firms invest, while the big firm does not.

1.4 Discussion of modeling assumptions

In this section, we discuss the main modeling assumptions that we have made in the paper. We also discuss the potential limitations, robustness, and extensions of these assumptions.

First, we assume in our analysis that the amount of R&D spending is fixed and also that it is the same for the large and the small firm. An interesting extension would be to examine continuous investment whereby each extra dollar spent on R&D increases the probability of success. Incorporating this assumption would, however, make the model much more complex. We believe, however, that our major qualitative results will still obtain in this case. R&D will still be procyclical (though the relation between R&D spending and x will be continuous and not binary as in our model). If acquisitions are allowed, then the same economic mechanism will apply and the big firm will have less incentives to invest in R&D at intermediate demand states as it will have an option to obtain access to innovation through acquisition. At high levels of demand, big and small firms will invest in R&D given the large gains from successful innovation.

Second, we assume that the probability of successful innovation equals $1/n$, where n is the number of firms that invest in R&D. As shown in the online appendix, our general results hold if the probability of successful innovation by a firm is independent of the number of other firms that invest in R&D. We thank the referee for suggesting this alternative specification.

Third, we need to impose some restrictions on parameter values to be able to analytically prove some of our results. However, further analysis shows that our results are robust to reasonable variations of parameter values. We present this additional analysis in the online appendix.

Finally, in generating our predictions, we implicitly assume that a wide range of the values of x is feasible so there is a positive probability of finding the firm in various regions in Figures 3, 4, and 6. Thus, substantial variation in demand is required to generate the full spectrum of our predictions.

1.5 Predictions of the model

Below we summarize the empirical predictions we generate with the model. We test these predictions in the empirical section of this paper.

P1. *Acquisitions are procyclical.*

This result is illustrated in Figure 5 and follows from the fact that equilibrium profits as well as the benefit of acquisitions are increasing in the demand level x. It is supported by Proposition 4.

P2. *Firm R&D is procyclical.*

This prediction follows from Propositions 2 and 3 and is illustrated in Figures 3 and 4. Higher values of demand make it more attractive for firms to invest in R&D either to keep innovation to themselves or to become an attractive acquisition target, if an acquisition is possible.

P3. *Large firms' R&D is less procyclical than small firms' R&D.*

Unlike small firms, large firms may find it disadvantageous to engage in an "R&D race" with small firms at intermediate states of demand, as they can obtain access to innovation by later acquiring a small firm that succeeded in its R&D efforts. It follows from Proposition 2 that there is a non-monotonic relation between the large firm's investment policy and the state of x. This is also illustrated in Figure 4. It always invests in regions II and IV in Figure 4, never invests in region I, and there are equilibria in region III in which it does not invest either. Furthermore, Propositions 4 and 5 show that there exists an intermediate region in which only the big firm invests. A similar situation occurs with two small firms, as illustrated in Figure A.2 of the online appendix. The regions in which the big firm invests alternate with those in which it does not, giving rise to a non-monotonic relation between demand and the large firm's R&D investment.[20]

P4. *Possibility of being acquired induces innovation efforts by large and small firms, but especially by the small firms.*

This prediction is illustrated in Figures 3 and 4 and follows from the fact that the possibility of an acquisition amplifies the potential gain from successful R&D. It follows from Lemma 1, part g, that $x_2 < x_3$, so there always exists a region (x_2, x_3) such that there is no equilibrium with the small firm investing if takeovers are precluded, while there are equilibria in the same region that involve the small firm investing if takeovers are allowed. Thus, possibility of being acquired leads to more R&D by small firms.

P5. *Greater bargaining power of the small firm leads to more aggressive innovation efforts by the small firm.*

This prediction follows from the fact that, having the ability to capture a greater fraction of the acquisition surplus, the small firm will tend to invest in R&D more aggressively to increase the odds of being acquired by the larger firm. This prediction follows from Proposition 5 and Corollary 6. It is also illustrated in Figure 6 and Figure A.1 in the online appendix. The region in which only the big firm invests shrinks with increased bargaining power of the small firm, as shown in Figure 6, and completely disappears with very high bargaining power of the small firm ($\eta = 0.9$, fig A.1), while the region in which both firms invest expands.

P6. *Increased product market competition leads to more R&D but less so for large firms.*

The intuition for this prediction is similar to that of prediction 3. With more small firms in the industry, big firms become less motivated to invest in their own R&D programs (and face intense competition with small firms) and are more inclined to let small firms innovate and then acquire those that innovate successfully. This result is illustrated in Figure A.2 of the online appendix. We show that small firms invest more aggressively when facing competition with another small firm in both R&D and acquisition markets. The regions with at least one equilibrium in which a small firm invests expand. In addition, there emerges a region in which in the only pure-strategy Nash equilibrium, both small firms invest, while the big firm does not.

[20] To generate this prediction, we implicitly assume that a wide range of the values of x is feasible, including those in regions I–IV in Figure 4. Thus, a substantial variability of demand conditions is necessary for the mechanisms in our model to work. We thank the referee for pointing this out.

2. Data and Empirical Methodology

2.1 Sample

Our data come from the merged CRSP-Compustat Database, the Securities Data Corporation (SDC), the St. Louis Federal Reserve Economic Database (FRED), and the Census of Manufactures. We start with the merged CRSP-Compustat Database and exclude companies in the financial (SIC codes 6000 to 6999) and utilities (SIC codes 4900 to 4999) industries. Our initial sample includes 12,941 firms operating in 181 different three-digit SIC industries and 117,151 firm-year observations during the period 1984–2006. We merge with these data a sample of mergers and acquisitions from Securities Data Corporation (SDC) from the same period of time. We also drop companies for which we are unable to compute acquisition liquidity or our main control variables. Our final sample of firms with matched industry demand data, and with lagged and contemporaneous non-zero assets, includes 11,288 firms with 84,471 firm-year observations.

Table 1 presents the summary statistics for our main variable, *annual R&D expenditures scaled by sales*,[21] and also the annual acquisition rate by different size groups. Panel A shows that the highest R&D activity as a percentage of sales is concentrated among firms with below-median size. R&D for firms between the 25th and 50th percentiles of market capitalization is 2.4% of sales. Given that market capitalization reflects growth options and R&D may capture many growth options, the fact that R&D is very low at the lowest size decile is not surprising. At the highest size decile, R&D is also a low fraction of stock market capitalization, consistent with many growth options being already exercised for these large firms. Panel B shows the acquisition rates of firms based on their stock market capitalization. Firms in the lowest size groups are more likely to be acquired.

2.2 Identification strategy: Acquisition activity and industry demand and supply

In our analysis, we wish to examine the effect of expected acquisition activity on firm R&D. We face a fundamental identification problem that R&D and acquisitions may both result from fundamental demand conditions. Firms conduct R&D not just because they may sell out to another firm but also because of fundamental demand conditions. Acquisitions as well also respond to these fundamental demand conditions. Thus, to separate out the effect of expected acquisition activity on R&D, we have to control for industry demand and also find exogenous asset liquidity shift variables or instruments that

[21] We note that the distribution of R&D/Sales is skewed to the right, with many firms reporting zero R&D. We examined whether this had an effect on our regression results and found that it did not. Our results hold using quantile regressions at the 50th (median regression) and 75th percentiles, and the results with these quantile regressions are actually slightly stronger than the results we report. We also examine R&D scaled by assets, and our results, including later regression results, are robust to this alternative scaling.

Table 1
R&D and acquisition summary statistics

Panel A: R&D/Sales

Variable	Mean	Median	Std. Dev.	N
R&D/Sales, size < 10%	0.266	0.000	1.716	7348
R&D/Sales, 10% < size < 25%	0.487	0.016	2.793	11018
R&D/Sales, 25% < size < 50%	0.669	0.024	3.125	18381
R&D/Sales, 50% < size < 75%	0.450	0.015	2.324	18381
R&D/Sales, 75% < size < 90%	0.153	0.001	1.063	11019
R&D/Sales, 90% < size < 100%	0.056	0.004	0.271	7348
Panel B: Acquisition rate				
Annual acquisition rate, size < 10%	0.162	0.186	0.087	23
Annual acquisition rate, 10% < size < 25%	0.099	0.098	0.026	23
Annual acquisition rate, 25% < size < 50%	0.095	0.097	0.026	23
Annual acquisition rate, 50% < size < 75%	0.086	0.080	0.025	23
Annual acquisition rate, 75% < size < 90%	0.070	0.071	0.034	23
Annual acquisition rate, 90% < size < 100%	0.055	0.051	0.028	23

Table 1 reports summary statistics for R&D scaled by sales and number of acquisitions by year for different size groups. After assigning firms to size groups by year, we average the rates by year and then average over all the years in our data. Size is defined as the log of the market equity value.

affect acquisition activity but do not affect firm-level corporate R&D. We thus construct several different measures of industry asset liquidity. We also construct the direct probability that a firm is a target using an instrumental variable approach. Thus, we do not rely solely on exogenous variables or our instrumental variable approach. This dual approach provides reassurance that our results are robust to different methods to control for endogeneity.

To begin, we discuss our controls for fundamental industry demand conditions. We then discuss our measures of acquisition activity and liquidity in the market for acquisitions. Finally, we discuss our instrumental variable regression approach where we endogenize the probability that a firm is an acquisition target and the instruments we use to help with identification.

2.2.1 Industry demand conditions. To capture industry demand, we use measures of downstream demand that we obtain from the Federal Reserve on the value of industrial production seasonally by industry, converted into four digit SIC codes. The industrial production data are publicly available series available from the Federal Reserve based on data from the Census Bureau.[22] We aggregate these measures to the three-digit level and then calculate the annual change for each year. We then link these data to each industry by "downstream" industries using the input output matrix of the U.S. economy from the Bureau of Economic Analysis in the closest lagged census year (this matrix is published every five years) using the Bureau of Economic Analysis "use" tables, where

[22] These data are available at http://www.federalreserve.gov/releases/g17/table1_2.htm, starting from the year 1919.

a downstream industry is one that uses 1% or more of the industry's output.[23] Given that most industries sell to multiple downstream industries, to construct our final measure of changes in demand we weight the percentage change of each downstream industry by the percentage sold to that industry at the three-digit level. For industries that sell directly to consumers, we use the change in consumer income in real dollars. For industries that sell directly to the government, we use the change in government military expenditures in real dollars as the downstream demand index, as military expenditures are plausibly exogenous to each industry's shipments itself.

We construct two measures of demand changes using these data. First, following Maksimovic and Phillips (2001), *Vdshock* is the detrended annual percentage change in the downstream industry using the input-output matrix. To detrend this variable, we regress it on industry and year fixed effects indicator variables and then take the residual from this regression. The detrended variable represents the "shock" or unanticipated change to demand. *Vexpand* is a "discretized" version of *Vdshock,* which equals one when *Vdshock* is positive and zero otherwise. We use both variables in our tests because of potential non-linearities in the effect of increases in demand on R&D. In our model, the response of R&D intensity to changes in demand is highly non-linear.

2.2.2 Industry acquisition activity. Our first measure of *expected* asset liquidity in the market for acquisitions is a *three-year lagged average measure of industry asset transactions*, broken up into inside and outside industry transactions. It follows Schlingemann, Stulz, and Walkling (SSW) (2002) in that SSW examine how a firm's probability of selling is related to overall industry acquisition activity. We differ from SSW as we average the lagged industry M&A activity to capture what a firm might expect will be the potential market for its assets, following Ortiz-Molina and Phillips (forthcoming), who examine the effect of inside liquidity on a firm's cost of capital. This measure captures the *historical liquidity* of an industry's assets using the value of past M&A activity in the firm's industry over the last three years (we also examine the last five years, and our results are robust to this change). Shleifer and Vishny (1992) argue that a high volume of transactions in an industry is evidence of high liquidity because the discounts that sellers must offer to attract buyers are smaller in more active resale markets.

We thus obtain the value of all M&A activity involving publicly traded targets in each three-digit SIC industry and in each year from the Securities Data Corporation (SDC). We include both mergers and acquisitions of assets. For full firm purchases, deal value is the purchase price paid to target shareholders. For acquisition of assets, deal value is the reported purchase price. Acquisitions

[23] Input output tables are from the Bureau of Economic Analysis Web site and are publicly available at http://www.bea.gov/industry/#io. The latest input-output table at the time of our analysis is for 2007. We match these data into SIC codes using publicly available correspondence tables.

of assets are important conceptually and economically to our argument. Conceptually there are many firms who develop R&D in divisions and then sell that division. In our sample, overall acquisitions of assets are particularly important as they comprise approximately 75% of the total deals by number.

If SDC does not report corporate transactions in an industry-year, we set the value of transactions equal to zero. We then scale the value of transactions in the industry by the total book value of assets in the industry, and average this ratio over the past three years, not including the contemporaneous year. To compute the value of the assets in each industry, we sum the assets in the industry reported by single-segment firms and the segment-level assets reported by multiple-segment firms in the Compustat segment data, breaking up the multiple-segment firms into their component industries using the value of reported assets by their component industries. Averaging over past years smooths the temporary ups and downs in M&A activity and allows us to better capture the intrinsic saleability of an industry's assets.[24]

We decompose our measure of asset liquidity to distinguish between inside buyers of assets–those who operate in the same three-digit SIC industry as the target–and outside buyers–those who do not currently operate in the industry. We use the Compustat Segment tapes to further refine this calculation following Ortiz-Molina and Phillips (forthcoming). We classify a purchase as an inside purchase if the buyer has any segments with the same three-digit SIC code as the assets purchased–checking over each reported SIC code of the target if the target reports multiple SIC codes. *Inside Industry M&A* is the value of M&A activity in the industry involving acquirers that operate within the industry, scaled by the book value of the assets in the industry. *Outside Industry M&A* is the value of M&A activity in the industry involving acquirers that operate outside the industry, scaled by the book value of the assets in the industry. Both of these variables are again averaged over the past five years.

We also calculate the cumulative abnormal announcement return to past targets in each industry in the prior year as an additional measure of what a target firm might expect to receive if they receive a buyout offer. We calculate the cumulative abnormal return for each past deal in the industry and average over all deals in each industry at the three-digit SIC code level. Excess returns are cumulated from 30 days prior to the announcement date of each deal to 10 days post-deal. Parameters of the market model (α, β) used to calculate excess returns are estimated from regressions of each stock return on the S&P market return using trading days -255 to - 31 prior to the announcement date.

2.2.3 The probability of being a target. Our second main measure of *expected* asset liquidity in the market for acquisitions is a firm's individual

[24] Our analysis is unaffected if we use five years of M&A data instead of three years. We have calculated the persistence of lagged industry M&A and found it to be very persistent. The correlation between 1 and 3-years lagged inside industry M&A activity is 0.752. The correlation between 1- and 5-year inside M&A activity is 0.640. The correlation between 3- and 5-year lagged inside industry M&A activity is .898.

probability of being an acquisition target. We thus include the target dummy variable in the R&D regressions and instrument this endogenous variable using as an instrument a measure of the unexpected mutual fund flow following Edmans, Goldstein, and Jiang (2012). This method is analogous to a two-stage least squares method, where the first stage is a linear probability model of the probability a firm is a target.

We use this second approach as there is the concern that the previous lagged industry acquisition activity may itself be caused by something fundamental that is driving both industry acquisition activity and R&D. For example, if demand shocks are persistent, they may affect both the probability of a merger (historically) and may continue to affect the demand for the product. The IV approach combined with the industry lagged fundamentals provides additional confidence in our results and conclusions.

The unexpected mutual flow variable captures the pricing pressure from changes in mutual fund holdings that are caused by redemptions that induces the mutual fund to sell stocks. This unexpected mutual fund flow has been shown to have persistent valuation effects that Edmans, Goldstein, and Jiang (2012) show extend up to 24 months. It is likely to be exogenous to fundamentals but may impact acquisition likelihood through a firm's discount from fundamentals as it captures deviations from predicted valuation that are caused by investors redeeming mutual fund shares that subsequently cause the mutual funds to sell stocks. The mutual fund flow instrument has been used successfully recently by Edmans, Goldstein, and Jiang (2012) as an exogenous instrument that affects firm's acquisition probability through the discount or valuation channel. We test in the next section whether this variable affects firm R&D only through the probability of an acquisition and find that this is indeed the case.[25]

We estimate the regression using an instrumental variable approach (see command ivreg2 in Stata). In unreported results, we also used a two-step generalized method of moments (GMM) approach and obtained similar results. Standard errors are estimated that allow for heteroscedasticity and industry-year clustering of the errors. While we use a single-equation instrumental variable approach, for general interest and to motivate the other control variables for the R&D regression, we also use the results of the first-stage target prediction model using a linear probability model. The variables used in this target prediction model include variables motivated by Ambrose and Megginson (1992), Maksimovic and Phillips (2001), and Harford (2005), as well as the mutual fund flow instrument excluded from the R&D regressions.

25 Edmans, Goldstein, and Jiang (2012) show that *Mfflow* only affects takeovers indirectly, through its effect on firm valuation. It is still a valid instrument for our purpose as long as it is exogenous to fundamentals but affects takeover probability either directly or indirectly.

2.2.4 Control variables. The firm-specific control variables included in both the target prediction regression and the R&D regressions follow the basic specification of Ambrose and Megginson (1992) and Harford (2005). We lag these variables one period. These control variables include *Log(Cash/Sales),* which is the natural log of the ratio of cash to sales, *NWCNA,* which is net working capital divided by sales, *Tangibility,* which is the proportion of tangible assets, and the *P-E ratio,* which is the price-to-earnings ratio. The *institutional ownership* variable follows Edmans, Goldstein, and Jiang (2012). Institutional ownership is the percentage of stock owned by institutional investors.

We also include an economy-wide variable to the supply of capital. We use the spread between the rate on commercial & industrial (C&I) loans and the Fed funds rate as a measure for aggregate liquidity following Harford (2005) and also shown by Maksimovic, Phillips, and Yang (forthcoming) to affect both private and public merger waves. Lown et al. (2000) find that this spread is strongly correlated with the tightening of liquidity measured from the Federal Reserve Senior Loan Officer (SLO) survey. We also control for industry competition and firm misvaluation or unexplained valuation. Our measure of industry competition is based on the Census Herfindahls as updated and extended to non-manufacturing industries by Hoberg and Phillips (2010a). The variable *"compete"* is equal to one minus the Herfindahl index. We also examine if our results are robust to the text-based industry concentration measure developed in Hoberg and Phillips (2011). This later measure is only available for years 1997 onward, and thus these results are only available for a subset of our sample period.

In addition, several authors have also recently argued that a significant fraction of merger activity of public firms can be explained by misvaluation or unexplained valuation. For example, Rhodes-Kropf, Robinson, and Viswanathan (RKRV) (2005) argue that while economic shocks might be fundamental determinants of merger activity, misvaluation by public markets may determine who buys whom and how mergers are clustered in time. We adopt a variant of the RKRV measure of firm- and industry-specific unexplained valuation and check whether the addition of this variable affects our findings. We label this variable in our tables *UV, RKRV* to indicate that it is unexplained valuation based on the RKRV model. To calculate the measures of unexplained valuation, we use model (3) from RKRV, as updated by Hoberg and Phillips (2010a).[26] First, we regress log market value of equity on log book value of equity, net income, an indicator for negative net income, and leverage ratio by industry using a historical lagged 10-year rolling window. Following Hoberg and Phillips, we use only lagged data in the calculation of these

[26] As discussed by Rhodes-Kropf, Robinson, and Viswanathan (2005), the key to investigating these effects is obtaining a good measure of misvaluation. Just using reported Tobin's q cannot distinguish fundamental value from potential misvaluation. Measures of misvaluation are of necessity valuation anomalies relative to a model of market expectations. While intended to measure misvaluation, they may also pick up the market's expectation of future performance.

coefficients to avoid any look-ahead bias. Then, we use the estimated industry-specific regression coefficients to compute the predicted market value of equity, assuming that a firm's market value at time *t* is a function of its current characteristics and the industry-specific value of characteristics estimated from past years. The unexplained valuation measure is then the difference between the actual valuation and the predicted valuation both at time *t*. For robustness we also calculate a second unexplained valuation measure using the valuation model from the Pastor and Veronesi (2003) (PV), model 1, as described in Hoberg and Phillips (2010a). In our tables, this variable is reported as *UV, PV*. *Firm-level UV, PV* is the firm-level unexplained valuation computed based on the PV model. *Firm-level UV, RKRV* is the firm-level unexplained valuation computed based on the RKRV model. *Industry-level UV, RKRV* and *Industry-level UV, PV* are the industry-level unexplained valuation variables based on RKRV and PV, respectively.[27]

2.3 Summary statistics

Table 2 presents summary statistics for our sample of Compustat Firms.

Our demand variables are presented in the first group. We present the detrended annual percentage change (*Vdshock*) in the downstream industry and also its discretized version (*Vexpand*). We study the effect of both demand shock variables in our regressions.

The second group of variables in Table 2 represents measures of the liquidity in the market for mergers. *Industry M&A Activity* is the asset liquidity measure capturing the value of M&A activity in the industry, while. *Inside Industry M&A* is the value of M&A activity involving acquirers from the same industry. *Outside Industry M&A* is the value of M&A activity involving acquirers operating outside the industry. *Cum. Abn. announcement return* is the industry-level mean abnormal announcement returns to acquisition targets in the previous year.

The third group of variables in Table 2 is our unexplained valuation variables which may capture either unexplained future growth prospects or misvaluation. The last group of variables is our ownership and the instruments for the target instrumental variable regression, unexpected mutual fund flow, from Edmans, Goldstein, and Jiang (2012).

3. Firm R&D Multivariate Results

3.1 R&D and industry M&A activity

We now turn to our main results where we examine firm-level R&D. We examine R&D scaled by sales. We examine whether industry merger activity affects firm R&D. We include variables capturing size, demand changes, and

27 In our sample, the correlation between the PV and RKRV measures is 0.93.

Table 2
Summary statistics

Variable	Mean	Median	Std. Dev.	Min.	Max.	N
			Demand and supply variables			
Vdshock	0.050	0.047	0.069	−0.270	0.903	84472
Vexpand	0.823	1.000	0.382	0.000	1.000	84472
			Liquidity variables			
Industry M&A Activity	0.044	0.185	0.078	0.000	1.840	81060
Inside industry M&A Activity	0.016	0.005	0.030	0.000	0.214	81060
Outside industry M&A Activity	0.027	0.009	0.067	0.000	1.840	81060
C&I spread	1.597	1.632	0.252	1.160	2.120	81531
Cum. Abn. announcement return	0.126	0.115	0.152	−0.887	3.715	84472
			Valuation variables			
Firm-level UV, RKRV	0.070	0.063	0.853	−4.795	7.511	58788
Firm-level UV, PV	0.069	0.058	0.827	−6.157	13.241	57186
Industry-level UV, RKRV	0.077	0.109	0.318	−1.652	1.783	77899
Industry-level UV, PV	0.077	0.111	0.306	−2.102	1.601	77849
			Ownership and Instrument			
Inst. Ownership	20.804	9.829	24.818	0.000	99.995	84472
Mfflow	−1.032	−0.167	2.996	−319.331	0.000	41120

Table 2 reports summary statistics for the main variables. *Vdshock* is a de-trended demand shock variable constructed from the input-output matrix. *Vexpand* is a discretized version of *Vdshock*. *Industry M&A activity* is the lagged asset liquidity measure constructed based on Schlingemann, Stulz, and Walkling (2002). *Age* is time in 100s of years since the founding year, incorporation year (if founding is missing), or the first year the firm appears in CRSP tapes (if both founding and incorporation years are missing). *Inside Industry M&A* is the value of M&A activity involving acquirers from the same industry. *Outside Industry M&A* is the value of M&A activity involving acquirers operating outside the industry. *Cum. Abn. announcement return* is industry-level mean abnormal target announcement returns to acquisitions in the previous year. *C&I spread* is the commercial and industrial loan spread. *Firm-level UV, PV* is the firm-level unexplained valuation computed from the Pastor and Veronesi (PV) model. *Firm-level UV, RKRV* is the firm-level unexplained valuation computed from the Rhodes-Kropf, Robinson, and Viswanathan (RKRV) model. *Industry-level UV, RKRV,* and *Industry-level UV, PV* are the industry-level unexplained valuation variables. *Inst. Ownership* is the percentage of common equity owned by institutional investors. *Mfflow* is the unexpected mutual funds flow variable.

variables capturing both the liquidity and competitiveness of industries. We test the predictions outlined earlier in section 1.5 from the model. We examine two different demand shock variables, *"Vexpand"* in Panel A and *"Vdshock"* in Panel B. We interact these demand variable with firm size to test Predictions 2 and 3.

Table 3 presents results for *inside* industry M&A activity. Table 3, Panel A, shows that R&D increases with demand but less so for large firms, as is evident by the negative coefficient on the demand shock variable interacted with size. Thus, small firms' R&D is more sensitive to demand. The results in Panel B also show overall similar results.

Table 3 also shows that M&A activity affects firm R&D in several ways. First, the value of M&A activity increases firm R&D, as shown by the positive coefficients on the inside industry M&A activity measure. Second, the interaction between inside industry M&A activity and size is negatively related to firm R&D. Thus, large firms increase their R&D less than small firms in industries with high acquisition activity. These results are consistent with our Prediction 5 that greater bargaining power increases firm R&D, particularly for small firms.

Table 3
R&D regressions with inside industry M&A activity

Panel A: Regressions with Vexpand

Independent variable	Dependent variable : R&D expenditures scaled by sales						
Vexpand	0.350***	0.327***	0.656***	0.537***	0.508***	0.497***	0.454***
	(0.100)	(0.096)	(0.135)	(0.123)	(0.128)	(0.131)	(0.126)
Log(net assets)		−0.117***	−0.056***	−0.038***	−0.029***	−0.043***	−0.124***
		(0.017)	(0.011)	(0.009)	(0.009)	(0.011)	(0.025)
Age		−0.249***	−0.249***	−0.220***	−0.218***	−0.159***	−0.194***
		(0.042)	(0.042)	(0.036)	(0.036)	(0.033)	(0.036)
*Vexpand*Log(net assets)*			−0.075***	−0.063***	−0.055***	−0.055***	−0.052***
			(0.019)	(0.018)	(0.016)	(0.017)	(0.015)
Inside industry M&A Activity				6.825**	6.305**	6.229**	5.065*
				(2.941)	(2.928)	(2.828)	(2.920)
*Ins M&A * Log(net assets)*				−0.665**	−0.621**	−0.620**	−0.514**
				(0.279)	(0.285)	(0.261)	(0.252)
Compete						0.017**	0.113***
						(0.007)	(0.027)
*Compete*Log(net assets)*							−0.016***
							(0.004)
Firm-level UV, PV					0.141***	0.141***	0.143***
					(0.016)	(0.017)	(0.017)
Industry-level UV, PV					−0.139	−0.133	−0.130
					(0.116)	(0.109)	(0.126)
C&I spread							0.423*
							(0.254)
Observations	84,471	84,459	84,459	81,047	56,934	51,001	49,233
R-squared	0.017	0.033	0.034	0.037	0.034	0.052	0.047
Adj. R-squared	0.0165	0.0326	0.0333	0.0369	0.0340	0.0517	0.0462
Control variables	No	No	No	No	No	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	No

Panel B: Regressions with Vdshock

Independent variable							
Vdshock	0.561	0.247	1.078*	1.044**	0.708	0.705	0.682
	(0.435)	(0.440)	(0.594)	(0.517)	(0.543)	(0.568)	(0.573)
Log(net assets)		−0.118***	−0.109***	−0.079***	−0.066***	−0.080***	−0.163***
		(0.017)	(0.018)	(0.013)	(0.013)	(0.017)	(0.033)
Age		−0.252***	−0.256***	−0.227***	−0.227***	−0.162***	−0.197***
		(0.044)	(0.044)	(0.038)	(0.039)	(0.032)	(0.037)
*Vdshock*Log(net assets)*			−0.195**	−0.222***	−0.149*	−0.146*	−0.130*
			(0.099)	(0.083)	(0.079)	(0.080)	(0.075)
Inside industry M&A Activity				7.274**	6.709**	6.598**	5.461*
				(2.939)	(2.915)	(2.830)	(2.908)
*Ins M&A * Log(net assets)*				−0.696**	−0.649**	−0.655**	−0.546**
				(0.272)	(0.280)	(0.258)	(0.253)
Compete						0.020***	0.117***
						(0.007)	(0.028)
*Compete*Log(net assets)*							−0.016***
							(0.004)
Firm-level UV, PV					0.141***	0.142***	0.144***
					(0.016)	(0.017)	(0.017)
Industry-level UV, PV					−0.111	−0.104	−0.065
					(0.115)	(0.109)	(0.125)
C&I spread							0.423*
							(0.256)
Observations	84,471	84,459	84,459	81,047	56,934	51,001	49,233
R-squared	0.014	0.031	0.031	0.035	0.032	0.050	0.045
Adj. R-squared	0.0142	0.0305	0.0306	0.0345	0.0315	0.0494	0.0442
Control variables	No	No	No	No	No	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	No

Table 3 reports estimates from *R&D* regressions. The dependent variable is *R&D* expense scaled by sales in the previous year. *Vdshock* is a de-trended demand shock variable constructed from the input-output matrix. *Vexpand* is a discretized version of *Vdshock*. *Inside industry M&A Activity* is the lagged value of M&A activity involving acquirers from the same industry averaged over the past three years. *Compete* is a measure of industry concentration equaling one minus the Herfindahl index. *Firm-level UV, PV* is the firm-level unexplained computed from the Pastor and Veronesi (PV) model. *Industry-level UV, PV* is the industry-level unexplained valuation variable. *C&I spread* is the commercial and industrial loan spread. Control variables are tangible assets, cash, and net working capital scaled by sales, price-to-earnings ratio, dividend payment dummy, and institutional ownership. Standard errors are clustered by industry-year. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

We also examine outside industry M&A purchasing activity. In this case, we sum the value of all M&A activity when the acquirer is outside the target's three-digit SIC code. We find that outside M&A activity does not significantly impact R&D, which is consistent with targets getting lower premiums from outside industry purchasers and thus facing lower incentive effects. The coefficients are significantly lower than those for inside M&A activity. For brevity, we do not present these results for outside industry M&A purchasing activity.

The much stronger, significant results for inside industry M&A activity are consistent with firms looking to competitor inside-industry firms as potential acquirers when they evaluate the payoffs of conducting R&D. The overall results are consistent with Shleifer and Vishny (1992), who predict that inside industry acquirers are willing to pay more for competitor firms, and with increased competition from potential buyers leading small firms to invest more in R&D.

Our final test is to examine Prediction 6 that product market competition increases firm R&D and more so for small firms. We test this prediction by including the variable *"Compete"* and also interacting it with firm size. We find that product market competition increases firm R&D but less so for large firms. The intuition is that firms have to do more R&D to stay competitive in competitive industries and that small firms incentive to increase R&D is particular large, either because they can sell out to larger firms or because it enables them to survive in the longer run.

The results in Table 3 are economically significant. For example, a one-standard-deviation decrease in *Size* (log of net assets) results in an increase in the *R&D-to-Sales* ratio by 25.9 percentage points (0.259). Increasing *Inside industry M&A Activity* by one standard deviation leads 8.1 percentage points more R&D per dollar of sales. Also, firms spend 24.8 percentage points less (.248) on R&D in times of economic expansions (*Vexpand* = 1) than in times when industries are contracting (*Vexpand* = 0).

Table 4 tests Prediction 5 that the bargaining power of target firms increases potential target firm's R&D. To test Prediction 5, we examine the average cumulative abnormal returns to acquisition announcements in the previous year by other target firms in the same three-digit SIC code industry. The rationale is that abnormal announcement returns to past industry targets are likely to be related to the expected return a target will get if they receive a takeover offer. The returns are likely to be correlated with the probability that a firm is a target, and we thus do not include other M&A activity variables in this regression.

The idea is that following periods of high abnormal returns to other firms' acquisition announcements in their industries, target shareholders may naturally anticipate high returns to their firms and higher bargaining power in the event of an acquisition. This anticipation may encourage potential target firms to intensify their R&D programs in an effort to create a successful innovation and attract potential bidders.

Table 4
R&D and abnormal announcement returns

Independent variable	Dependent variable: R&D expenditures scaled by sales			
Vexpand	0.189***	0.112*		
	(0.065)	(0.061)		
Log(net assets)	−0.010	−0.122***	−0.037***	−0.144***
	(0.012)	(0.019)	(0.009)	(0.024)
Age	−0.177***	−0.231***	−0.180***	−0.234***
	(0.031)	(0.039)	(0.031)	(0.040)
*Vexpand*Log(net assets)*	−0.042***	−0.033***		
	(0.012)	(0.012)		
Abn. announcement return	0.593**	0.520**	0.579**	0.511**
	(0.271)	(0.225)	(0.267)	(0.226)
*(Abn. AR)*Log(net assets)*	−0.086**	−0.077**	−0.085**	−0.076**
	(0.040)	(0.035)	(0.039)	(0.036)
Compete		0.142***		0.145***
		(0.019)		(0.020)
*Compete*Log(net assets)*		−0.016***		−0.017***
		(0.003)		(0.003)
Vdshock			0.447	0.267
			(0.508)	(0.462)
*Vdshock*Log(net assets)*			−0.152**	−0.129**
			(0.065)	(0.061)
Observations	65,341	58,852	65,341	58,852
R-squared	0.140	0.147	0.140	0.147
Adj. R-squared	0.138	0.145	0.138	0.145
Industry dummies	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes

Table 4 reports estimates from *R&D* regressions. The dependent variable is *R&D* expense scaled by sales in the previous year. *Vdshock* is a de-trended demand shock variable constructed from the input-output matrix. *Vexpand* is a discretized version of *Vdshock*. *Log(net assets)* is the natural log of the asset value. *Age* is time in 100s of years since the founding year, incorporation year (if founding is missing), or the first year the firm appears in CRSP tapes (if both founding and incorporation years are missing). *Abn. AR* is industry-level mean cumulative abnormal announcement returns surrounding acquisition announcements to target firms in the previous year. *Compete* is a measure of industry competitiveness equaling one minus the Herfindahl index. Standard errors are clustered by industry-year. Control variables are tangible assets, cash, and net working capital scaled by sales, price-to-earnings ratio, dividend payment dummy, and institutional ownership. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 4 shows strong support for Prediction 5. The bargaining power of target firms strongly increases firm R&D as shown by the significant positive coefficients on the lagged cumulative abnormal returns (*lagCARsic*). The table also shows that this effect is larger for smaller firms as the coefficient on the interaction variable of *"lagCARsic"* with firm size is negative. Overall this table supports the conclusion that small firms' R&D increases strongly when their bargaining power in acquisitions increases.

3.2 R&D and the probability of being a target

In this section, when examining R&D, instead of variables capturing industry M&A activity, we compute a firm-specific measure of the probability a firm is a target. As discussed earlier, there is a potential identification problem given a firm's predicted probability of being a target and its R&D may respond to the same demand changes. We thus reexamine our results using as an instrument unexpected mutual fund redemption flow, *Mfflow*, for an indicator variable "*target*" thus capturing the predicted probability of being a target in the R&D

regression. The assumption is that the instrument, the unexpected mutual flow variable, only affects R&D by affecting a firm's probability of being a target.

We first report the results of the first-stage regression where we predict the probability of being a target. For all specifications, the dependent variable equals one if the firm was a target in an acquisition attempt in a given year and zero otherwise. In Table 5, we estimate a linear probability model to predict the probability of being a target given that we include interaction variables. We also use both fundamental demand and supply variables and other lagged firm-specific variables, L*og(Cash/Sales), NWC,* which is net working capital divided by sales, *Tangibility, P-E ratio*, following the basic specification of Ambrose and Megginson (1992) and Harford (2005). In the last two specifications, we include the unexpected mutual fund flow, *Mfflow*.[28]

Table 5 shows that coefficients of most variables have the expected signs. The coefficient for *Vdshock* is positive and marginally significant in regressions with no year dummies. *Vdshock* is an annual measure, so inclusion of year dummies makes it insignificant. Size is positively related to the probability of being taken over; however, size interacted with demand shock is negative—small firms have a relatively higher probability of acquisition at high industry demand states.

Columns 1 and 2 in Table 5 use the unexpected valuation from RKRV, and columns 3 through 6 use the unexpected valuation measures based on model 1 in Pastor and Veronesi's (2003) paper, as adapted by Hoberg and Phillips (2010a). Industry-level unexplained valuation is positive throughout, perhaps reflecting industries that are viewed as having positive future cash flows or that industries that are more positively "misvalued" may have higher acquisition intensity. However, within industries, firm-level unexplained valuation is negative, as acquirers target relatively undervalued firms. These facts are consistent with RKRV and also Maksimovic and Phillips (2001). Finally, the coefficient on C&I spread is negative as expected, as low spreads make debt capital very accessible.

With respect to our controls, the coefficient on institutional ownership for all specifications is positive, consistent with institutional owners facilitating acquisitions, and the evidence in Ferreira, Massa, and Matos (2010). In columns 5 and 6 in Table 6, we report the results that include our instrument, unexpected mutual fund redemption flow. Unexpected mutual fund redemption flow, *Mfflow*, is positive and significantly related to the probability of an acquisition.

We now present the regression for firm R&D with the merger target dummy variable that is instrumented with *Mfflow* and its squared value. We also include all control variables. We estimate the model using a single-equation instrumental variable estimator allowing for the target indicator variable to be

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28 We also estimate the IV model using a probit model as the first stage. These results are presented as Tables 3 and 4 of the online appendix. Angrist and Krueger (2001, p. 80) note serious potential concerns with the probit two-stage model, and as such we rely on the linear probability model. The misspecification worry is that the errors are not normal.

Table 5
Target prediction regressions

Independent variable	Dependent variable: Target dummy				
Vdshock	0.018	0.080	0.023	0.087	0.157
	(0.071)	(0.070)	(0.071)	(0.070)	(0.136)
Log(equity value)	−0.002	−0.003	−0.005*	−0.005	−0.013**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)
Age	0.087***	0.086***	0.087***	0.086***	0.073***
	(0.010)	(0.011)	(0.010)	(0.011)	(0.012)
*Vdshock*Log(equity value)*	−0.010	−0.015	−0.011	−0.015	−0.022
	(0.015)	(0.016)	(0.015)	(0.016)	(0.025)
Firm-level UV, RKRV	−0.013***	−0.012***			
	(0.004)	(0.004)			
Industry-level UV, RKRV	0.026***	0.018**			
	(0.009)	(0.009)			
C&I spread		−0.048***		−0.049***	−0.089***
		(0.010)		(0.010)	(0.013)
Compete	0.033***	0.034***	0.035***	0.036***	0.055****
	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)
*Compete*Log(net assets)*	−0.006***	−0.006***	−0.006***	−0.006***	−0.009***
	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)
Cash/Sales	−0.002	−0.001	−0.001	−0.001	−0.009*
	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)
Leverage	0.055***	0.054***	0.055***	0.054***	0.075***
	(0.008)	(0.009)	(0.008)	(0.009)	(0.014)
Net WC/Sales	0.014	0.019	0.016	0.021	−0.111**
	(0.019)	(0.018)	(0.019)	(0.018)	(0.043)
Tangibility	−0.201***	−0.184**	−0.196**	−0.180**	−1.959***
	(0.076)	(0.074)	(0.077)	(0.075)	(0.411)
P/E	−0.084**	−0.069*	−0.083**	−0.068*	−0.092**
	(0.035)	(0.036)	(0.035)	(0.036)	(0.047)
Divd dummy	0.001	0.001	0.001	0.001	−0.002
	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)
InstOwn	0.001***	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Firm-level UV, PV			−0.008**	−0.008**	−0.014***
			(0.003)	(0.003)	(0.005)
Industry-level UV, PV			0.021**	0.013	0.016
			(0.009)	(0.009)	(0.012)
Mfflow					0.365***
					(0.129)
Observations	49,946	47,433	49,840	47,329	28,575
R-squared	0.086	0.078	0.086	0.078	0.075
Year dummies	Yes	No	Yes	No	No

Table 5 presents results from our target prediction regression estimated with a linear probability model. The dependent variable is the target dummy, equaling one if the firm was a target in an acquisition attempt in a given year, and zero otherwise. *Vdshock* is a de-trended version of demand shock variable constructed from the input-output matrix. *Log(market value)* is the natural log of the market value of equity. *Cash/Sales* is the ratio of cash to sales. *Net WC/ Sales* is the ratio of net working capital to sales. *Tangibility* is the ratio of tangible assets. *P-E ratio* is the price-to-earnings ratio. *Divd dummy* is a dummy variable equaling one for dividend-paying firms and zero otherwise. *Inst. Ownership* is the percentage of common equity owned by institutional investors. *C&I spread* is the commercial and industrial loan spread. *Firm-level UV, PV* is the firm-level unexplained valuation computed from the Pastor and Veronesi (PV) model. *Firm-level UV, RKRV* is the firm-level unexplained valuation computed from the Rhodes-Kropf, Robinson, and Viswanathan (RKRV) model. *Industry-level UV, RKRV* and *Industry-level UV, PV* are the industry-level unexplained valuation variables. Standard errors are clustered by industry-year. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 6
R&D with instrumented target from mutual fund flows

	Dependent variable: R&D expenditures scaled by sales		
Target dummy	3.528**	3.896***	3.764***
	(1.451)	(1.462)	(1.394)
Vexpand	0.767***	0.647***	0.666***
	(0.241)	(0.206)	(0.209)
Log(net assets)	−0.316***	−0.305***	−0.291***
	(0.078)	(0.080)	(0.075)
Age	−0.345***	−0.371***	−0.364***
	(0.129)	(0.128)	(0.124)
*Vexpand*Log(net assets)*	−0.108***	−0.093***	−0.095***
	(0.035)	(0.031)	(0.031)
Compete	0.083**	0.041	0.044
	(0.039)	(0.039)	(0.038)
*Compete*Log(net assets)*	−0.010*	−0.004	−0.004
	(0.005)	(0.005)	(0.005)
Firm-level UV, RKRV		0.208***	
		(0.045)	
Industry-level UV, RKRV		−0.188*	
		(0.105)	
Firm-level UV, PV			0.181***
			(0.039)
Industry-level UV, PV			−0.212**
			(0.100)
C&I spread	0.908**	0.904***	0.872***
	(0.360)	(0.341)	(0.332)
Observations	46,470	44,510	44,410
Control variables	Yes	Yes	Yes

Table 6 reports estimates from *R&D* regressions using instrumental variable approach and *Mfflow* as an instrument for the target indicator variable and all the control variables from the target prediction regression. The dependent variable is *R&D* expense scaled by sales in the previous year. *Log(net assets)* is the log of the asset value. *Age* is time in 100s of years since the founding year, incorporation year (if founding is missing), or the first year the firm appears in CRSP tapes (if both founding and incorporation years are missing). *Compete* is a measure of industry competitiveness equaling one minus the Herfindahl index. *C&I spread* is the commercial and industrial loan spread. *Firm level UV, RKRV* is the firm-level unexplained valuation computed from the Rhodes-Kropf, Robinson, and Viswanathan (RKRV) model. *Industry-level UV, RKRV* is the industry-level unexplained valuation variable. *C&I spread* is the commercial and industrial loan spread. Control variables include tangible assets, cash, and net working capital scaled by sales, price-to-earnings ratio, dividend payment dummy, and institutional ownership. Standard errors are clustered by industry-year. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

endogenous. All models are estimated allowing for robust standard errors with industry-year clustering.

Table 6 presents the results using the excluded mutual fund flow instrument, *Mfflow*. The regressions include all control variables that we use in the previous linear probability target model in Table 5. The results for all specifications show that firms invest more in R&D when the predicted probability of being acquired is higher. Results in Table 6 show that takeover probability has an economically significant effect on firms' R&D. Thus, a 10-percentage-point increase in the probability of being taken over results in 35.3 to 38.9 percentage points (0.353 in column 1, to 0.389 in column 2) more R&D expenditures per dollar of sales.

Firms also invest more in R&D when there are positive demand realizations, particularly for small firms. Firms also invest more in R&D in more competitive industries but less for large firms. The variables interacted with firm size show

Table 7
R&D with instrumented target from mutual fund flows and HP concentration measures

Independent variable	Dependent variable: R&D expenditures scaled by sales					
Target dummy	2.496**	5.008**	4.783**	2.269**	4.819**	4.597**
	(1.110)	(2.011)	(1.870)	(1.064)	(1.951)	(1.814)
Vexpand	0.897***	0.678***	0.699***	0.868***	0.659***	0.679***
	(0.239)	(0.236)	(0.235)	(0.233)	(0.231)	(0.230)
Log(net assets)	0.276***	0.104	0.124	0.003	−0.246*	−0.221*
	(0.097)	(0.090)	(0.086)	(0.076)	(0.138)	(0.126)
Age	−0.225***	−0.422***	−0.413***	−0.235***	−0.436***	−0.427***
	(0.085)	(0.158)	(0.151)	(0.085)	(0.160)	(0.153)
*Vexpand*Log(net assets)*	−0.116***	−0.101***	−0.103***	−0.112***	−0.097***	−0.099***
	(0.031)	(0.036)	(0.036)	(0.030)	(0.035)	(0.035)
HP variable comp. measure	3.885***	3.799***	3.785***			
	(1.003)	(1.096)	(1.078)			
*HP variable*Log(net assets)*	−0.534***	−0.573***	−0.570***			
	(0.143)	(0.180)	(0.175)			
HP fixed comp. measure				1.574***	1.102***	1.128***
				(0.331)	(0.305)	(0.302)
*HP fixed*Log(net assets)*				−0.223***	−0.175***	−0.179***
				(0.047)	(0.051)	(0.050)
Firm-level UV, RKRV		0.237***			0.238***	
		(0.056)			(0.056)	
Industry-level UV, RKRV		−0.140			−0.143	
		(0.118)			(0.119)	
Firm-level UV, PV			0.206***			0.207***
			(0.048)			(0.048)
Industry-level UV, PV			−0.146			−0.150
			(0.107)			(0.108)
C&I spread	0.747**	0.958***	0.924***	0.693**	0.914**	0.880**
	(0.299)	(0.368)	(0.356)	(0.290)	(0.358)	(0.347)
Observations	46,401	39,619	39,536	46,420	39,647	39,564
Control variables	Yes	Yes	Yes	Yes	Yes	Yes

Table 7 reports estimates from *R&D* regressions using the instrumental variable approach and *Mfflow* as an instrument for the target indicator variable. The dependent variable is *R&D* expense scaled by sales in the previous year. *Log(net assets)* is the log of the asset value. *Age* is time in 100s of years since the founding year, incorporation year (if founding is missing), or the first year the firm appears in CRSP tapes (if both founding and incorporation years are missing). *HP fixed comp. measure* is 1-Hoberg-Phillips Herfindahl based on fixed industry definitions. *HP variable comp. measure* is 1-Hoberg-Phillips Herfindahl based on variable industry definitions. *C&I spread* is the commercial and industrial loan spread. *Firm-level UV, RKRV (PV)* is the firm-level unexplained valuation computed from the Rhodes-Kropf, Robinson, and Viswanathan (RKRV) model. (Pastor and Veronesi model). *Industry-level UV, RKRV (PV)* is the industry-level unexplained valuation variable. *C&I spread* is the commercial and industrial loan spread. Control variables include tangible assets, cash, and net working capital scaled by sales, price-to-earnings ratio, dividend payment dummy, and institutional ownership. Standard errors are clustered by industry-year. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

that the effects are stronger for small firms than for large firms as the size interaction variables are negative and significant.

In Table 7, instead of the Census Herfindahl-based competition measure, we estimate the regression using the text-based industry concentration measures developed in Hoberg and Phillips (2011). We use their text-based network variable classification, similar to a Facebook circle of friends, where each firm has its own distinct set of competitors. Thus, each firm has its own firm-specific Herfindahl. This measure is only available since 1997, so we use it for the subsample starting in 1997 (resulting in a loss of observations) and we also extrapolate it over the whole sample using the 1997 value for earlier years.

Table 7 shows that results are similar to those presented in Table 6 across our target prediction dummy, with text-based concentration measures being more significant and precise than the Census Herfindahls used in Table 6 for all regression specifications. Table 7 shows that R&D increases with product market competition, but less so for large firms in all specifications. The product-market competition effect is largest for the HP text-based network industry (TNIC) Herfindahl, consistent with this measure capturing competition that is localized around each firm.

Overall, the results are similar to the previous results that show that industry M&A activity is correlated with R&D. Firms invest more in R&D when the market for acquisitions is stronger as the acquisition market presents an additional way for firms to monetize their investment. Results are stronger in competitive markets as firms are more likely to find a buyer in more competitive markets. The results are also consistent with acquirers buying other firms to differentiate themselves from their competition and to potentially reduce the competition they face.

4. Conclusions

In this paper, we examine how M&A activity and competition affect the decision to conduct R&D and innovate. Our model and empirical tests show that the acquisition market impacts the decision to conduct R&D. We model the incentives for large and small firms to conduct R&D based on their size, the gains of commercialization, and the potential for firms to merge or acquire other firms post-innovation. Our model shows that large firms optimally may decide to let small firms conduct R&D and innovate and then subsequently acquire these small innovative companies. Unlike small firms, large firms may find it disadvantageous to engage in an "R&D race" with small firms at intermediate states of demand, as they can obtain access to innovation by acquiring small innovative firms.

Our results show that the possibility of an acquisition amplifies the potential gains from innovation, particularly for smaller firms. We show that firms' incentives to conduct R&D to innovate increase with industry acquisition activity and more so for small firms than large firms. R&D also varies positively with industry demand and the expected probability that a firm is an acquisition target. Both of these effects are stronger for small firms than for large firms.

We also show that greater bargaining power of small firms, captured by the past target excess returns on acquisition announcements, as well as higher inside asset liquidity in the M&A market, leads to more investment in R&D by small firms. Having the ability to capture a greater fraction of the acquisition surplus provides incentives for firms to increase their investment in R&D to increase the possibility of being acquired. Finally, we show that market structure and competition are important. Increased competition leads to more R&D by firms but less so for large firms.

We conclude that M&A activity strongly increases firms' incentives to conduct R&D, but less for large firms as they may buy smaller firms for their technology to use it in their existing business. Competition also increases incentives for firms to conduct R&D, especially for small firms.

Appendix

1. Equilibrium profit functions

One small firm: no acquisition: equilibrium profits. The inverse demand functions (5) and (6) are linear in prices. We then substitute these functions into profit functions (4), differentiate with respect to prices (firms maximize their profits by setting prices competitively), set the derivatives equal to zero, and solve the resulting system of equations. This produces equilibrium prices

$$p_1=\left(-2+\left(-1+\gamma^2\right)K_1\right)\left(\alpha_2\gamma K_2+\alpha_1\left(-2+\left(-2+\gamma^2\right)K_2\right)\right)\kappa\sqrt{x},$$
$$p_2=\left(-2+\left(-1+\gamma^2\right)K_2\right)\left(\alpha_1\gamma K_1+\alpha_1\left(-2+\left(-2+\gamma^2\right)K_1\right)\right)\kappa\sqrt{x},$$

where

$$\kappa=\left[4-2\left(-2+\gamma^2\right)K_2+K_1\left(\gamma^4K_2+4(1+K_2)-\gamma^2(2+5K_2)\right)\right]^{-2}.$$

We then substitute equilibrium prices into inverse demand functions (5) and (6) to get equilibrium quantities, then into profit functions (4) to obtain profits.

The equilibrium profits of the two firms are given by

$$\pi_1(\alpha_1,\alpha_2)=x\kappa K_1(1+(1-\gamma^2)K_1)(\alpha_2\gamma K_2+\alpha_1((\gamma^2-2)K_2-2))^2,$$
$$\pi_2(\alpha_1,\alpha_2)=x\kappa K_2(1+(1-\gamma^2)K_2)(\alpha_1\gamma K_1+\alpha_2((\gamma^2-2)K_1-2))^2.$$

The profit of the merged firm. The profit of the merged firm is obtained by optimizing over the product prices and is given by

$$\pi_m(x,\alpha_m)=\frac{\alpha_m^2x\left[-2\gamma K_1K_2+(1+K_1)K_2+(1+K_2)K_1\right]}{-4(1+K_2)+4K_1((\gamma^2-1)K_2-1)}, \tag{A1}$$

where $\alpha_m=\alpha'$ if the merged entity commercializes innovation and $\alpha_m=\alpha$ otherwise.

Two small firms, equilibrium profits. For ease of exposition, we assume $\alpha_1=\alpha_2=\alpha_3=\alpha$. When there are two small firms, the profit functions are computed analogously to the case with one small firm and are given by (for $K_1=10, K_2=1$)

$$\pi_1(\alpha,\alpha,\alpha)=-5\alpha^2x(1+\gamma)(4-3(-1+\gamma)\gamma)^2(-11+\gamma(-11+20\gamma))\kappa_1,$$
$$\pi_2(\alpha,\alpha,\alpha)=\pi_3(\alpha,\alpha,\alpha)=-2\alpha^2x(11+3(2-5\gamma)\gamma)^2(-1-2\gamma+\gamma^3)\kappa_1,$$

where

$$\kappa_1=(44-3\gamma(-33+\gamma(2+27\gamma)))^{-2},$$

if neither firm innovates.

If the big firm innovates,

$$\pi_1(\alpha',\alpha,\alpha)=5x(1+\gamma)(-11+\gamma(-11+20\gamma))(2\alpha\gamma(1+\gamma)+\alpha'(-4+(-5+\gamma)\gamma))^2\kappa_1,$$
$$\pi_2(\alpha',\alpha,\alpha)=\pi_3(\alpha',\alpha,\alpha)=-2x(-1-2\gamma+\gamma^3)(5\alpha'\gamma(1+\gamma)+\alpha(-11+\gamma(-11+10\gamma)))^2\kappa_1.$$

If one small firm (firm 2) innovates,

$$\pi_1(\alpha,\alpha',\alpha)=-2.5x(1+\gamma)(-11+\gamma(-11+20\gamma))(\alpha'\gamma(1+\gamma)+2\alpha(-2+(-2+\gamma)\gamma))^2)\kappa_1,$$
$$\pi_2(\alpha,\alpha',\alpha)=x(\alpha\gamma(1+\gamma)(-31+3\gamma(-7+10\gamma))+\alpha'(44+\gamma(88+\gamma(-23+3\gamma(-24+5\gamma)))))^2\kappa_2,$$

where

$$\kappa_2=\frac{-2(-1-2\gamma+\gamma^3)}{(4-3(-1+\gamma)\gamma)^2}\kappa_1$$

$$\pi_3(\alpha,\alpha',\alpha)=x(11+3(2-5\gamma)\gamma)^2(\alpha'\gamma(1+\gamma)+2\alpha(-2+(-2+\gamma)\gamma))^2\kappa_2.$$

2. Proofs

Proof of Lemma 1

a) Using the profit functions in the appendix,

$$\pi_1(I,NI)-\pi_1(NI,NI)=x\kappa K_1\left(1+\left(1-\gamma^2\right)K_1\right)\left[\left(\alpha\gamma K_2+\alpha'\left(\left(\gamma^2-2\right)K_2-2\right)\right)^2 - \left(\alpha\gamma K_2+\alpha\left(\left(\gamma^2-2\right)K_2-2\right)\right)^2\right]$$

and

$$\pi_1(NI,NI)-\pi_1(NI,I)=x\kappa K_1\left(1+\left(1-\gamma^2\right)K_1\right)\left[\left(\alpha\gamma K_2+\alpha\left(\left(\gamma^2-2\right)K_2-2\right)\right)^2 -\left(\alpha'\gamma K_2+\alpha\left(\left(\gamma^2-2\right)K_2-2\right)\right)^2\right].$$

It is easy to see that the term $\left(\alpha_2\gamma K_2+\alpha_1\left(\left(\gamma^2-2\right)K_2-2\right)\right)$ is negative for $\alpha_1>\alpha_2$ and its absolute value is increasing in α_1 and decreasing in α_2. Therefore, because $\alpha'>\alpha$, $\pi_1(I,NI)-\pi_1(NI,NI)>0$ and $\pi_1(NI,NI)-\pi_1(NI,I)>0$.

b) The proof is identical to the proof of a. Replace K_1 with K_2.

c)

$$[\pi_1(I,NI)-\pi_1(NI,NI)]-[\pi_2(NI,I)-\pi_2(NI,NI)]=$$

$$x\kappa(K_1-K_2)\left(\alpha'-\alpha\right)\left((4+3K_2)\left(\alpha'+\alpha\right)+K_1\left(3\left(\alpha'+\alpha\right)+K_2\left(2.4375\alpha+2.1875\alpha'\right)\right.\right.>0.$$

d)

$$[\pi_1(I,NI)-\pi_1(NI,I)]-[\pi_2(NI,I)-\pi_2(I,NI)]=$$

$$x\kappa(K_1-K_2)\left(\alpha'^2-\alpha^2\right)\left(4\left(K_2\left(1-\gamma^2\right)+1\right)+K_1\left(1-\gamma^2\right)\left(4+\left(4-3\gamma^2\right)K_2\right)>0\right.$$

because $K_1-K_2>0$, $\alpha'^2-\alpha^2>0$, $4(K_2(1-\gamma^2)+1)>0$, and $4+(4-3\gamma^2)K_2>0$.

e) Using the profit functions derived above,

$$\frac{\pi_1(I,NI)-\pi_1(NI,I)}{2(\pi_2(NI,I)-\pi_2(NI,NI))}=$$

$$\frac{K_1\left(-1+\left(-1+\gamma^2\right)K_1\right)\left(4+K_2\left(8-4\gamma^2+\left(4-5\gamma^2+\gamma^4\right)K_2\right)\right)\left(\alpha+\alpha'\right)}{2\left(-2+\left(-2+\gamma^2\right)K_1\right)K_2\left(-1+\left(-1+\gamma^2\right)K_2\right)\left(-2(\alpha+\alpha')+K_1\left(\alpha(-2+\gamma(2+\gamma))+\left(-2+\gamma^2\right)\alpha'\right)\right)}.$$

For $\gamma=0.5$ and $K_2=1$, this expression is equal to

$$\frac{\pi_1(I,NI)-\pi_1(NI,I)}{2(\pi_2(NI,I)-\pi_2(NI,NI))}=\frac{3.94643(1+0.75K_1)K_1\left(\alpha+\alpha'\right)}{(2+1.75K_1)(K_1(0.75\alpha+1.75\alpha')+2(\alpha+\alpha'))}.$$

Now let us consider the limit

$$\lim_{K_1\to\infty}\frac{\pi_1(I,NI)-\pi_1(NI,I)}{2(\pi_2(NI,I)-\pi_2(NI,NI))}=\frac{1.6913(\alpha+\alpha_i)}{0.75\alpha+1.75\alpha_i}.$$

It follows that $\lim_{K_1\to\infty}\frac{\pi_1(I,NI)-\pi_1(NI,I)}{2(\pi_2(NI,I)-\pi_2(NI,NI))}>1$ iff $\alpha_i<16.03\alpha$. Therefore, as long as $\alpha_i<16.03\alpha$, there exists $\mu>1$ such that for $K_1/K_2>\mu$ $\frac{\pi_1(I,NI)-\pi_1(NI,I)}{2(\pi_2(NI,I)-\pi_2(NI,NI))}>1$, because clearly $\frac{\pi_1(I,NI)-\pi_1(NI,I)}{2(\pi_2(NI,I)-\pi_2(NI,NI))}$ is a continuous function of K_1.

f) If $\gamma = 0.5$ and $K_2 = 1$, then

$$\frac{2(\pi_1(I,NI)-\pi_1(NI,NI))}{\pi_2(NI,I)-\pi_2(I,NI)}=\frac{0.203175(4/3+K_1)\left(21.0938\alpha_i^2-5.625\alpha\alpha_i-15.4688\alpha^2\right)}{(k_1+8/9)(k_1+1.6)\left(\alpha_i^2-\alpha^2\right)}.$$

The limit of this expression for $K_1 \to \infty$ is $\frac{4.2856\alpha_i^2-1.1429\alpha\alpha_i-3.1419\alpha^2}{\alpha_i^2-\alpha^2} > 1$for $\alpha_i > \alpha$.

g) Consider the quantity $\pi_2(NI,I)-2\pi_2(NI,NI)+\pi_2(I,NI)=$ $x\kappa K_2(1+(1-\gamma^2)K_2)[((\alpha'-\alpha)((\gamma^2-2)K_1-2)^2+\gamma K_2)]>0$, where

$$\kappa=\left[4-2\left(-2+\gamma^2\right)K_2+K_1\left(\gamma^4K_2+4(1+K_2)-\gamma^2(2+5K_2)\right)\right]^{-2}.$$

■

Proof of Proposition 2

1) Let $V_{1,2}(A_1, A_2)$ be the value of the big (small) firm as a function of its own actions and those of its competitor. Then, for $x < x_1$,

$$V_1(I,NI)=\pi_1(I,NI)x-RD;\ V_1(NI,NI)=\pi_1(NI,NI)x.$$

It follows that for $x < x_1$ $V_1(I,NI) < V_1(NI,NI)$. It also follows from Lemma 1 c) that $V_2(NI,I) < V_2(NI,NI)$. Then, (NI,NI) is the Nash equilibrium for $x < x_1$, while neither (I,NI) nor (NI,I) is an equilibrium in this region. Furthermore, the value of the small firm if both firms invest is $V_2(I,I)=0.5[(\pi_2(I,NI)+\pi_2(I,NI)]x-RD$, while $V_2(I,NI)=\pi_2(I,NI)x$, so $x < x_3$ (I,I) is not a Nash equilibrium. Lemma 1 f) establishes that $x_1 < x_3$; therefore, the only Nash equilibrium for $x < x_1$ is (NI,NI).

2) If $x_1 < x < x_3$, then (I,NI) is a Nash equilibrium. Indeed, $V_1(NI,NI) < V_1(I,NI)$ for $x_1 < x$, and $V_2(I,I) < V_2(I,NI)$ for $x < x_3$. It follows that neither (I,I) nor (NI,NI) is an equilibrium. (NI,I) is not an equilibrium either as long as condition e) of Lemma 1 holds: it is straightforward to see that for $x > x_4 V_1(NI,I) < V_1(I,I)$.Thus, (I,NI) is the only Nash equilibrium in this region.

3) Finally, for $x > x_3$ it becomes optimal for the small firm to invest as well. In this region,

$$V_2(I,I)=\frac{(\pi_2(NI,I)+\pi_2(I,NI))x}{2}-RD;\ V_2(I,NI)=\pi_2(I,NI)x,$$

so $V_2(I,I) > V_2(I,NI)$. On the other hand, $V_1(I,I) > V_1(NI,I)$ for $x > x_3 > x_4$ (Lemma 1 d) establishes that $x_3 > x_4$). It is also straightforward to see that (NI,NI) is not an equilibrium for $x > x_1$. Lemma 1 f) ensures that $x_3 > x_1$. Therefore, (I,I) is the only Nash equilibrium in this region. ■

Proof of Proposition 3

Note that a merger always results in increased market power, so if $I_m = 0$, a merger always occurs. Also note that condition $\pi_2(NI,I)-\pi_2(NI,NI) > \pi_2(NI,NI)-\pi_2(I,NI)$ implies that $x_2 < x_3$. Then, for $x < x_{1m}$,

$$V_1(I,NI)=(\pi_m(I)-\pi_2(I,NI))x-RD;\ V_1(NI,NI)=(\pi_m(NI)-\pi_2(NI,NI))x.$$

Therefore, $V_1(I,NI) < V_1(NI,NI)$. On the other hand, $\pi_m(I)-\pi_m(NI) > 0$, and therefore

$$\pi_m(I)-\pi_m(NI)+\pi_2(NI,NI)-\pi_2(I,NI) > \pi_2(NI,NI)-\pi_2(I,NI).$$

It follows that $x_{1m} < x_2$ and for $x < x_{1m} V_2(NI,NI) > V_2(NI,I)$. It follows that (NI,NI) is a Nash equilibrium, while neither (I,NI) nor (NI,I) is an equilibrium. Furthermore, because

$\pi_m(I)-\pi_m(NI)>\pi_1(I,NI)-\pi_1(NI,NI)$, it follows that $x_{1m}<x_1<x_3$ (Lemma 1 f), and $V_2(I,NI)>V_2(I,I)$,so (I,I) is not a Nash equilibrium.

For $x_{1m}<x<x_2$, the only Nash equilibrium is (I,NI). Indeed, in this region $V_2(NI,NI)>V_2(NI,I)>V_2(I,I)$ and the small firm never invests in this region, while the big firm invests as $V_1(I,NI)>V_1(NI,NI)$.

For $x_2<x<x_3$, the following inequalities hold: $V_1(I,NI)>V_1(NI,NI); V_1(I,I)<V_1(NI,I); V_2(I,NI)>V_2(I,I); V_2(NI,I)>V_2(NI,NI)$.

The first inequality has been proven above for $x>x_{1m}$. The second results from comparing the values of the big firm if it invests:

$$V_1(I,I)=0.5(\pi_m(I)-\pi_2(I,NI))x+0.5(\pi_m(I)-\pi_2(NI,I))x-RD,$$

and if it does not:

$$V_1(NI,I)=(\pi_m(I)-\pi_2(NI,I))x.$$

The third equation comes from comparing the values of the small firm if it invests: $V_2(I,I)=\frac{(\pi_2(NI,I)-\pi_2(I,NI))x}{2}-RD$ and if it does not: $V_2(I,NI)=\pi_2(I,NI)x$, the fourth equation has been proven above.

Therefore, both (I,NI) and (NI,I) are Nash equilibria. In addition, there is a mixed-strategy equilibrium in which the big firm invests with probability ϕ_1 and the small firm invests with probability ϕ_2. To find these probabilities, note that in this equilibrium both firms must be indifferent between investing and not. Therefore,

$$\phi_1 V_2(I,I)+(1-\phi_1)V_2(NI,I)=\phi_1 V_2(I,NI)+(1-\phi_1)V_2(NI,NI)$$

and

$$\phi_2 V_1(I,I)+(1-\phi_2)V_1(I,NI)=\phi_2 V_1(NI,I)+(1-\phi_2)V_1(NI,NI)$$

or

$$\phi_1=\frac{V_2(NI,NI)-V_2(NI,I)}{V_2(I,I)-V_2(NI,I)-V_2(I,NI)+V_2(NI,NI)}$$

and

$$\phi_2=\frac{V_1(NI,NI)-V_1(I,NI)}{V_1(I,I)-V_1(NI,I)-V_1(I,NI)+V_1(NI,NI)}.$$

It is straightforward to see that $0<\phi_1<1$ and $0<\phi_2<1$ so the mixed-strategy equilibrium always exists.

Finally, for $x>x_3, V_1(I,I)>V_1(NI,I)$ and $V_2(I,NI)<V_2(I,I)$; therefore, (I,I) is the only Nash equilibrium. ■

Proof of Proposition 5

First consider the case $x_{1\eta}<x_{2\eta}$. Consider the values of the big firm:

$$V_1(I,NI)=\pi_1(I,NI)x+(1-\eta)(\pi_m(I)-\pi_1(I,NI)-\pi_2(I,NI))x-RD$$

and

$$V_1(NI,NI)=\pi_1(NI,NI)x+(1-\eta)(\pi_m(NI)-\pi_1(NI,NI)-\pi_2(NI,NI))x.$$

It follows that if $x<x_{1\eta}$, then $V_1(NI,NI)>V_1(I,NI)$. Similarly, the values of the small firm are

$$V_2(NI,I)=\pi_2(NI,I)x+\eta(\pi_m(I)-\pi_1(NI,I)-\pi_2(NI,I))x-RD,$$

$$V_2(NI,NI)=\pi_2(NI,NI)x+\eta(\pi_m(NI)-\pi_1(NI,NI)-\pi_2(NI,NI))x.$$

So, for $x<x_{1\eta}<x_{2\eta}$, $V_2(NI,NI)>V_2(NI,I)$. Finally, because $x_{1\eta}<x_{2\eta}<x_{3\eta}, V_2(I,I)<V_2(I,NI)$, neither (NI,I) nor (I,NI) nor (I,I) is a Nash equilibrium.

If $x_{1\eta} < x < x_{2\eta}$ it can be easily verified that $V_2(I,NI) > V_2(I,I)$, $V_1(I,NI) > V_1(NI,NI)$, and $V_2(NI,I) < V_2(NI,NI)$, so (I,NI) is the only equilibrium in this region. The proof of equilibrium strategies for $x > x_{2\eta}$ follows exactly the proof of Proposition 3.

Now consider the case $x_{1\eta} > x_{2\eta}$. Clearly (NI,NI) is the only Nash equilibrium if $x < x_{2\eta}$. If $x_{2\eta} < x < x_{1\eta}$, it is easy to verify that $V_1(NI,NI) > V_1(I,NI)$, $V_2(NI,NI) < V_2(NI,I)$, and $V_2(I,I) < V_2(I,NI)$. It follows that the only Nash equilibrium in this region is (NI,I). The rest of the proof follows closely the proof of Proposition 3. ■

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