Do Public and Private Firms Behave Differently? An Examination of Investment in the Chemical Industry

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ABSTRACT

Using a comprehensive panel dataset of U.S. production capacity by firm in seven commodity chemical industries, I compare the investment behavior of public and private firms when presented with near identical project opportunities. I find that private firms invest differently, and more efficiently, than public firms. Specifically, private firms are more likely than public firms to increase capacity prior to a positive demand shock (an increase in price and quantity) and less likely to increase capacity before a negative demand shock. This result holds when considering only a subsample of firms that change incorporation status. The private firm investment advantage is particularly strong among leveraged buyouts and is not explained by the level of chemical division diversification. These findings are consistent with theories in which public firms are subject to greater agency concerns, leading to sub-optimal investment relative to private firms.

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Take two firms operating in the same industry—one public, one private. Will they invest in a similar way? Headlines today discuss the consequences of going public or being taken private. Potential benefits of public ownership include easier access to capital and a stock price which aggregates information. This could allow public firms to better uncover and capture positive NPV opportunities. Private firms, however, tend to have more concentrated ownership and thus may be less subject to agency problems and wasteful investment. They are also shielded from short-termism arising from the pressure of earnings management and scrutiny from Wall Street analysts. Private firms compose a significant percentage of the U.S. economy[1]—a better understanding of the advantages and disadvantages of this organizational form is crucial.

Despite a wealth of theories and anecdotes, there has been little empirical study of the implications of public or private incorporation on investment behavior. The reason for this is clear: data is not readily available, as private firms generally do not disclose financial information. This paper introduces a new dataset to enable the comparison of public and private firms. I collect panel data on comprehensive U.S. production capacity by firm for seven commodity chemicals from 1989 to 2006[2]. The sample includes 124 firms, 45 of which are private. By observing annual changes in capacity, I can see investment decisions made by all firms, public or private. I can further evaluate these decisions by incorporating information on the market environment for each chemical.

I find that private firm capacity increases are timed better: private firms are more likely than public firms to increase capacity prior to a positive demand shock and less likely to increase capacity before a negative demand shock. Capacity utilization rates are similar

[1] *Forbes* magazine lists 394 private U.S. firms in 2006 with estimated revenues above $1 billion.
[2] Other studies which have used this data source include Gilbert and Lieberman (1987), Lieberman (1987), Bell and Campa (1997), and Mullainathan and Scharfstein (2001).

before the new capacity is introduced. Hence, private firms appear to realize a higher marginal return on their investments. This result holds when controlling for proxies for the cost of investment. An endogeneity concern is that firms choose whether to be public or private. Perhaps the type of firm that goes public also tends to invest at the wrong time. To address sample selection concerns, I examine a subsample of firms that undergo a transition from private to public status (or vice versa). These firms also invest more efficiently during their private years.

Why do private firms invest more efficiently? I find this advantage to be most pronounced among private equity-run firms. To the extent private equity has a particular focus on aligning incentives, these findings are consistent with theories in which public firms, especially in a low growth, mature industry, are subject to greater agency issues and hence invest sub-optimally relative to private firms. I also test the effect of potential differences in the scope of the chemical businesses of public and private firms and find this internal capital market issue does not explain the results, although there is suggestive evidence that increased diversification within the chemical division itself leads to investment that is less responsive to market signals.

The chemical industry and this dataset provide a particularly attractive setting for comparing public and private firm investment. First, by studying capacity changes for specific chemical products, I can isolate decisions made at a common, identifiable project level instead of at the firm level. To the extent the basic corporate finance theory setting applies—NPV is additive and projects are separable—the decision on this project can be evaluated without worrying about the rest of the firm. Firm-level investment measures such as capital expenditures or R&D, by comparison, are more problematic since no two firms have the same portfolio of businesses. Should two companies spend the same amount on

R&D simply because they reside in the same SIC code? Second, commodity chemicals are a homogenous product—Firm A's sodium chlorate must adhere to the same molecular formula as Firm B's. This strips away concerns about unobserved differences in firms' project opportunities due to, say, branding or quality, further facilitating a clean comparison. Third, the optimality of undertaking these projects, in general tricky for the econometrician to uncover, can be estimated here for each chemical each year using market data for that specific product. This may be more precise than assuming measured Tobin's *q* (anyway unavailable for private firms except by proxy) dictates investment. Fourth, from a data standpoint, the sample of private chemical firms is quite rich. Though on average public firms are larger, some private firms are also quite large (and public quite small). Cargill and Koch Industries, the two largest U.S. private firms[3], are both in the sample. Fifth, the data is free of selection and reporting bias; the relevant investment data can be computed for every public and private chemical-producing firm and is not subject to accounting manipulation.

Armed with this chemical capacity data for both public and private firms, how can the relative efficiency of investment actions be measured? In the cyclical commodity chemical business, all else equal, profits are high when a positive demand shock—higher prices and higher quantity demanded—hits the market. Similarly, negative demand shocks are associated with bad times. Using industry-level quantity and price data for each chemical, I identify the years in which positive and negative demand shocks occur and hence the years in which it was good or bad to invest.

A few studies have worked around data availability constraints to say something about differences between public and private incorporation. Kaplan (1989) studies leveraged buyouts (LBO's) and finds that after the LBO, operating income and cash flow increase

[3] See *Forbes*, "The Largest Private Companies," 11/9/2006

while capital expenditures decrease relative to the firm's history and, to a lesser extent, relative to the industry. Matsa (2007) finds that supermarket LBO's experience higher store shelf out-of-stocks. These papers do not address non-LBO private firms. Michaely and Roberts (2007) study private firm payout policy in the U.K. Bargeron et al. (2008) focus on mergers and compare the acquisition premiums paid by public and private acquirers. They find that target shareholders earn significantly higher premiums when the bidding firm is public, suggesting public firms may overpay. There is, to the best of my knowledge, however, no empirical research which compares the capital expenditure investment efficiency of public and the full range of private firms.

Section I provides theoretical motivation for the empirical work. Section II describes the data and the research design. Section III provides the empirical results on differences between public and private firms. Section IV attempts to explain these differences, and section V concludes.

I. Why might public and private firms invest differently?

I detail below ways in which public and private firms differ and the resulting implications for investment behavior. Public firms generally have a more diverse ownership structure and greater separation between ownership and control. Jensen (1989) hones in on this difference, noting that:

> "the public corporation is not suitable in industries where long-term growth is slow, where internally generated funds outstrip the opportunities to invest them profitably, or where downsizing is the most productive long-term strategy… industries under pressure today include steel, chemicals, brewing, tobacco, television and radio broadcasting, wood and paper products. In

> these and other cash-rich, low-growth or declining sectors, the pressures on management to waste cash flow through organizational slack or investments in unsound projects is often irresistible."

Thus agency issues may plague public firms in the chemical industry and result in less optimal investment. Public firms are subject to the market for corporate control, however, giving shareholders the ability to remove poor management through proxy fights or via acquisition. Whether this mechanism offsets the agency issues brought on by broad-based ownership is an open question. Bargeron et al. (2008) find that public firms pay higher premiums for their acquisition targets than do private firms. It is possible that public firms purchase systematically different types of firms, or that they achieve greater synergies to warrant a higher price. Observable differences in the targets, however, do not explain the difference in premiums paid. They do find that high managerial ownership in the public firm narrows the public-private premium gap, suggesting agency problems in public firms may be responsible for overpayment in acquisitions. Anderson and Reeb (2003) find that family-controlled firms in the S&P 500 outperform their peers, as measured by accounting and market-based yardsticks. To the extent the more concentrated ownership and long-term horizons of family firms are more characteristic of private than public incorporation, this evidence also suggests the agency-corporate control scale may tip in favor of private firms.

The cost of capital literature suggests that one benefit of being public is obtaining capital at more attractive terms and being less financially constrained through access to equity markets. Survey evidence supports this claim; Brau and Fawcett (2006), for example, find the strongest reason given by CFO's for going public is the creation of shares for use in acquisitions. The empirical evidence is inconclusive; Michaely and Roberts (2007) find that in the U.K., private firms are nearly as likely as public firms to pay a dividend. If paying dividends is a proxy for lack of financial constraint, public and private firms may have similar access to capital. Regardless, the impact of lower financial constraint depends on whether the additional funds are spent efficiently or wastefully. Firms less financially constrained can pounce on opportunities when they arise, a case found more commonly in growth industries. But if agency issues are a concern, lower financial constraint may combine with empire-building tendencies and lead to less optimal investment. In fact, the LBO literature (see, for example, Kaplan (1989)) attributes findings of improved performance post-buyout to improved incentives, partially brought on by the constraining effect of debt service.

Public firms possess a stock price which can provide a valuable signal. For example, Grinblatt and Titman (2002) note that "a manager would probably think twice about expanding the core business after its stock price fell." Chemmanur and Fulghieri (1999) provide a model in which this signal comes at the cost of duplication of information production, a cost ultimately borne by the firm. For firms which choose to go public, this cost is outweighed by the useful public signal. Subrahmanyam and Titman (1999) go further to suggest a public stock price allows serendipitous information to be revealed. If this signal truly reveals optimal value-creation advice and is useful above and beyond duplication costs, public firms may invest more efficiently.

Zingales (1995) notes that going public provides liquidity to initial investors. This aids the investors, but it is not obvious how operations are affected beyond the impact now of greater separation between ownership and control. Shah and Thakor (1988) argue that a firm's entrepreneur and managers care about idiosyncratic risk. By going public, a firm increases the presence of diversified investors who do not care about idiosyncratic risk. Hence, idiosyncratic risk matters less to a public firm, so public firms will have a lower hurdle rate and accept more projects. Thus this diversification benefit of being public may lead to greater investment. Efficiency implications are unclear. Public firms must be more open in disclosing their activities, whether through financial reports or discussions with analysts. Revealing this competitive information can put them at a disadvantage versus private firms. This informational advantage may improve private firm investment timing.

Last, evidence suggests there is something inherent in being public that affects corporate decision making. Grinblatt and Titman (2002) note that a public corporation "may be pressured to do things in ways that it would not otherwise do." This is consistent with what Brau and Fawcett (2006) find in their survey of CFO's: the primary reason given by CFO's as to why they choose to remain private is the loss of managerial decision-making control. An article by McKinsey & Company (2003) speculates that in the commodity chemical industry, "privately held commodity companies, which are free to buck pressure for conformity, might stand a better chance of breaking out of the industry's self-destructive investment cycles." Direct evidence of the impact of public scrutiny comes from Michaely and Roberts (2007), who find that public and private firms pay dividends differently—private firms are significantly less likely to smooth dividends. They conclude there is something inherent about being public, beyond agency conflicts and information asymmetry, that leads to this difference in payout policy. What is this public market mechanism that influences firm activity, and does it push firms towards or away from optimal behavior? A survey by Graham et al. (2005) reveals that CFO's of public companies admit a willingness to undertake negative NPV activities, including delaying projects and selling assets, in order to meet earnings estimates. There is evidence this actually occurs. Bartov (1993) provides suggestive results that public firm managers smooth earnings by selling assets. Bushee (1998) finds that high institutional ownership makes public firms less likely to cut R&D to stem an earnings decline. But when those institutional investors are short-term owners (e.g., have high turnover), the probability of cutting R&D to reverse an earnings decline increases significantly. Thus public markets appear to influence firms, and influence them negatively.

II. Data description and research design

Chemical production capacity data come from the 1989 through 2006 volumes of the *Directory of Chemical Producers*, published by SRI Consulting[4]. This annual publication gives the total U.S. capacity by firm, by plant, at the start of the year for numerous chemical products. This study focuses on seven of these chemicals, chosen using the following criteria:

1) At least one private firm produced the chemical during the sample period.
2) Capacity figures must be well-defined (e.g., not subject to feedstock choices.)
3) Capacity cannot be switched between multiple products in response to shifts in market demand.
4) The chemical must not be produced as the by-product of another process[5].
5) Quantity and price data for the chemical must be available from sources detailed below.

[4] According to their website and printed materials, SRI gathers this data by employing industry experts and surveys, reviewing industry journals, printed sources, and websites, and maintaining ongoing contact with the global chemical industry.
[5] Some metals manufacturers produce sulfuric acid as a by-product of their smelter operations. These producers account for roughly 15% of sulfuric acid capacity. Since their acid capacity is a by-product of their metals capacity decisions, these firms are not analyzed (although their capacity is included in the total).

All chemicals which meet the above criteria are used. For each chemical, all plants are first aggregated by firm to a total capacity number for each firm. Each firm's capacity time series is then used to capture decisions to increase capacity. A firm is considered to have increased capacity of chemical *c* during year *t* if its capacity at the start of year *t+1* is at least 5% higher than at the start of year *t*. This follows the specification used by Gilbert and Lieberman (1987). They chose a dichotomous measure for investment because economies of scale and technological considerations can alter the optimal expansion increment. They chose a 5% threshold to screen out incremental expansions driven by learning-based improvements achieved at negligible investment cost. Note that while one to two years is the typical lead time for a new construction project (Lieberman (1987)), the timing of the capacity increase measure is such that I record an expansion as occurring in the year it actually begins operation, not the year in which the decision was made to build. A plant that is still being built cannot take advantage of a strong selling environment. This binary capacity increase measure will be the dependent variable in linear probability model regressions[6]. Capacity reductions and exit are not considered in this study. Capacity tends to be sunk and fairly irreversible, and reduction or exit decisions can be motivated by longer-term, strategic concerns.

Capacity increases can be achieved through brownfield expansion, in which capacity at a given plant is increased; greenfield expansion, in which a new plant is built; or acquisition. An expansion is coded as brownfield if the capacity increase occurs at an existing plant, identified by its city and state. Capacity at a new location for that firm is coded as greenfield, provided it was not purchased from a different firm. To identify these acquisitions, I examine all new plants to see if, the prior year, another firm owned a plant in

[6] Results in this paper are similar when this binary measure is replaced by the actual percentage increase in capacity.

that same city but no longer does in the current year. If so, I perform an article search to see if this plant has simply changed hands (almost always the case). The only capacity increases not considered in this study are acquisitions of capacity from another firm of the same incorporation type. Public firm A buying an asset from public firm B is not considered an increase in capacity undertaken by public firm A because the decision is offset by another public firm deciding to sell, thereby leaving no net change in public firm capacity. A public firm purchasing an asset from a private firm, however, *is* counted as a public firm decision to increase capacity; this is a bet made between public and private firms and thus captures differences in their behavior. While internal (brownfield or greenfield) construction is likely performed by third-party contractors using standard designs and at standard costs, acquisitions may close at prices which reflect the current attractiveness of the industry. Since transaction price data is not available, the base case in this study assumes no correlation between the price paid for a plant and its future attractiveness; e.g., assets are sold at replacement cost. I perform robustness checks by running regressions which consider only internal growth decisions in which the costs of adding capacity are unlikely to be related to the demand environment.

Each firm is designated public or private each year by finding the ultimate owner and researching its history using Compustat, Dun & Bradstreet's Million Dollar Directory, SEC filings, LexisNexis, and internet searches. Joint ventures and cooperatives (non-profit entities) are excluded from the analysis, although their capacity is included in the annual totals. The average number of employees for each firm is found using internet searches and Dun & Bradstreet. Table I provides summary statistics for the sample. While public firms are, on average, larger, there are significant private firms as well. The two largest private firms in the nation, Cargill and Koch Industries, are both chemical manufacturers and represented in the sample. Nevertheless, this table stresses the need to control for firm size in the regressions to separate the effect of being private from the effect of being small. Public firms also hold greater market share within a particular chemical business, though here the discrepancy between public and private firms is not as large: the median public firm has 2.4% of the market, while the median private firm holds 1.7%.

Annual data on demand and production for the seven chemicals are taken from the Minerals Yearbook published by the U.S. Department of the Interior, Chemical & Engineering News: Facts & Figures of the Chemical Industry issues, and the Chemical Market Reporter. Price data come from the Minerals Yearbook and the Inorganic Chemicals (MQ325A) and Fertilizers and Related Chemicals (MQ325B) Current Industrial Reports, published by the U.S. Census Bureau. Additional details on data collection and variable construction are provided in the appendix.

How can investment efficiency now be extracted from capacity decisions? In cyclical, capital intensive industries, the timing of capacity increases is crucial. This paper makes the assumption that it is best to bring on new capacity prior to a positive demand shock. Positive demand shocks are outward shifts of the demand curve. When this happens, price and quantity both increase along the supply curve until a new equilibrium is reached. Similarly, negative demand shocks are to be avoided; new capacity is not needed when customers are reducing their purchases. In a negative demand shock, the demand curve shifts to the left, leading to a new equilibrium with lower prices and lower quantity. Positive and negative *supply* shocks have indeterminate effects on firm profitability. A negative supply shock in the commodity chemical industry might take the form of a sudden increase in input prices. When this happens, the supply curve shifts up; prices increase, and quantity decreases. These effects offset, and the resulting profitability impact depends further on market power—to what extent can chemical firms pass on price increases? Hence I define the key variable used in this study, *Demand shock*, which for each chemical-year takes on one of three values depending on the supply-demand dynamics :

Market event	Price change	Quantity change	"*Demand shock*" variable value
Positive demand shock	Up	Up	1
Positive supply shock	Down	Up	0
Negative supply shock	Up	Down	0
Negative demand shock	Down	Down	-1

Investment in new capacity is thus deemed optimal when it is positively correlated with *Demand shock*. Cohen et al. (2007) employ a similar price-quantity "pair" identification strategy to isolate demand shifts in the shorting market for individual stocks. They find that when the stock loan fee ("price") and percentage of shares on loan ("quantity") both increase, signifying an increase in shorting demand, future stock returns fall. My measure is forward-looking to capture industry attractiveness subsequent to a firm's introduction of additional capacity, so *Demand shock* in year t is coded as "1" if both quantity and price levels increase from year t to year $t+1$.

III. A comparison of public and private firm investment decisions

A. Investment frequency and increment size

I first summarize the characteristics that describe investment without regard to optimality. Panel A of Table II shows that in my sample across all chemical products organic brownfield or greenfield capacity construction occurs on average every 11 years;

public firms build new capacity in 8.6% of firm-years and private firms build in 8.8% of their years. Panel B shows that these expansions are small on average; for public firms, the average increase adds 1.5% to total industry capacity while the median increase adds 0.4%. Private firm expansions are slightly smaller.

To control for other factors, I perform regressions in panel C. In specification (1), the dependent variable is binary and equal to one if the firm opened new capacity for a particular chemical product in year *t*. Independent variables include a dummy variable equal to one if the firm-year is private. I also include *firm size*, as measured by the log of the average number of employees in the firm, and *firm share*, equal to the firm's market share in the particular chemical at the start of year *t*. These two variables are not necessarily related; a firm could be very small but focused in just one chemical product with large market share. Another control is necessitated by the varying prevalence of public and private firms by chemical. If there happen to be more private firms in the higher growth chemical industries, for example, they will appear to invest more frequently overall. I therefore include product fixed effects. Similarly, calendar fixed effects control for the prevalence of public and private firms in years in which investment in general is particularly attractive. I find no significant differences in new construction investment frequency between public and private firms (the coefficient on the private indicator is positive but with a t-statistic of only 0.66). Firm size and share also do not appear to have significant impact. Thus there does not appear to be a story about differences in public and private firm organic investment frequency. In specification (2), the dependent variable is the actual capacity amount added, and the sample includes only expansion events. Controlling for firm size and market share, there is again no significant difference in how much public and private firms add when they do so.

B. Investment Efficiency

I next estimate a linear probability model to determine the relative efficiency of public and private firm investment. The dependent variable is binary and is equal to one if the firm increased capacity for a particular chemical product in year *t*. The independent variables include *Demand shock*, a dummy variable equal to one if the firm is private, and the interaction between this dummy and *Demand shock*. The coefficient on this key interaction term thus gives the differential response of private firm capacity to future changes in price and demand. Also included as a control is the size of the firm, as proxied for by the log of the average number of employees. Size is also interacted with *Demand shock*. The regression includes product and year fixed effects to control for factors influencing investment specific to certain chemical industries or time periods, assuming these factors remain fixed. Firm fixed effects are included and control for differences in overall firm characteristics and investment policies (e.g., some firms may love to spend; others might be thrifty). Firm effects also allow the evaluation of each firm's investment sensitivity to its particular demand environment. The standard errors are clustered by firm to address correlation of the residuals within the cluster[7]. The results are presented in Table III.

The coefficient of -0.019 on *Demand shock* in specification (1) shows that for public firms, an increase in capacity is followed by price and demand declines (at the 10% level of significance). Thus their capacity appears ill-timed. The coefficient on the *Private*Demand shock* variable is 0.046 and is significant at the 5% level, however. Thus new private firm capacity is more sensitive to the attractiveness of the environment than new public firm capacity. Controlling for firm size in specification (2), the results are unchanged. The

[7] Errors are also, alternatively, clustered by year and by product. The significance of results is generally unchanged.

coefficient on *Firm size*Demand shock* is positive (though not significant), suggesting larger firms may invest more efficiently[8]. Since private firms are on average smaller, this provides comfort that being private is not simply a noisy proxy for being small. In specifications (3) and (4), I add the industry capacity utilization level in year *t-1* as an additional control[9]. This is calculated by dividing total annual U.S. production by average total capacity. The optimality of bringing on new capacity prior to a positive demand shock could be questioned if utilization levels also happen to be lower; existing plants could simply ramp up production to meet demand. The *Private*Capacity utilization* interaction term is positive, and thus there is no evidence that lower utilization detracts from the stronger forward demand environment enjoyed by private firms.

C. Investment costs

A concern with these results might be the lack of information on the costs of increasing capacity. Though cash flows should be higher in a positive demand shock environment, if investment costs are also correspondingly higher, the net present value of investment at these times is not unambiguously higher. Could this be happening in this sample? Capacity increases are of two types: new capacity construction (brownfield or greenfield), and asset purchases. It is possible that asset sale price negotiations take into account the cash flows resulting from future demand growth, and thus when demand is projected to be high, buyers must pay more for assets. Public firms may be acquiring assets

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[8] Regressions including interaction terms should include all constituent terms. *Firm size* alone is not present in Table III or other regressions because this value (average employee count) is the same for all of a firm's years, and thus this variable cannot be separately identified in the presence of firm fixed effects. The influence of firm size is captured in the interaction term, as firm size varies much more in the cross-section than it does within a given firm over time. Similarly, the private dummy variable should be interpreted cautiously; it is identified only by the firms in the sample which change public/private status.

[9] Lagged capacity utilization (*t-1*) is used instead of contemporaneous (*t*) because new capacity enters directly into the capacity utilization calculation for year *t*, contaminating the direction of causality.

from private firms at the wrong time, when a negative demand shock is poised to strike. But perhaps all parties know this, and consequently the assets are purchased at fire-sale prices—public firms use their deep pockets to scoop up assets. Indeed, Pulvino (1998) finds that less financially constrained airlines take advantage of distressed airlines by purchasing their planes at discounted prices.

Brownfield and greenfield construction costs, however, are unlikely to be similarly correlated with commodity chemical cycles; a new building should cost the same no matter what the sodium chlorate market looks like. So if private firms appear to invest more efficiently only because transaction and acquisition costs are missing from the analysis, then there should be no difference between public and private firms when considering only organic growth. In Table IV I present separate results for capacity increases via acquisition and via construction. When building new capacity, private firms once again display better timing: the *Private*Demand shock* variable is significantly positive (specifications (1) and (2)). Therefore it is difficult to argue that the weaker price and demand environment following public firm investment is offset by lower investment costs.

D. Endogeneity of the public-private decision

Firms are not randomly assigned public or private status. Is there an underlying property of firms which choose to go public which leads to their relative inefficiency? To help control for this, I extract a limited sample which includes only those firms which change status from public to private or vice versa. While there is likely a change in some firm characteristic driving the switch, many firm-specific factors are likely to be constant, such as some or all of the key managers, or corporate culture. I rerun the regressions for only the six firms in the sample that change status. I omit firm size controls since the public and private firm-years will already be of similar size by construction. The results are in Table V. Capacity increases made by these firms during their private years do not experience a significantly different market environment from those made during public years, as the coefficient on *Private*Demand shock* is 0.084 with a t-statistic of only 0.57. This coefficient value, however, is nearly twice the magnitude of the coefficients found in Table III using the entire sample, and thus the lack of significance may be due to lack of power. Focusing on capacity increases from construction, specification (2) shows that during private incorporation years these firms build more efficiently, as *Private*Demand shock* is significantly positive at 10% with a sizable coefficient of 0.174. In addition, industry capacity utilization is significantly higher for construction undertaken during the private years. It appears the relative efficiency of private investment holds even within a given firm.

IV. Why do private firms invest more efficiently?

A. Agency costs

Are certain types of private firms better than others? Kaplan (1989) finds that leveraged buyouts (LBO's) have better operating results and cash flow than public firms in the same industry in the three years after the buyout. He attributes the improvements to better incentives present in the LBO structure; LBO and private equity firms claim to target slack management with poor incentives. Bargeron et al. (2008) find that private operating companies pay lower acquisition premiums than public firms, 40.9% to 46.5%. But private equity firms pay the lowest premiums of all—only 28.5%. Because of private equity's explicit focus on aligning incentives, private firms that are the product of leveraged buyouts may thus be different from private firms which have simply never gone public. I therefore separate the private firms in my sample into precisely these two groups. Six private firms are the product of LBO's. Table VI looks at the investment decisions relative to public firms of private firm non-LBO's (sample A) and LBO's (sample B) separately. There are two interesting results. First, specifications (1A) and (2A) show that private non-LBO's increase capacity at better times than public firms, and thus this is not simply an LBO effect. Second, specifications (1B) and (2B) show not only that LBO's invest more efficiently than public firms, but they also respond better to demand shocks relative to public firms than non-LBO private firms, as the *Private*Demand shock* coefficient is 0.163 for LBO's and 0.050 for private non-LBO's. Regressions (1C) and (2C) show this difference is significant. Sample C includes only the private firms and introduces a dummy variable *LBO* which equals one if the firm is an LBO and zero if it is private but not an LBO. The interaction term *LBO*Demand shock* is positive and significant at the 5% level. Although private firms overall tend to be less subject to agency concerns than public firms because of lesser separation of ownership and control, LBO's may exemplify this advantage with their focus on aligning incentives—using high leverage, taking board seats, and constantly monitoring management. This result then provides cross-sectional support for agency issues as the source of private firm relative investment efficiency.

B. Internal capital market dynamics

A vast literature suggests that internal capital markets may distort investment allocation. Could systematic differences in divisional organization or scope between public and private firms be driving variation in investment efficiency? All results presented thus far control for firm size, as measured by employee count. Given size, it is not obvious why public and private firms would differ in scope. But the question is worth exploring. The bulk of internal capital market research focuses on unrelated diversification[10]. Unfortunately, the presence of non-chemical business lines is not readily available for my sample of private firms. Empirical study of scope *within* a division, however, has also been pursued: Khanna and Tice (2001) find using a sample of retailers that conglomerate firms with related divisions can be more responsive to changes in investment opportunities than focused firms. Mullainathan and Scharfstein (2001) find that a chemical firm's production capacity is less sensitive to external demand when the firm itself demands the chemical product internally.

The *Directory of Chemical Producers* provides, in addition to capacity data, a comprehensive profile of the U.S. chemical operations of each chemical producing firm. Hence, to study the impact of within-division business scope, I extract an estimate of the number of distinct U.S. chemical plants operated by each firm by averaging totals tallied at three points in time. I also record the average number of chemical divisions; Koch Industries, for example, has four divisions in 1995 according to SRI: Koch Hydrocarbon, Koch Nitrogen, Koch Refining, and Koch Sulfur Products. The number of plants and the number of divisions are two measures of the degree to which firms are either focused, or broadly integrated across many chemical products. Panel A of Table VII shows that the correlations between firm size and number of chemical plants and number of chemical divisions are 0.35 and 0.49, respectively, and thus these scope measures are not fully captured by firm size. Regression specification (1) in panel B of Table VII once again regresses the capacity increase dummy variable on *Demand shock* and its private firm interaction, this time including the interaction term *Chem plants*Demand shock* to capture the impact of this scope variable on investment efficiency. The *Private*Demand shock* coefficient is still significant at the 5% level with a t-statistic of 2.30. Regression (2) controls for

[10] This literature begins with such papers as Lang and Stulz (1994) and Berger and Ofek (1995).

industry capacity utilization, and regressions (3) and (4) substitute the second scope measure, *Chem divisions*Demand shock*. Private firm capacity increase continues to be more responsive to demand shocks in all four specifications. Turning to the scope variables themselves, there is suggestive evidence that a diverse portfolio of chemicals makes firm investment less responsive to market signals. In regression (4), the *Chem divisions* interactions with *Demand shock* and *Industry capacity utilization* are both negative, significantly so with respect to capacity utilization (-0.046 with t-statistic -2.03). To the extent more divisions means more internal sharing of production, this result is consistent with the findings of Mullainathan and Scharfstein (2001).

C. Positive versus negative shocks

Are private firms doing a better job of investing at good times, or avoiding investment at bad times? To provide more color on the differences between public and private firm investment, I examine the response to positive and negative shocks separately. In Table VIII, I rerun this paper's primary regression. In column (1A), however, the *Demand shock* variable now only captures positive shocks; it equals one if price and quantity both increase and zero otherwise. Similarly, column (1B) uses a new *Demand shock* variable which equals (positive) one if price and quantity both decrease and zero otherwise. The *Private*Demand shock* interaction term is significant for negative shocks but not for positive shocks, suggesting on the surface that the private advantage gets its bite from avoiding bad investments. For organic growth, however, private firms are more responsive to both good and bad times, with both positive and negative shock private interaction terms significant at the 10% level in specifications (2A) and (2B). The divergence in relative response to shocks comes from acquisitions; both publics and privates acquire similarly prior to positive shocks, but before a negative shock, public firms are significantly more likely to buy, and private firms to sell. A future analysis of transaction costs or announcement effects may shed light on who is winning this pre-negative shock asset transfer game.

D. Additional robustness checks

In addition to the chemical market outlook, firms may consider their relative competitive position and the actions of rival firms when deciding whether to invest in additional capacity. Gilbert and Lieberman (1987) find that a firm's market share in a particular chemical affects its decision making[11]. Therefore, I compute a new variable, $Share_{f,c,t}$, which equals the capacity share of firm f in chemical product c at the start of year t. I interact this variable with the demand shock and capacity utilization variables and add them to the regressions. I find all the key results concerning the impact of being private unchanged. The market share interaction variables are generally insignificant.

Export opportunities and import threats may distort the interpretation of changes in price and demand. Suppose a supply shock local to the U.S. raises production costs for U.S. producers and consequently the prices they must charge. Normally, this would lower U.S. demand. If cheaper imports become available, however, U.S. quantity consumed could rise despite the higher prices charged by U.S. sellers. This higher price and higher demand scenario would then actually not be an optimal time to open new capacity as a U.S. producer. To account for this possibility, I redefine the *Demand shock* variable: I replace U.S. demand with U.S. output, which equals demand plus exports minus imports. This *Output shock* variable equals +1 if price and output increase and -1 if they decrease. In the cheap import

[11] Specifically, he finds that firms with larger market share are more likely to expand when past capacity utilization has been high. Also, small share firms are more likely to invest following their own share gains and when others in the industry are investing.

scenario described above, though demand rises along with price, U.S. output would fall. This year would not, then, be coded as a good (+1) time to bring on new capacity. The main results are unchanged after replacing *Demand shock* with *Output shock*.

Expectation of a positive demand shock may attract entry from new, startup firms. Startups are likely to be private. Could the apparent increased private firm response to favorable market environments, then, actually simply reflect new entrant response? To control for this, I eliminate all capacity increases which take the form of entry decisions by new players—firms which previously did not manufacture the chemical. I find that private firms are still more responsive than public firms among only incumbents[12].

V. Discussion and Conclusion

Using a dataset which allows me equal visibility into the decisions of public and private firms in the commodity chemical industry, I find that private firms invest differently than public firms and argue that private investment is more efficient.. Specifically, private firms better time capacity increases to coincide with positive demand shocks and avoid negative demand shocks. I address endogeneity concerns by looking at a sample of firms that change status and find these firms invest more efficiently during their private years. Agency costs and resulting inattention may be responsible for this result, as the private firm advantage is strongest in private equity owned firms, which have an explicit focus on aligning incentives. Differences in within-division internal capital market structure between public and private firms do not appear to affect investment efficiency, although increased divisional diversity alone does appear to reduce investment efficiency.

[12] Tables for all robustness checks in this section are available from the author.

Future extensions include exploration of the conditions under which the private firm advantage is strongest. Does, for example, the degree of access to capital in the economy at a particular time matter? The differences in acquisition activity are also worth examining more deeply. Public firms appear to be buying capacity from private firms just as the market environment is about to falter. By looking at transaction costs and stock market reactions, we may be able to see whether this is bad timing or strategic fire sale shopping. Capacity closures have not been studied here, but they present a new set of issues. Are public or private firms more likely to exit? Do political considerations matter? The commodity chemical setting lends itself well to the study of strategic interaction; how do public and private firms respond to the actions of rivals? Identifying a specific, homogenous, investment that can be compared across firms enables a deeper understanding of corporate decision making.

Appendix

Additional details on dataset construction

Capacity is sometimes built to replace existing, outdated facilities and not as a response to market conditions. The timing of the completion of new capacity and the removal of old capacity may not align precisely, which can lead to temporary increases or decreases in total firm capacity. To reduce the possibility brought on by these timing differences that replacement capacity is mistakenly recorded as a deliberate capacity increase, I do not count as a capacity increase in the regressions increases that are subsequently reversed the next year. Similarly, I do not count as an increase expansions which merely bring total capacity back to the prior year's level.

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Table I

Chemical Firm Summary Statistics

Chemical Product	Public Firms	Private Firms
Aluminum	7	8
Ammonia	30	15
Chlorine	17	5
Phosphoric acid	19	7
Sodium chlorate	11	2
Sulfuric acid	40	16
Urea	17	13
Total unique firms	79	45
Mean # employees	23,957	8,341
Median # employees	9,857	583
Mean chemical market share	6.2%	3.7%
Median chemical market share	2.4%	1.7%

Table II

Internal Expansion Frequency and Size

Panel A counts the total number of public and private firm-years in the full sample and the number of firm-years in which each group increased capacity through internal greenfield or brownfield expansion by at least 5%. Panel B measures the average and median expansion size relative to total industry capacity for these expansions. Panel C provides results from OLS regressions which incorporate total firm size and firm market share within the industry in addition to public or private status. The dependent variable Expansion dummy (>5%) is equal to one if firm *f* realized an increase in capacity via construction for chemical *c* in year *t* and zero otherwise. The dependent variable Expansion amount is the actual capacity added, conditional on an increase occurring. Private dummy is equal to one if firm *f* is private in year *t* and zero if it is public. Firm size is the log of the average number of employees. Firm Share is the market share of firm *f* in chemical *c* at the start of year *t*. All regressions include year and product fixed effects. Standard errors are adjusted for heteroskedasticity and clustered by firm. T-statistics are in parentheses.

Panel A: Expansion Frequency

	Internal expansion occurrences	Total firm-years	Percent
Public Firms	128	1,482	8.6%
Private Firms	52	593	8.8%

Panel B: Expansion Size

	Internal expansion occurrences	Avg % increase industry capacity	Median % increase industry capacity
Public Firms	128	1.46%	0.44%
Private Firms	52	1.19%	0.40%

Panel C: Determinants of Expansion Frequency and Size

Dependent variable:	Expansion dummy (>5%)	Expansion amount
	(1)	(2)
Private dummy$_{ft}$	0.011	85.0
	(0.66)	(1.06)
Firm size$_f$	-0.002	14.2
	(-0.54)	(0.88)
Firm share$_{f,c,t}$	-0.007	767.3***
	(-0.09)	(4.31)
Number obs	2,137	180

Table III

Capacity Response to Future Demand Shocks

OLS regressions are run in which the dependent variable is equal to one if firm *f* realized an increase in capacity for chemical *c* in year *t* and zero otherwise. Demand shock is a variable equal to +1 if price and demand both increase from year *t* to year *t+1*, zero if price and demand move in opposite directions, and -1 if price and demand both decline. Industry capacity utilization equals industry production divided by industry capacity in year *t-1*. Private dummy equals one if firm *f* in year *t* is private. Firm size is the log of the average number of employees. All regressions include product, year, and firm fixed effects. Standard errors are adjusted for heteroskedasticity and are clustered by firm. T-statistics are in parentheses.

	(1)	(2)	(3)	(4)
Demand shock$_{t,t+1}$	-0.019*	-0.068	-0.020*	-0.066
	(-1.81)	(-1.37)	(-1.91)	(-1.26)
Industry capacity utilization$_{t-1}$			-0.020	0.263
			(-0.23)	(0.57)
Private * Demand shock$_{t,t+1}$	0.046**	0.055**	0.048**	0.056**
	(2.23)	(2.28)	(2.32)	(2.25)
Private * Industry cpcty utilization$_{t-1}$			0.188	0.144
			(0.95)	(0.73)
Firm size * Demand shock$_{t,t+1}$		0.005		0.005
		(1.03)		(0.93)
Firm size * Indus cpcty utilization$_{t-1}$				-0.031
				(-0.64)
Private dummy$_{ft}$	0.034	0.035	-0.243	-0.205
	(0.30)	(0.31)	(-1.10)	(-0.91)
Number obs	1,959	1,959	1,816	1,816

*, **, *** indicate significance at 10%, 5%, 1%.

Table IV

Capacity Response by Type: Organic growth vs. Acquisition

The OLS dependent variable in columns (1) and (2) is equal to one if firm *f* realized an increase in capacity through either greenfield or brownfield construction for chemical *c* in year *t* and zero otherwise. In columns (3) and (4), the dependent variable is equal to one if a capacity increase was realized via an acquisition from the opposite incorporation type (e.g., equals one if a private firm acquires capacity from a public firm, but equals zero if a private firm acquires capacity from another private firm) and zero otherwise. The sum of the "Organic growth" and "Acquisition" variables equals the dependent variable in Table III. The independent variables are as defined in Table III. All regressions include product, year, and firm fixed effects. Standard errors are adjusted for heteroskedasticity and are clustered by firm. T-statistics are in parentheses.

	Dependent variable			
	Organic growth (1)	Organic growth (2)	Acquisition (3)	Acquisition (4)
Demand shock$_{t,t+1}$	-0.054	-0.060	-0.014	-0.006
	(-1.29)	(-1.36)	(-0.54)	(-0.23)
Industry capacity utilization$_{t-1}$		-0.035		0.297
		(-0.09)		(1.45)
Private * Demand shock$_{t,t+1}$	0.042**	0.044**	0.013	0.012
	(2.02)	(2.04)	(1.06)	(1.03)
Private * Industry cpcty utilization$_{t-1}$		0.187		-0.043
		(1.02)		(-0.66)
Firm size * Demand shock$_{t,t+1}$	0.004	0.005	0.001	0.001
	(0.94)	(0.98)	(0.50)	(0.22)
Firm size * Indus cpcty utilization$_{t-1}$		-0.004		-0.027
		(-0.09)		(-1.28)
Private dummy$_{ft}$	-0.047	-0.237	0.082	0.033
	(-0.38)	(-1.03)	(1.58)	(0.47)
Number obs	1,959	1,816	1,959	1,816

*, **, *** indicate significance at 10%, 5%, 1%.

Table V

Investment Efficiency of Public/Private Status Changers

The firms in this sample all changed from public to private status (or vice versa) between 1989 and 2006. In an OLS regression, the dependent variable in column (1) is equal to one if firm *f* realized an increase in capacity for chemical *c* in year *t* and zero otherwise. The dependent variables in columns (2) and (3) are equal to one if capacity increased via organic growth and via acquisition, respectively. All other variables are as defined in Table III. All regressions include product and firm fixed effects. Standard errors are adjusted for heteroskedasticity and clustered by year. T-statistics are in parentheses.

	Dependent variable		
	All capacity increases (1)	Organic growth (2)	Acquisition (3)
Demand shock$_{t,t+1}$	-0.016 (-0.21)	-0.024 (-0.77)	0.008 (0.11)
Industry capacity utilization$_{t-1}$	-0.65 (-1.02)	-0.97* (-1.71)	0.32 (1.11)
Private * Demand shock$_{t,t+1}$	0.084 (0.57)	0.174* (1.71)	-0.091 (-0.62)
Private * Industry cpcty utilization$_{t-1}$	1.82* (1.63)	2.20** (2.06)	-0.38 (-0.87)
Private dummy$_{ft}$	-1.62* (-1.67)	-1.95** (-2.08)	0.33 (0.95)
Number obs	84	84	84

*, **, *** indicate significance at 10%, 5%, 1%.

Table VI

Private Firm Investment: LBO versus non-LBO

Sample A includes all public firms and only those private firms which are not LBO's. Sample B includes all public firms and only those private firms that are the result of a leveraged buyout. Sample C includes all private firms only. The dependent variable in these OLS regressions is equal to one if firm *f* realized an increase in capacity for chemical *c* in year *t* and zero otherwise. The LBO variable in sample C is a dummy variable equal to one if the private firm is an LBO, zero if it is not. All other variables are as defined in Table III. All regressions include product, year, and firm fixed effects. Standard errors are adjusted for heteroskedasticity and clustered by firm. T-statistics are in parentheses.

	Sample A: Private non-LBO's and public firms		Sample B: LBO's and public firms		Sample C: LBO's and Private non-LBO's	
	(1A)	(2A)	(1B)	(2B)	(1C)	(2C)
Demand shock$_{t,t+1}$	-0.081	-0.077	-0.087	-0.080	-0.027	-0.027
	(-1.63)	(-1.46)	(-1.52)	(-1.33)	(-0.43)	(-0.40)
Industry capacity util$_{t-1}$		0.344		0.394		0.339
		(0.74)		(0.93)		(0.43)
Private * Demand shock$_{t,t+1}$	0.049**	0.050**	0.164***	0.163***		
	(2.02)	(1.98)	(3.20)	(3.19)		
Private * Industry cpcty util$_{t-1}$		0.111		0.400		
		(0.58)		(0.38)		
LBO * Demand shock$_{t,t+1}$					0.137	0.134
					(2.46)**	(2.31)**
LBO * Industry cpcty util$_{t-1}$						-0.390
						(-0.41)
Firm size * Demand shock$_{t,t+1}$	0.007	0.006	0.008	0.007	0.004	0.004
	(1.32)	(1.16)	(1.32)	(1.15)	(0.47)	(0.43)
Firm size * Indus cpcty util$_{t-1}$		-0.039		-0.040		-0.031
		(-0.78)		(-0.88)		(-0.33)
Private dummy$_{ft}$	0.071	-0.135	-0.048	-0.532		
	(0.56)	(-0.59)	(-0.21)	(-0.53)		
Number obs	1,915	1,774	1,454	1,350	549	508

*, **, *** indicate significance at 10%, 5%, 1%.

Table VII

The Effect of Within-Division Diversification on Investment Efficiency

Panel A shows the correlations between Firm size (as measured by number of employees), the number of chemical plants operated by each firm, and the number of chemical divisions in each firm. All three variables are averages estimated over all of a firm's years. The dependent variable in OLS regressions in Panel B is a dummy variable equal to one if firm *f* realized an increase in capacity for chemical *c* in year *t* and zero otherwise. All regressions include product, year, and firm fixed effects. The Firm size, Chem plants, and Chem divisions variables alone do not appear in these regressions because they are absorbed by the firm fixed effects. Standard errors are clustered by firm. T-statistics are in parentheses.

Panel A

Correlations	Firm size	Chemical plants	Chemical divisions
Firm size	1.00		
Chemical plants	0.35	1.00	
Chemical divisions	0.49	0.77	1.00

Panel B

	(1)	(2)	(3)	(4)
Demand shock$_{t,t+1}$	-0.062	-0.061	-0.075	-0.075
	(-1.22)	(-1.13)	(-1.54)	(-1.46)
Industry capacity utilization$_{t-1}$		0.246		0.214
		(0.53)		(0.47)
Private * Demand shock$_{t,t+1}$	0.058**	0.059**	0.053**	0.054**
	(2.30)	(2.27)	(2.17)	(2.12)
Private * Industry cpcty utilization$_{t-1}$		0.133		0.107
		(0.67)		(0.53)
Chem plants * Demand shock$_{t,t+1}$	0.0005	0.0004		
	(0.59)	(0.53)		
Chem plants * Indus cpcty util$_{t-1}$		-0.0015		
		(-0.26)		
Chem divisions * Demand shock$_{t,t+1}$			-0.003	-0.004
			(-1.09)	(-1.25)
Chem divisions * Indus cpcty util$_{t-1}$				-0.046**
				(-2.03)
Firm size * Demand shock$_{t,t+1}$	0.004	0.004	0.008	0.008
	(0.68)	(0.62)	(1.39)	(1.37)
Firm size * Indus cpcty utilization$_{t-1}$		-0.027**		-0.009
		(-0.51)		(-0.17)
Private dummy$_{ft}$	0.035	-0.196	0.034	-0.172
	(0.31)	(-0.86)	(0.31)	(-0.76)
Number obs	1,959	1,816	1,959	1,816

*, **, *** indicate significance at 10%, 5%, 1%.

Table VIII

Positive versus Negative Demand Shocks

The OLS dependent variable in columns (1A) and (1B) is equal to one if the firm increased capacity and zero otherwise. In columns (2A) and (2B), the dependent variable equals one if an increase occurs organically, and columns (3A) and (3B) capture only increases via acquisition. The Demand shock variable in Positive shock columns is equal to one if chemical price and quantity demanded both increase from year *t* to year *t+1* and zero otherwise; in Negative shock columns this variable equals one if price and quantity both decline. All regressions include product, year, and firm fixed effects. Standard errors are clustered by firm. T-statistics are in parentheses.

	All capacity increases		Organic growth		Acquisition	
	Positive shock (1A)	Negative shock (1B)	Positive shock (2A)	Negative shock (2B)	Positive shock (3A)	Negative shock (3B)
Demand shock$_{t,t+1}$	-0.045	0.122*	-0.071	0.087	0.026	0.035
	(-0.43)	(1.77)	(-0.91)	(1.44)	(0.48)	(0.80)
Industry capacity util$_{t-1}$	0.316	0.243	0.002	-0.030	0.314	0.273
	(0.71)	(0.53)	(0.00)	(-0.08)	(1.53)	(1.27)
Private * Demand shock$_{t,t+1}$	0.048	-0.093***	0.062*	-0.053*	-0.013	-0.039**
	(0.98)	(-3.21)	(1.81)	(-1.81)	(-0.52)	(-2.00)
Private * Industry cpcty util$_{t-1}$	0.104	0.155	0.161	0.182	-0.057	-0.027
	(0.54)	(0.81)	(0.88)	(1.01)	(-0.87)	(-0.42)
Firm size * Demand shock$_{t,t+1}$	0.002	-0.011	0.004	-0.008	-0.002	-0.003
	(0.15)	(-1.53)	(0.49)	(-1.20)	(-0.43)	(-0.78)
Firm size * Indus cpcty util$_{t-1}$	-0.036	-0.028	-0.008	-0.003	-0.029	-0.025
	(-0.78)	(-1.53)	(-0.19)	(-0.07)	(-1.37)	(-1.13)
Private dummy$_{ft}$	-0.179	-0.198	-0.226	-0.224	0.047	0.026
	(-0.80)	(-0.89)	(-0.98)	(-0.98)	(0.68)	(0.37)
Number obs	1,816	1,816	1,816	1,816	1,816	1,816

*, **, *** indicate significance at 10%, 5%, 1%.