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

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Abstract

I compare the U.S. capacity expansion decisions of public and private producers of 7 commodity chemicals from 1989 to 2006. I find that private firms invest differently than public firms. 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. Potential mechanisms include public firm overextrapolation of past demand shocks and agency problems arising from greater separation between ownership and control.

I. Introduction

Take 2 firms operating in the same industry: 1 public and 1 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 that aggregates information. This could allow public firms to better uncover and capture positive net present value (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; a better understanding of the advantages and disadvantages of this organizational form is thus crucial.

Despite a wealth of theories and anecdotes, there is a shortage of empirical study on whether there are differences in public and private firm investment

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behavior. There are 2 challenges. First, it is difficult to see what private firms are doing as they generally do not disclose financial statements. Second, it is hard, even with public companies, to *evaluate* a firm's investment choices. We cannot typically see the firm's project opportunity set. Is one firm more profitable than another because of skill, good luck, or the fact that it operates in different industries? This paper introduces a new empirical approach that enables both equal visibility into public and private investment decisions and a simple technique for comparing them. I collect a comprehensive panel of U.S. production capacity by firm for 7 commodity chemicals from 1989 to 2006.[1] Chemical capacity changes can thus serve as a measure of investment.

The chemical industry and this data set have features that enable this paper's research design. First, there is ample representation of private firms. The sample includes 128 firms, 52 of which are private. Though, on average, public firms are larger, some private firms are also quite large (and some public ones are quite small). Cargill and Koch Industries, the 2 largest U.S. private firms,[2] are both in the sample. The data are also not obviously subject to selection or reporting bias concerns; capacity is captured for every public and private chemical-producing firm. Second, commodity chemicals are a homogeneous product. Firm A's sodium chlorate adheres to the same molecular formula as Firm B's. This mitigates concerns about unobserved differences in firms' project opportunities due to, say, branding or quality. Third, analysis is conducted at the granular, chemical plant level. Broad firm-level investment measures, such as capital expenditures or research and development, by comparison, are more problematic since no two firms have the same portfolio of businesses. Fourth, with commodity chemicals, market prices and quantities can be used to reveal the attractiveness of investment, as an alternative to the commonly used Tobin's q, a measure only available at the firm level and anyway unavailable for private firms.

This paper proposes a simple technique to evaluate chemical firm investment. In essence, I implement the basic idea that it is better to open a new store when demand for its wares is high than when it is low. In the cyclical commodity chemical business, all else equal, profits are higher when a positive demand shock (higher prices and higher quantity demanded) hits the market. Similarly, negative demand shocks are associated with poor results. 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 bring new capacity online.

I find that public and private firm investment size and frequency, within these specific chemical industries, look similar. Private firm capacity increases, however, appear better timed: Private firms are approximately 5% 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. This effect is not driven by acquisitions, in which the purchase price might account for the demand environment. Industry capacity utilization rates are similar before public and private

[1] Other studies that have used this data source include Gilbert and Lieberman (1987), Lieberman (1987), Bell and Campa (1997), and Mullainathan and Scharfstein (2001).

[2] See *Forbes*, "America's Largest Private Companies 2015," Oct. 28, 2015.

capacity introduction; thus, new private firm investment enjoys a stronger selling environment.

This measure of investment efficiency, which correlates capacity increases with demand shocks, though simple to implement, comes with a trade-off: I cannot claim that this research design perfectly captures optimal investment. Thus, I perform additional tests. I find that among the public firms in the sample, those whose investment patterns line up more strongly with this demand shock measure are more profitable than their competitors. This provides some direct evidence of this measure's validity. To address concerns about how well demand shocks are captured, I focus only on larger shocks and find similar results. Because capacity is a long-lived investment, identifying the attractiveness of only single years may not be sufficient. Requiring shocks to persist beyond a year does not change the message.

Why are there differences in public and private chemical firm investment behavior? I explore 2 mechanisms. First, it is instructive to step back from the difference to consider public and private firm expansions on their own to see if, in general, investment is well timed. In fact, the average firm in the sample does not actually open capacity at the right time. Though private firm capacity is greeted by a directionally positive shock, public firms are more likely to open capacity into a negative demand shock than a positive one. This seems surprising. There is evidence, however, of such behavior in the chemical and other cyclical, capital intensive industries.

Greenwood and Hanson (2015) present a model and supporting evidence from the dry bulk shipping industry showing that "high current ship earnings are associated with higher ship prices and higher industry investment, but predict low future returns on capital." They find this happens because of a behavioral explanation: Firms "mistakenly believe that abnormally high profits will persist into the future." This is problematic, in particular, in the shipping industry because the product is homogeneous and there are time-to-build delays. Because feedback is not immediate, by the time shipping capacity comes online, potentially including supply from competitors, firms are disappointed in the results. The chemical industry shares these features, as new capacity has a time to build of 1 to 2 years. Greenwood and Hanson (2015) note that "a number of capital intensive industries, including chemicals ... have experienced boom-bust cycles that resemble those we have documented in dry bulk shipping."

Supporting the possibility that firms mistime investment by overextrapolating demand, I find that firms are indeed significantly more likely to invest in new capacity following positive demand shocks in the *past*. Private firms, however, are *less* susceptible to this behavior. This is consistent with Gilje and Taillard (2016) who focus on the natural gas industry. They find that private firms are 60% less likely than public firms to drill wells in response to past positive changes in natural gas prices and attribute this to public firms having easier access to capital. If firms in cyclical, time-to-build industries are subject to behavioral biases, as in Greenwood and Hanson (2015), a public firm's access to capital can exacerbate investment mistakes. From a practitioner's perspective, "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."[3]

A second, partially related, reason private firms may time investment better is fewer agency problems. A key cost of public ownership is the separation of ownership and control (Jensen (1989)). I posit that better aligned incentives lead to better decision-making. To the extent future demand can be anticipated, and errors in extrapolating past demand can be avoided, private firms should see better results. To test this idea, I look cross sectionally within private firms. Michaely and Roberts (2012) note that "ownership structures of private firms exhibit far greater diversity than those of public firms," and many private firms are, in fact, structured like public firms. I thus extract private equity (PE)–run chemical firms. Alignment of incentives is the particular focus of PE firms, and there is evidence that this can lead to better firm outcomes. Kaplan (1989) finds that leveraged buyouts (LBOs) have better cash flow than public firms in the same industry, which he attributes to better incentives present in the LBO structure. Davis, Haltiwanger, Handley, Jarmin, Lerner, and Miranda (2014) find improvements in total factor productivity following PE buyouts, and Cohn, Nestoriak, and Wardlaw (2017) and Bernstein and Sheen (2016) show that PE firms appear to have superior operational skill in the context of workplace safety and restaurant management. I find the chemical capacity investment decisions of PE-run firms to respond most strongly to demand shocks, followed by private non-PE firms, followed by public firms. This hierarchy of outcomes is consistent with a link between incentive alignment and managerial effort and firm performance. I also test the effect of internal capital markets, distortions arising from international trade, and strategies driven by market share and find these do not explain the results.

Firms choose whether to be public or private, and thus endogeneity is a concern. Perhaps public and private firms in my sample are systematically different in ways that impact investment results. Because the unit of analysis is at the commodity chemical project level, much potential variation is removed (e.g., that public and private firms have different growth prospects). I cannot completely solve this issue, but to help address this concern, I control for differences in firm size and organizational scope between public and private firms in my regressions and robustness checks.[4]

A few other studies have worked around data availability constraints to say something about differences between public and private incorporation. Gilje and Taillard (2016) focus on the natural gas industry and is the closest to this study. They find that public natural gas firms drill more than private firms in response to high natural gas price environments. A key difference in their setting is that the unit of investment is much smaller. Drilling a gas well happens very quickly, and drilling is much more frequent than building a new chemical plant or plant expansion. Time-to-build delays, which can exacerbate cyclicality and errors, are not important in their study. Two papers match firms more coarsely using broad

[3] *McKinsey Quarterly*, "Multiple Choice for the Chemical Industry," 2003.

[4] I also attempt to examine a subsample of firms that undergo a transition from private to public status (or vice versa). While these firms time investment better during their private years, the small sample of such firms makes meaningful statistical inference difficult.

industry codes but present useful large sample evidence on the difference between public and private firms. Asker, Farre-Mensa, and Ljungqvist (2015) compare observably similar public and private U.S. firms and find that private firms are more responsive to changes in investment opportunities. Maksimovic, Phillips, and Yang (2019) compare public and private firms matched on initial conditions instead of in the cross section and find that public firms grow faster when downstream demand increases. As in Gilje and Taillard (2016), these papers measure response after shocks are revealed and do not focus on the future demand environment. Michaely and Roberts (2012) study the private firm payout policy in the United Kingdom. Bargeron, Schlingemann, Stulz, and Zutter (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.

II. Why Might Public and Private Firms Invest Differently?

I detail subsequently 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 sub-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. Anderson and Reeb (2003) find that family-controlled firms in the Standard & Poor's (S&P) 500 outperform their peers, as measured by accounting and market-based yardsticks. To the extent that the more concentrated ownership and long-term horizons of family firms are more characteristic of private than public incorporation, this evidence suggests the agency-corporate control scale may tip in favor of private firms.

One potential 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 chief financial officers (CFOs) for going public is the creation of shares for use in acquisitions. Bharath and Dittmar (2010) find that financially constrained public firms are less likely to go private, suggesting access to capital is a benefit of public markets. But additional capital can be a double-edged sword. Are funds spent efficiently or wastefully? Firms less financially constrained can pounce on opportunities when they arise, as illustrated in Gilje and Taillard (2016). But if agency issues or investment mistakes (as in Greenwood and Hanson (2015)) are a concern, lower financial constraint may lead to less optimal investment. The LBO literature (see, e.g., 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 that can provide a valuable signal. 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 that 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.

Public firms may be subject to the pressures of "short-termism." Grinblatt and Titman (2002) note that a public corporation "may be pressured to do things in ways that it would not otherwise do." Brau and Fawcett (2006) find in their survey of CFOs that the primary reason given by CFOs as to why they choose to remain private is the loss of managerial decision-making control. A survey by Graham, Harvey, and Rajgopal (2005) reveals that CFOs of public companies admit a willingness to undertake negative NPV activities, including delaying projects and selling assets, in order to meet earnings estimates. Direct evidence of the impact of public scrutiny comes from Michaely and Roberts (2012), who find that public and private firms pay dividends differently; private firms are significantly less likely to smooth dividends. Asker et al. (2015) find that private firms are more responsive than public firms to changes in investment opportunities, particularly in industries in which stock prices are most sensitive to earnings news.

III. Data Description and Research Design

Chemical production capacity data come from the 1989–2006 volumes of the *Directory of Chemical Producers*, published by SRI Consulting.[5] 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 7 of these chemicals, chosen using the following criteria:

i) At least 1 private firm produced the chemical during the sample period.

ii) Capacity figures must be well defined (e.g., not subject to feedstock choices).

[5]SRI gathers these data by employing industry experts and surveys, reviewing industry journals, printed sources, and websites, and maintaining ongoing contact with the global chemical industry.

iii) Capacity cannot be switched between multiple products in response to shifts in market demand.

iv) The chemical must not be produced as the by-product of another process.[6]

v) Quantity and price data for the chemical must be available from sources detailed subsequently.

All chemicals that meet the preceding 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.[7] Thus, EXPAND (an indicator variable that equals 0 or 1 each year, for each firm, in each chemical industry) will be the primary dependent variable in linear probability model regressions.

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 those that are subsequently reversed the next year. Similarly, I do not count as an increase expansions that merely bring total capacity back to the prior year's level. Note that while 1–2 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.

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 acquisitions, I examine all new plants to see if, in the prior year, another firm owned a plant in 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). I thus add acquisitions in which assets move from public to private ownership or from private to public

[6] 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).

[7] I relax this measure in a robustness check in Section V.C.

ownership to the sample. Acquisitions are recorded as occurring in the year the deal closes. I distinguish between organic growth and acquisition in order to control for the possibility that these methods' expansion costs may differ systematically if construction costs and acquisition prices do not vary the same way with industry attractiveness.

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, U.S. Securities and Exchange Commission filings, LexisNexis, Capital IQ, and Internet searches. Joint ventures and cooperatives (non-profit entities) are excluded from the analysis, although their capacity is included in the annual totals. I use employee counts as a proxy for firm size since revenues are not available for private firms. For public firms, the average number of employees is found by averaging the employee counts from Compustat. For private firms, the average employee count is gathered by sampling years of the Dun & Bradstreet Million Dollar Database, Internet searches, and news articles in LexisNexis. Table 1 provides summary statistics for the sample. The data set has 128 unique firms, 76 public and 52 private. While public firms are, on average, larger, there are significant private firms as well. Two of the largest private firms in the nation, Cargill and Koch Industries, are both chemical manufacturers and present in the sample. Nevertheless, this table stresses the need to control for firm size in the analysis to separate the effect of being private from the effect of being small. Public firms also hold, on average, 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 1.6%.

TABLE 1

Chemical Firm Summary Statistics

Table 1 provides summary statistics for the chemical firm sample. Chemical market share is calculated each year as the total capacity of firm *f* in chemical *c* divided by total industry capacity for chemical *c*.

Chemical Product	Public Firms	Private Firms
Aluminum	8	8
Ammonia	32	16
Chlorine	17	5
Phosphoric acid	19	9
Sodium chlorate	9	3
Sulfuric acid	40	21
Urea	20	14
Total unique firms	76	52
Mean no. of employees	25,440	7,493
Mean chemical market share	5.6%	3.2%
Median chemical market share	2.4%	1.6%

Annual data on demand and production for the 7 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. Fundamental demand for the chemicals in this study is driven by the general macro economy, agriculture, and various other factors. Aluminum and chlorine have a wide variety of uses across the economy. Ammonia, phosphoric acid, sulfuric acid, and urea are primarily used as fertilizer, although all have significant additional applications. Sodium chlorate's primary use is as a bleaching agent for the pulp and paper industry.

How can investment now be evaluated using capacity decisions? In cyclical, capital intensive industries, the timing of capacity increases is crucial. I implement a simple intuition that it is better to open new capacity when demand is high than when it is low. I assume that it is best to bring on new capacity when there is 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 to the left, prices increase, and quantity decreases. These effects offset, and the resulting profitability impact can depend on the extent to which chemical firms can pass on price increases. Similarly, a positive supply shock (e.g., lower input prices) results in higher volume but lower prices.

Hence, I define the key demand shock variable used in this study, DEM_SHK, which for each chemical-year takes on 1 of 3 values:

Market Event	Price Change	Quantity Change	DEM_SHK 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

New capacity is deemed better when it is positively correlated with DEM_SHK. DEM_SHK in year t is coded as 1 if both quantity and price levels increase from year t to year $t+1$. In other words, if a firm opens new capacity this year, was this year one in which demand was increasing? Cohen, Diether, and Malloy (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.

One complication is the potential interaction between capacity expansions and subsequent changes to price and quantity. New capacity is an increase in supply. Consider a simultaneous positive demand shock. If the rightward shift in the demand curve is small relative to the rightward shift in the supply curve, the supply shock will dominate; equilibrium aggregate quantity will increase and price will decrease. If the positive demand shock is large, however, price will increase along with quantity. Similarly, consider a positive supply shock that accompanies a negative demand shock. If the shift in the demand curve is small, price will fall and quantity will rise. If the negative demand shock is large, quantity can fall along with price. Hence, my measure will likely miss small demand shocks. This is not ideal, but larger shocks are the ones that are more relevant from an investment perspective. The data will show as well in Section IV.A that expansions are very small relative to the industry and thus should not distort measurement of demand shocks significantly.

This investment efficiency measure benefits from simplicity, but with simplicity comes trade-offs. In addition to potentially missing small shocks, demand shocks could be measured and identified with error due simply to noise in prices and quantities. There could be profitable strategies that delay investment or consider more complex competitive dynamics. Expansion and operating costs may be related to factors that affect demand. Perhaps a strong macro economy or high crop prices (ultimate demand drivers for some chemicals in this study) are associated with increased labor, materials, or other chemical production costs such that strong demand does not necessarily mean strong profit.

Ideally, plant-by-plant costs and cash flows could provide direct NPV evidence that investment positively correlated with this demand shock measure performs better. These data, unfortunately, are unavailable, even for public firms. I can, however, make firm-level comparisons between those more and less responsive to demand shocks when opening capacity. If this is truly a better way to invest, it should manifest, all else equal, in higher profits.

Profitability data are available for the public firms in the sample. For each public firm, I calculate EXP_DSHK_CORR: the correlation between its plant expansions, a binary (0,1) variable, and DEM_SHOCK. Higher values thus signify more capacity increases that arrive in positive demand shock times and fewer in negative shock times. In Table 2, I regress each firm's EBIT (earnings before interest and taxes) and net income margins, both winsorized at the 5% level, on EXP_DSHK_CORR. I include chemical industry and year fixed effects, with standard errors clustered by firm. Columns 1 and 3 show that the higher the correlation between a firm's capacity openings and positive demand shocks, the higher the firm's profit margin compared to its chemical industry competitors. The coefficient on EBIT_MARG is 0.097. As the standard deviation of EXP_DSHK_CORR across all firms is 0.17, a 1-standard-deviation improvement in this variable is associated with just under a 1.7% difference in absolute EBIT margin. In columns 2 and 4, I add firm size as a control. The coefficient on EXP_DSHK_CORR is still positive, but the significance weakens. One reason for this could be that firms with positive correlation between expansion decisions and demand shocks (successful investing) are also those that grow large. This potential multicollinearity, then, between the 2 independent variables can reduce the precision of the estimates. Though not the perfect test, this provides some comfort that the demand shock measure and profits are related.

Should the expectation be that chemical firm capacity, on average, opens in strong demand environments? Perhaps surprisingly, there is documented evidence in cyclical industries of large capital investments realizing below average returns. Greenwood and Hanson (2015) present a model and empirical support from the dry bulk shipping industry showing that "high current ship earnings are associated with higher ship prices and higher industry investment, but predict low future returns on capital." They attribute this partially to firms "mistakenly believing that

TABLE 2

Demand Shock Investing and Firm Profitability

Table 2 presents estimates from ordinary least squares (OLS) panel regressions of firm investment efficiency on profitability. The dependent variables are a firm's earnings before interest and taxes divided by sales, or EBIT margin (EBIT_MARG), and net income divided by sales, or net margin (NET_MARG) each year. EXP_DSHK_CORR is the correlation between a firm's capacity expansions each year (a binary variable equal to 1 if that firm expanded capacity in a particular chemical-year) and DEM_SHK. DEM_SHK for a chemical is equal to +1 if price and quantity consumed both increase from year t to year $t+1$, 0 if price and quantity move in opposite directions, and −1 if both decline. FIRM_SIZE is the log of firm sales each year. The regressions include chemical product and year fixed effects. Standard errors are adjusted for heteroskedasticity and are clustered by firm. t-statistics are in parentheses. * and ** indicate significance at the 10% and 5% levels, respectively.

	EBIT_ MARG	EBIT_ MARG	NET_ MARG	NET_ MARG
	1	2	3	4
EXP_DSHK_CORR	0.097**	0.081*	0.081**	0.053
	(2.08)	(1.69)	(2.31)	(1.29)
FIRM_SIZE		0.0027		0.0050
		(0.68)		(1.36)
No. of obs.	1,415	1,415	1,415	1,415

abnormally high profits will persist into the future." As a result, they overinvest in booms. The key friction in the commodity shipping industry is the lag between investment initiation and completion of over 1 year. Because feedback is not immediate, by the time new ships are built, potentially including supply from competitors, firms are disappointed in the results.

The chemical industry shares these characteristics with bulk shipping. Expansions take 1–2 years to build, and the product is a commodity. Greenwood and Hanson (2015) note that "a number of capital intensive industries, including chemicals ... have experienced boom-bust cycles that resemble those we have documented in dry bulk shipping." From a practitioner perspective, a McKinsey & Company study on the chemical industry also points out that the chemical industry is subject to cyclicality and mistimed investment.[8] Thus, whether chemical firms time capacity to arrive in a strong demand environment is an open question.

In Section V.C, I conduct robustness checks with alternative demand shock definitions to minimize misclassifications and sharpen the results. I also attempt to isolate the cost side of expansion to see if there is evidence that higher costs accompany periods of strong demand.

IV. Empirical Results

A. Investment Frequency and Increment Size

I first summarize the characteristics that describe new chemical industry investment. Panel A of Table 3 shows that across all 7 chemical products organic brownfield or greenfield capacity construction is built, on average, every 11 years; public firms build new capacity in 9.1% of firm-years and private firms build in 9.5% of their years. Panel B shows that these expansions are small on average; for public firms, the average increase adds 1.6% to total industry capacity while the median increase adds 0.5%. Private firm expansions are slightly smaller.

[8] *McKinsey Quarterly*, "Multiple Choice for the Chemical Industry," 2003.

TABLE 3

Industry Expansion Frequency and Size

Panel A of Table 3 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 organic greenfield or brownfield expansion by at least 5%. Panel B measures the average and median expansion size relative to total industry capacity. Panel C provides results from OLS regressions, which incorporate total firm size in addition to public or private status. The dependent variable EXPAND is equal to 1 if firm *f* realized an increase in capacity via construction for chemical *c* in year *t*, and 0 otherwise. The dependent variable EXPAND_AMT is the actual capacity added, conditional on an increase occurring. PRIV is equal to 1 if firm *f* is private in year *t*, and 0 if it is public. FIRM_SIZE is the log of the average number of employees. 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

	Organic Expansion Events (>5%)	Total Firm-Years	Percent
Public firms	126	1,386	9.1%
Private firms	55	578	9.5%

Panel B. Expansion Size

	Organic Expansion Events (>5%)	Avg. % Increase Industry Capacity	Median % Increase Industry Capacity
Public firms	126	1.6%	0.48%
Private firms	55	1.1%	0.35%

Panel C. Determinants of Expansion Frequency and Size

	Dependent Variable			
	EXPAND	EXPAND	EXPAND_ AMT	EXPAND_ AMT
	1	2	3	4
PRIV	0.013	0.011	12.1	39.3
	(0.73)	(0.65)	(0.28)	(0.44)
FIRM_SIZE		−0.001		10.2
		(−0.29)		(0.54)
Product fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
No. of obs.	1,964	1,964	181	181

This helps mitigate concerns that new supply contaminates measurement of demand shocks.

Regression provides a more informative comparison. In panel C, columns 1 and 2, the dependent variable, EXPAND, is binary and equal to 1 if the firm increased capacity for a particular chemical product by at least 5% in year *t*. Independent variables are a dummy variable equal to 1 if the firm-year is private (PRIV) and FIRM_SIZE, measured by the log of the average number of employees in the firm. The varying prevalence of public and private firms by chemical necessitates chemical product fixed effects; if there happen to be more private firms in higher growth chemical industries, for example, they may appear to invest more frequently overall. Similarly, year fixed effects control for the ratio 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 with a *t*-statistic of only 0.73 in column 1 and very similar in column 2 with firm size controls. Firm size itself does not have significant impact. Thus, there does not appear to be a story about differences in public and private firm organic investment frequency. In columns 3 and 4, the dependent variable is the actual capacity amount added, conditional on having built new capacity. Controlling for firm size and chemical industry, there is again no significant difference in how much public and private firms add when they do so.

B. Investment Timing

I next estimate a linear probability model to look for differences in the response of public and private firm investment to the demand environment. The dependent variable, EXPAND, is binary and equal to 1 if the firm increased capacity for a particular chemical product in year t by at least 5%. The independent variables include DEM_SHK, an indicator variable equal to 1 if the firm is private, and the interaction between this dummy and DEM_SHK. The coefficient on this key interaction term thus gives the differential response of private firm capacity to future changes in demand. Also included as a control is the size of the firm, as proxied for by the log of the average number of employees, and size is also interacted with DEM_SHK. 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. The results are presented in Table 4.

TABLE 4

Demand Shocks Following New Capacity Introduction

Table 4 presents estimates from OLS panel regressions explaining capacity increase decisions by public and private firms across 7 chemical products from 1989 to 2006. The dependent variable is equal to 1 if firm f realized at least a 5% increase in capacity for chemical c in year t, and 0 otherwise. The samples in column 2 include only public firms and in column 3 only private firms. DEM_SHK is equal to +1 if chemical price and quantity consumed both increase from year t to year $t+1$, 0 if price and quantity move in opposite directions, and −1 if both decline. IND_UTIL equals industry production divided by industry capacity in year $t-1$. PRIV is a dummy variable equal to 1 if firm f in year t is private. FIRM_SIZE is the log of the average number of firm employees. FIRM_SIZE alone drops out of the regressions because it is the same for all of a firm's years and thus cannot be separately identified in the presence of firm fixed effects. 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. * and ** indicate significance at the 10% and 5% levels.

	All	Public	Private	All	All	All	All
Sample	1	2	3	4	5	6	7
$\text{DEM\_SHK}_{t,t+1}$	−0.012	−0.026**	0.023	−0.026**	−0.124**	−0.025**	−0.114*
	(−1.14)	(−2.50)	(1.08)	(−2.52)	(−2.08)	(−2.56)	(−1.81)
IND_UTIL_{t-1}						0.043	0.711
						(0.37)	(1.29)
PRIV × $\text{DEM\_SHK}_{t,t+1}$				0.050**	0.069**	0.050**	0.067**
				(2.15)	(2.29)	(2.19)	(2.16)
PRIV × IND_UTIL_{t-1}						0.141	0.031
						(0.57)	(0.13)
FIRM_SIZE × $\text{DEM\_SHK}_{t,t+1}$					0.011*		0.010
					(1.65)		(1.44)
FIRM_SIZE × IND_UTIL_{t-1}							−0.073
							(−1.27)
PRIV				0.014	0.014	−0.215	−0.118
				(0.17)	(0.16)	(−0.87)	(−0.47)
No. of obs.	1,964	1,386	578	1,964	1,964	1,815	1,815

Column 1 begins by regressing all firm capacity introductions on DEM_SHK without controls. The coefficient is negative, and thus the average capacity expansion does not arrive concurrently with a positive demand shock. In fact, public firm expansions, surprisingly, are more likely to precede a negative than a positive demand shock, as the DEM_SHK coefficient in column 2 is -0.026, significant at the 5% level. Thus, their capacity appears ill-timed, consistent with the findings in Greenwood and Hanson (2015) on the dry bulk shipping industry. Private firm expansions, however, do directionally open into positive demand environments. Column 4 combines public and private firm investment with an interaction term. The coefficient on the PRIV $\times$ DEM_SHK variable is 0.050 and is significant at the 5% level. Thus, new private firm capacity is more likely to arrive in a more attractive selling environment. With respect to economic magnitude and interpretation, the coefficient value of 0.050 means when facing a positive shock, a private firm is 5% more likely to increase capacity, and before a negative shock, a private firm is 5% less likely to grow. Controlling for firm size in column 5, the results are unchanged. The coefficient on FIRM_SIZE $\times$ DEM_SHK is positive, suggesting larger firms may invest more efficiently.[9] Since private firms are, on average, smaller, this provides comfort that the apparent private firm effect is not simply a noisy proxy for a small firm effect. In columns 6 and 7, I add the industry capacity utilization level in year $t-1$ (IND_UTIL) as an additional control.[10] This is calculated by dividing total annual U.S. production by average total capacity separately for each chemical. The optimality of bringing on new capacity prior to a positive demand shock could be questioned if utilization levels also happen to be lower, as existing plants could simply ramp up production to meet demand. The PRIV $\times$ IND_UTIL interaction term is positive (though not significant), and thus there is no evidence that lower utilization detracts from the stronger forward demand environment enjoyed by private firms.

C. Investment Method

A concern with these results might be 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 NPV of investment at these times is not necessarily higher. Could there be systematic variation in investment costs that are correlated with demand shocks? Capacity increases come in 2 forms: new construction (brownfield or greenfield) and asset purchases. It would be reasonable to expect price negotiations for asset purchases to take into account future cash flow prospects. If all parties believe that future

[9]Regressions including interaction terms should include all constituent terms. FIRM_SIZE alone is not present in Table 4 or later regressions because it (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. I am comfortable that 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 PRIV should be interpreted cautiously; it is identified only by the firms in the sample that change public/private status.

[10]Own firm capacity utilization is an alternative specification, but the data are unavailable. Lagged capacity utilization ($t-1$) is used instead of contemporaneous (t) because new capacity, though small, enters directly into the capacity utilization calculation for year t, potentially contaminating the direction of causality.

demand will be high, buyers will pay more for assets. Similarly, perhaps all firms correctly anticipate downturns and price accordingly. This introduces a potential problem with interpreting the prior results. Public firms appear more inclined than private firms to increase capacity when a negative demand shock is poised to strike. But this may actually be optimal if assets can be acquired at fire sale prices. Indeed, Pulvino (1998) finds that less financially constrained airlines take advantage of distressed airlines by purchasing their planes at discounted prices.

Organic brownfield and greenfield construction costs, however, are less likely to be correlated with commodity chemical cycles; labor and materials costs for a new factory should not be driven by sodium chlorate demand.[11] So, by examining only build decisions, the potential influence of investment costs is mitigated. In Table 5, I present separate results for capacity increases via construction and via acquisition. Columns 1 and 2 look at build decisions separately for public and private firms, respectively, and show results that mimic the results in Table 4; public firm construction is mistimed. Column 3 adds controls and the interaction term and shows that when building new capacity, private firm timing is better: the PRIV × DEM_SHK variable is positive, though only significant at the 10% level. Splitting expansion observations between 2 regressions reduces power relative to Table 4. This provides some comfort that the cost of new capacity is not

TABLE 5

Method of Capacity Increase: Construction vs. Acquisition

Table 5 presents estimates from OLS panel regressions evaluating capacity increase decisions by method of increase. The dependent variable in columns 1–3 and 7, BUILD, is equal to 1 if firm f realized at least a 5% increase in capacity through either internal greenfield or brownfield construction for chemical c in year t, and 0 otherwise. The dependent variable in columns 4–6, ACQUIRE, is equal to 1 if a capacity increase in year t was realized via an acquisition from the opposite incorporation type (e.g., equals 1 if a private firm acquires capacity from a public firm), and 0 otherwise. The sum of the BUILD and ACQUIRE variables equals the dependent variable in Table 4 for the corresponding samples. In regression 7, the sample consists only of capacity increase events (i.e., internal expansions and acquisitions). The independent variables are as defined in Table 4. 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. * and ** indicate significance at the 10% and 5% levels, respectively.

	Firms in Sample						
	Public	Private	All	Public	Private	All	All (Increases)
	BUILD	BUILD	BUILD	ACQUIRE	ACQUIRE	ACQUIRE	BUILD
Dependent Variable	1	2	3	4	5	6	7
$DEM\_SHK_{t,t+1}$	−0.017*	0.015	−0.087*	−0.009	0.008	−0.027	
	(−1.93)	(0.89)	(−1.87)	(−1.33)	(0.47)	(−0.77)	
IND_UTIL_{t-1}			−0.021			0.732**	−2.37
			(−0.05)			(2.28)	(−0.94)
PRIV × $DEM\_SHK_{t,t+1}$			0.040*			0.028	
			(1.87)			(1.37)	
PRIV × IND_UTIL_{t-1}			0.219			−0.188	2.27**
			(1.10)			(−1.33)	(2.09)
FIRM_SIZE × $DEM\_SHK_{t,t+1}$			0.007			0.002	
			(1.49)			(0.66)	
FIRM_SIZE × IND_UTIL_{t-1}			−0.009			−0.064**	0.249
			(−0.20)			(−2.05)	(0.92)
PRIV			−0.245			0.128	−1.67*
			(−1.07)			(1.03)	(−1.69)
No. of obs.	1,386	578	1,815	1,386	578	1,815	202

[11] I explicitly try to control for construction costs in a robustness check in Section V.C.

a hidden factor affecting results on relative investment timing efficiency. Columns 4–6 break out capacity additions through acquisition. The results are directionally similar, though, again, potentially more difficult to interpret without transaction prices.

It is interesting to note that the coefficient on PRIV × IND_UTIL changes sign between the build and acquisition regressions. Controlling for demand shocks, higher industry utilization increases private building while depressing private buying, relative to public firms. Column 7 of Table 5 explores this further. Conditional on increasing capacity, how are public and private firms choosing to execute their strategy? The sample in column 7 includes only expansion events: public and private, build and buy. The dependent variable is an indicator equal to 1 when the expansion is via construction. The positive and significant coefficient on PRIV × IND_UTIL confirms that tight industry capacity leads private firms, more so than public firms, to favor organic growth as the method of expansion. If plants are cheaper when they are not in heavy use, and if construction costs are relatively more constant, buying when industry plants are empty and building when they are full may be a smart strategy, given a desire to grow.

D. Positive vs. 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 6, I rerun this paper's primary regression. In columns 1–4, however, DEM_SHK now only captures positive shocks; it equals 1 if price and quantity both increase, and 0 otherwise. Similarly, columns 5–8 use a new DEM_SHK variable that equals (positive) 1 if price and quantity both decrease, and 0 otherwise. The PRIV × DEM_SHK interaction term coefficients for the first 4 regressions isolating positive demand shocks are positive but generally not significant. Regressions 5–8 show that private firms are, however, significantly less likely than public firms to increase capacity as a negative demand shock hits. Thus, the difference in private versus public investment appears to get its bite from avoiding bad investments. Focusing on organic growth in columns 3 and 7, the private firm disparity is similar across both positive and negative shocks. The difference between the direction of shocks is most apparent when looking at acquisitions. Column 4 shows that there is little difference in the acquisition response of public and private firms to positive shocks (PRIV × DEM_SHK coefficient of only 0.007). But, before a negative shock (column 8), private firms restrain themselves more from purchasing. One possible interpretation is that public firms, armed with deeper pockets, take advantage of private competitors by scooping up their assets at cheap prices, which anticipate the coming storm. This explanation seems inconsistent with public firms also building more capacity prior to downturns (column 7), though acquisitions are not subject to time-to-build delays; thus, the future demand environment should be more easily predictable. An alternative interpretation may be that private firms with better information (or the will to act on it) sell plants to public firms before a negative demand shock hits and reduces asset values.

TABLE 6

Positive vs. Negative Demand Shocks

Table 6 presents estimates from regressions examining investment response to positive and negative demand shocks. The dependent variable is noted by capacity increase type: equal to 1 if the firm increased capacity in year t by at least 5% (ALL), only via construction (BUILD), or by acquisition (ACQUIRE). DEM_SHK in Positive shock columns (1–4) is equal to 1 if chemical price and quantity demanded both increase from year t to year $t+1$, and 0 otherwise; in Negative shock columns (5–8), this variable equals 1 only if price and quantity both decline. The remaining independent variables are as defined in Table 4. 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. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	Positive Shock				Negative Shock			
	ALL	ALL	BUILD	ACQUIRE	ALL	ALL	BUILD	ACQUIRE
	1	2	3	4	5	6	7	8
$DEM\_SHK_{t,t+1}$	−0.040**	−0.114	−0.109	−0.004	0.027	0.177**	0.117*	0.060
	(−2.17)	(−0.92)	(−1.39)	(−0.06)	(1.38)	(2.14)	(1.69)	(1.13)
IND_UTIL_{t-1}		0.794	0.024	0.770**		0.705	−0.009	0.713**
		(1.47)	(0.06)	(2.41)		(1.28)	(−0.02)	(2.18)
$PRIV \times DEM\_SHK_{t,t+1}$	0.045	0.065	0.058*	0.007	−0.076**	−0.104***	−0.046	−0.058**
	(1.01)	(1.04)	(1.71)	(0.18)	(−2.30)	(−2.97)	(−1.51)	(−2.06)
$PRIV \times IND\_UTIL_{t-1}$		−0.014	0.197	−0.211		0.036	0.211	−0.175
		(−0.06)	(0.98)	(−1.51)		(0.14)	(1.06)	(−1.22)
$FIRM\_SIZE \times DEM\_SHK_{t,t+1}$		0.008	0.007	0.001		−0.017*	−0.012	−0.005
		(0.59)	(0.85)	(0.09)		(−1.94)	(−1.58)	(−0.97)
$FIRM\_SIZE \times IND\_UTIL_{t-1}$		−0.082	−0.014	−0.068**		−0.071	−0.008	−0.063**
		(−1.46)	(−0.33)	(−2.19)		(−1.23)	(−0.18)	(−1.97)
PRIV	0.008	−0.089	−0.236	0.147	0.024	−0.103	−0.229	0.126
	(0.09)	(−0.35)	(−1.03)	(1.19)	(0.28)	(−0.41)	(−1.00)	(1.01)
No. of obs.	1,964	1,815	1,815	1,815	1,964	1,815	1,815	1,815

V. Mechanisms

This section discusses potential channels driving differences between public and private firms. I focus first on how time-to-build delays and potential overextrapolation of past demand shocks can interact with access to capital. Second, I find support for weaker incentives from separation of ownership and control driving sub-optimal investment decisions. I then test additional stories and finish with robustness checks of the main results.

A. Overextrapolation of Past Demand

Table 4 shows that the average capacity increase arrives when demand is weakening, not strengthening. This is consistent with the Greenwood and Hanson (2015) finding that firms in cyclical, commodity industries with time-to-build delays can make investment mistakes. In particular, firms overinvest in new ships when current demand is strong partially because they overextrapolate demand shocks. This raises 2 questions. Is there evidence that chemical firms do indeed invest in response to past shocks that may not persist? And is there reason to think private firms may be less susceptible to this behavior?

In Table 7, I incorporate a lagged demand shock, from 2 years to 1 year before capacity comes online. As capacity construction requires 1–2 years, this is the window of past performance that precedes decisions to build new capacity that arrives during year 0. Column 1 simply regresses capacity increases on this past demand shock. The coefficient is essentially 0. When it comes to adding capacity, firms will build when demand is high, not low. In addition, capacity expansion is a rare event (in 9% of firm-years, according to Table 3).

TABLE 7
Investment Response to Past Shocks

Table 7 presents estimates from regressions examining investment response to past demand shocks. The dependent variable is noted by capacity increase type: equal to 1 if the firm increased capacity in year t by at least 5% (ALL), only via construction (BUILD), or only via acquisition (ACQUIRE). DEM_SHK$_{t-2,t-1}$ is equal to +1 if chemical price and quantity consumed both increase from year $t-2$ to year $t-1$, 0 if price and quantity move in opposite directions, and −1 if both decline. BIGP_SHK$_{t-2,t-1}$ is equal to +1 if chemical price and quantity consumed both increase by at least 4% from year $t-2$ to year $t-1$, and 0 otherwise. The remaining independent variables are as defined in Table 4. 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. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	ALL	ALL	ACQUIRE	BUILD	BUILD	BUILD
	1	2	3	4	5	6
DEM_SHK$_{t-2,t-1}$	0.008 (0.62)					
BIGP_SHK$_{t-2,t-1}$		0.094*** (2.66)	0.018 (0.92)	0.077** (2.14)	0.101** (2.37)	0.284* (1.84)
PRIV × BIGP_SHK$_{t-2,t-1}$					−0.073 (−1.42)	−0.117* (−1.89)
FIRM_SIZE × BIGP_SHK$_{t-2,t-1}$						−0.020 (−1.20)
PRIV					−0.031 (−0.34)	−0.028 (−0.31)
No. of obs.	1,964	1,964	1,964	1,964	1,964	1,964

Therefore, to sharpen the test, I limit past demand shocks to those that are big, positive shocks (BIGP_SHK). "Big" here is defined as 4% growth in both demand and price. In unreported results, I also tested 2% thresholds, which give coefficient magnitudes half as large as the 4% threshold. Column 2 shows that firms indeed increase capacity after they see a large, positive shock. Splitting investment by expansion type, columns 3 and 4 show that this is driven by construction of new capacity.

Do public and private firms respond equally? Columns 5 and 6 show that private firms appear less likely to invest in response to previous shocks. The coefficient on PRIV × BIGP_SHK is −0.117, significant at the 10% level, in column 6. This is consistent with Gilje and Taillard (2016) who find that private firms are 60% less likely than public firms to drill wells in response to past positive changes in natural gas prices. Notably, they do not find that public firm gas wells subsequently underperform. A key difference in their setting, however, is that the unit of investment is much smaller. Drilling a gas well happens very quickly (roughly 1 month), and drilling is frequent: the mean logarithm of the number of wells drilled in a given year is 3.58 for public firms. Time-to-build delays are non-existent.

Public chemical firms are thus more responsive than private firms to *past* positive shocks, which, looking at Table 4, do not persist and even show signs of reversal by the time capacity actually comes online. Gilje and Taillard (2016) attribute greater public firm response to their having greater access to capital. If firms in cyclical, time-to-build industries are subject to behavioral biases, as in Greenwood and Hanson (2015), a public firm's easier access to capital may exacerbate this bias.

B. Incentive Alignment

A key cost of public ownership is the separation of ownership and control (Jensen (1989)). I examine whether better aligned incentives lead to better investment performance. It is commonly thought that private firms have concentrated ownership structures, but this is false. Michaely and Roberts (2012) note that "ownership structures of private firms exhibit far greater diversity than those of public firms." They classify a significant share of private firms as "Private Dispersed," firms with ownership structures similar to public firms. Among private firms, however, alignment of incentives is the particular focus of PE firms, and there is evidence that this can lead to better firm outcomes. Kaplan (1989) finds that LBOs have better operating results and cash flow than public firms in the same industry in the 3 years after the buyout. He attributes the improvements to better incentives present in the PE structure; PE firms claim to target slack management with poor incentives. Davis et al. (2014) find improvements in total factor productivity following PE buyouts, and Cohn et al. (2017) and Bernstein and Sheen (2016) show that PE firm targets appear to exhibit superior operational skill in the context of workplace safety and restaurant management. Bargeron et al. (2008) find that private operating companies pay lower acquisition premiums than public firms, 40.9%–46.5%. But PE firms pay the lowest premiums of all, only 28.5%.

Because of PE's explicit focus on aligning incentives, private firms that are controlled by PE firms may be different from private firms, on average, since many private firms are structured like public firms. I, therefore, separate the private firms into precisely these 2 groups. Seven private firms are run by PE, as determined by literature searches and studying company history. Table 8 looks first, in columns 1–3, at the demand environment following public, private non-PE, and PE firm capacity expansion. There is a clear hierarchy; public firms, as before, appear to mistime capacity. Private non-PE firms face a neutral demand environment, while PE firms are positively associated with DEM_SHK. Columns 4–6 use interaction specifications with subsets of firms to examine whether these differences are statistically significant. The coefficient of 0.170 on PE $\times$ DEM_SHK in column 5 measures the difference in investment between public firms and PE firms and shows that PE firms bring capacity online into more favorable conditions than public firms. Column 6 includes only and all private firms in the sample. The interaction term PE $\times$ DEM_SHK is positive and significant at the 5% level, suggesting PE firms are more sensitive to demand shocks than "generic" private firms. If private firms overall are less subject to agency concerns than public firms because of closer ties between ownership and control, PE 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.

Better aligned incentives and operational skill could result in mitigating demand extrapolation bias, resulting in better performance once capacity comes online. Firms, of course, also attempt to predict future demand shocks, and strong incentives may improve this ability. Variation in skill exists; practitioner evidence suggests that "managers also need to be able to project demand more accurately—a capability often little developed in chemical companies. Investing relatively small sums to understand the dynamics of demand for chemical

TABLE 8
PE Firm Investment

Table 8 presents regressions that distinguish between different types of private firms. Regression samples are formed from subsets of 3 groups: all public firms, private firms that are not PE run, and PE-run firms. The dependent variable in these OLS panel regressions is equal to 1 if firm *f* realized an increase in capacity of at least 5% for chemical *c* in year *t*, and 0 otherwise. PRIV_NONPE is a dummy variable equal to 1 for private, non-PE firms. PE is a dummy variable equal to 1 for PE-owned firms. All other variables are as defined in Table 4. All regressions include product, year, and firm fixed effects. Standard errors are adjusted for heteroskedasticity and clustered by firm. *t*-statistics are in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Sample	Public	Private Non-PE	PE	Public & Private Non-PE	Public & PE	PE & Private Non-PE
	1	2	3	4	5	6
DEM_SHK$_{t,t+1}$	−0.026**	0.010	0.134*	−0.126**	−0.138**	−0.044
	(−2.50)	(0.45)	(1.87)	(−2.00)	(−2.38)	(−0.58)
IND_UTIL$_{t-1}$				0.826	1.284**	0.382
				(1.44)	(2.30)	(0.44)
PRIV_NONPE × DEM_SHK$_{t,t+1}$				0.061*		
				(1.95)		
PRIV_NONPE × IND_UTIL$_{t-1}$				0.005		
				(0.02)		
PE × DEM_SHK$_{t,t+1}$					0.170***	0.124**
					(3.20)	(1.99)
PE × IND_UTIL$_{t-1}$					−0.084	−0.538
					(−0.08)	(−0.52)
FIRM_SIZE × DEM_SHK$_{t,t+1}$				0.011	0.012**	0.008
				(1.64)	(2.04)	(0.65)
FIRM_SIZE × IND_UTIL$_{t-1}$				−0.085	−0.131**	−0.029
				(−1.42)	(−2.30)	(−0.29)
PRIV_NONPE				−0.071		
				(−0.28)		
PE					−0.070	
					(−0.07)	
No. of obs.	1,386	525	53	1,766	1,333	531

products, such as price elasticity with competing materials, can go a long way toward reducing profit volatility in a cyclical environment."[12]

C. Alternative Explanations and Robustness Checks

A vast literature suggests that internal capital markets may distort investment allocation (see, e.g., Lang and Stulz (1994), Berger and Ofek (1995), and Rajan, Servaes, and Zingales (2000)). 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. But size and scope may not be related. The bulk of internal capital market research focuses on unrelated diversification. Unfortunately, the presence of non-chemical business lines is not readily available for my sample of 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.

[12] *McKinsey Quarterly*, "Wooing Investors to Prevent Cyclicality," 1998.

The *Directory of Chemical Producers* provides, in addition to capacity data, a comprehensive profile of the U.S. chemical operations of each firm. To study the impact of within-division business scope, I record the number of chemical divisions operated by each firm by averaging totals tallied at 4 points in time. Koch Industries, for example, has 4 divisions in 1995 according to SRI: Koch Hydrocarbon, Koch Nitrogen, Koch Refining, and Koch Sulfur Products. The number of divisions (DIVS) is a measure of the degree to which firms are either focused or spread across many chemical products. The median firm has 2 chemical divisions, and the number of divisions ranges from 1 to 14. The correlation between chemical divisions and overall firm size (employees) is 0.52. Column 1 in Table 9 presents estimates from regressing the capacity increase indicator variable EXPAND on DEM_SHK and its private firm interaction, this time including the interaction term DIVS $\times$ DEM_SHK to capture the impact of this scope variable on investment efficiency.[13] The PRIV $\times$ DEM_SHK coefficient is still significant at the 5% level with a *t*-statistic of 2.15. Turning to the scope variable itself, it is notable that the DIVS $\times$ IND_UTIL interaction is negative with a *t*-statistic of -1.61, suggesting weakly that producing a diverse portfolio of chemicals makes investment in a given chemical less sensitive to levels of existing capacity. Internal needs and captive use may take priority over the external market environment, a result consistent with the findings of Mullainathan and Scharfstein (2001).

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. They find 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. Therefore, I compute a new variable, SHARE, which equals the capacity share of firm f in chemical product c at the start of year t. Market share and firm size are not necessarily related; a firm could be very small but focused in just 1 chemical product with large market share. The correlations between capacity share and size (employees) range from -0.12 in chlorine to 0.72 in aluminum. In column 2 of Table 9, I interact SHARE with the demand shock and capacity utilization variables and add them to the baseline regression. This regression loses some power: a new entrant, by definition, has 0 market share. Hence, I only include and examine increases undertaken by incumbents.[14] The coefficient on the key PRIV $\times$ DEM_SHK variable is slightly smaller but still significant. The market share interaction variables are directionally consistent with the results in Gilbert and Lieberman (1987).

A third concern is that export opportunities and import threats may distort the interpretation of changes in price and demand. Suppose a supply shock local to the United States raises production costs for U.S. producers and, consequently, the prices they must charge. Normally, this would lower U.S. quantity demanded.

[13] As I use an average number of divisions for all of a firm's years, the DIVS term drops out of the regression in the presence of firm fixed effects.

[14] Considering increases by only existing players alleviates concern over another alternate story: Does expectation of a positive demand shock attract entry from new, startup firms, which, early in their life cycle, are likely to be private?

TABLE 9
Seven Robustness Tests

Table 9 presents results that modify a variable from, or add a variable to, earlier regressions as robustness checks. The dependent variable EXPAND is equal to 1 if firm *f* realized an increase in capacity of at least 5% for chemical *c* in year *t*, and 0 otherwise. In column 4, the dependent variable CAP_CHG% is equal to the change in capacity for firm *f* in chemical *c* in year *t*, divided by total industry capacity in year *t*. In column 7, the dependent variable is BUILD, equal to 1 if the firm increased capacity in year *t* by at least 5% via construction only. DEM_SHK is a variable equal to +1 if chemical price and U.S. chemical quantity consumed both increase from year *t* to year $t+1$, 0 if price and quantity move in opposite directions, and −1 if price and quantity both decline. DEM_SHK_NOREV equals +1 if price and quantity both increase from year *t* to year $t+1$, except if price and quantity both then decrease from year $t+1$ to year $t+2$. DEM_SHK_BIG is similar to DEM_SHK, except price and quantity must both increase by at least 2%, or decrease by 2%, for the variable to equal +1 or −1, respectively. OUT_SHK is similar to DEM_SHK with quantity consumed (demand) replaced by U.S. quantity produced (output). SHARE is the capacity share of the firm in each chemical each year. DIVS is the average number of separate U.S. chemical divisions of the firm over all years as reported by SRI Consulting. COST is the annual building construction cost index from the *Engineering News-Record* deflated by the producer price index. All other variables are as defined in Table 4. Firm size controls include FIRM_SIZE (employees) interacted with the same variables interacted with PRIV in each regression. All regressions include product, year, and firm fixed effects, except column 7, which omits year effects because COST is the same for all firms each year. Standard errors are adjusted for heteroskedasticity and are clustered by firm. *t*-statistics are in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	EXPAND	EXPAND	EXPAND	CAP_CHG%	EXPAND	EXPAND	BUILD
Dependent Variable	1	2	3	4	5	6	7
$\text{DEM\_SHK}_{t,t+1}$	−0.115*	−0.096*		−0.013***			−0.091**
	(−1.82)	(−1.79)		(−2.91)			(−2.05)
$\text{DEM\_SHK\_NOREV}_{t,t+1}$					−0.120		
					(−1.80)		
$\text{DEM\_SHK\_BIG}_{t,t+1}$						−0.088	
						(−1.34)	
IND_UTIL_{t-1}	0.661	0.660	0.795	0.039	0.705	0.740	0.089
	(1.20)	(1.39)	(1.49)	(1.19)	(1.27)	(1.32)	(0.20)
$\text{PRIV} \times \text{DEM\_SHK}_{t,t+1}$	0.067**	0.048**		0.004**			0.038*
	(2.15)	(1.97)		(2.02)			(1.95)
$\text{PRIV} \times \text{DEM\_SHK\_NOREV}_{t,t+1}$					0.068**		
					(2.02)		
$\text{PRIV} \times \text{DEM\_SHK\_BIG}_{t,t+1}$						0.071**	
						(2.30)	
$\text{PRIV} \times \text{IND\_UTIL}_{t-1}$	−0.028	−0.094	0.027	−0.021*	0.037	0.041	0.165
	(−0.11)	(−0.47)	(0.11)	(−1.65)	(0.15)	(0.16)	(0.77)
$\text{SHARE} \times \text{DEM\_SHK}_{t,t+1}$		0.123					
		(0.99)					
$\text{SHARE} \times \text{IND\_UTIL}_{t-1}$		1.115					
		(1.54)					
SHARE		−1.163*					
		(−1.73)					
$\text{OUT\_SHK}_{t,t+1}$			−0.050				
			(−0.88)				
$\text{PRIV} \times \text{OUT\_SHK}_{t,t+1}$			0.054**				
			(1.99)				
$\text{DIVS} \times \text{DEM\_SHK}_{t,t+1}$	−0.0004						
	(−0.09)						
$\text{DIVS} \times \text{IND\_UTIL}_{t-1}$	−0.053						
	(−1.61)						
COST_{t-1}							0.048
							(0.19)
$\text{PRIV} \times \text{COST}_{t-1}$							−0.061
							(−0.49)
PRIV	−0.064	0.031	−0.113	0.012	−0.123	−0.122	−0.042
	(−0.25)	(0.15)	(−0.46)	(0.76)	(−0.48)	(−0.48)	(−0.10)
Firm size controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	1,815	1,815	1,815	1,815	1,815	1,815	1,815

If cheaper imports become available, however, U.S. consumption could rise despite the higher prices charged by U.S. sellers. What appears to be a higher price and higher quantity scenario is then actually a sub-optimal time to open new U.S. capacity. Similarly, higher prices and lower U.S. consumption might actually be a good time to invest if export demand is high. To account for these possibilities, I redefine the DEM_SHK variable: I replace U.S. demand with U.S. output, which equals demand plus exports minus imports. This OUT_SHK variable equals +1 if price and output increase, −1 if they decrease, and 0 otherwise. In the cheap import scenario described previously, though quantity demanded 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. Column 3 of Table 9 shows that replacing consumption with production does not change the results, as the coefficient on PRIV × OUT_SHK is significantly positive.

Columns 4–6 of Table 9 introduce modified variable definitions to check for robustness. The dependent variable used in all regressions thus far has been a binary measure of capacity increase. In column 4, I replace this measure with simply the actual change in capacity as a percentage of total industry capacity (CAP_CHG%). I prefer the binary measure because the size of capacity addition can be dictated by technological factors or, in the case of acquisitions, by the size of available targets. But it is worth checking whether public firms, though apparently investing more often at the wrong time, perhaps save their largest investments for the right time. This is not the case, as the coefficient on PRIV × DEM_SHK is still positive.

Capacity is a long-lived investment. In column 5, I check whether short-term shocks drive results. Beginning with the baseline specification from Table 4, I replace DEM_SHK with a new variable, DEM_SHK_NOREV, in which I eliminate all shocks in year t that are reversed in year $t+1$. Thus, the remaining shocks exhibit persistence beyond 1 year. The coefficient on PRIV × DEM_SHK_NOREV is still positive (0.068) and significant.

A size threshold is enforced on shocks in column 6: Is there a differential response when it matters most? DEM_SHK_BIG equals +1 when price and quantity both increase by at least 2% (as opposed to simply increasing). Similarly, negative shocks are only recorded when price and quantity both fall by 2%. This screen weeds out one-third of the shocks in DEM_SHK. The private interaction term is stronger than before in the resulting regression.

Last, I address the concern that expansion costs may impact the attractiveness of new capacity by examining costs directly. As discussed in Section III, the state of the macro economy is a key demand driver for the chemicals in this study. Agricultural demand for fertilizer, the pulp and paper industry, and a myriad of other uses also drive demand. If the general economy and these industries are doing well, perhaps there is also upward pressure on chemical production costs. To broadly capture expansion costs, I use the building cost index published by the *Engineering News-Record*, a publication that has tracked these costs since 1915. The index is meant to capture the yearly change in general construction costs for structures. Although it is not chemical industry specific, it should capture trends in labor and materials costs. I deflate the index using a producer price index and call this variable COST. In unreported results, regressing capacity construction on

COST in year $t-1$ (the primary year construction occurs) generates a directionally negative coefficient, meaning firm building takes place in lower cost years. Column 7 includes a full specification and shows that public and private firms face a similar building cost environment, as the coefficient on the PRIV $\times$ COST interaction is close to 0.

VI. Conclusion

Using a data set that allows me equal visibility into the decisions of public and private firms in the commodity chemical industry, I argue that private firms invest differently than public firms. Specifically, private firm capacity increases are more likely to coincide with positive demand shocks and avoid negative demand shocks. Among public firms, this correlation between investment and demand shocks is associated with higher profitability. In addition, conditional on expanding, private firms are more likely to strategically choose to build when industry utilization is high and acquire when utilization is low.

I suggest 2 channels that may drive these results. In cyclical commodity industries with time-to-build delays, relying on past outcomes to drive future investment can result in mistimed capacity. Public firms respond more than private firms to prior demand shocks. I also present evidence that stronger managerial incentives from a tighter linkage between ownership and control, a hallmark of PE-run private firms in particular, is a possible mechanism.

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