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RESOLVING THE COMMITMENT VERSUS FLEXIBILITY TRADE-OFF: THE ROLE OF RESOURCE ACCUMULATION LAGS

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We examine how time-consuming resource accumulation influences the classic strategy trade-off between commitment and flexibility. In particular, using 1975–95 data from the worldwide petrochemical industry, we study the impact of new plants' time-to-build on firms' decisions to invest under uncertainty. Our results suggest a nontrivial positive effect of resource accumulation lags on investment. Contradicting conventional wisdom, we show that competition may be fiercer in industries in which firms accumulate resources more slowly and that uncertainty is not always a disincentive for investment. The robustness of these results is only diminished for extremely long resource accumulation lags.

In December 2000, the management of Airbus announced its plans to spend $11.9 billion to launch a new super jumbo jet, the A380. This commitment entailed a ten-year investment of financial and organizational resources in the long-haul high-capacity aircraft market, a market that is big enough to allow only one firm to make a profit. The credible commitment to the A380 made by Airbus preempted Boeing from competing in the super jumbo jet market. Indeed, a few months later, Boeing's management announced that it would cancel a project to build a high-capacity plane, a "stretched" version of its popular B747. Airbus management's decision was made at a time of substantial uncertainty about the future of air travel and the commercial viability of a super jumbo jet. The company could have remained flexible by waiting until the market and technological investment conditions grew more certain, but it would have risked being preempted by Boeing (Besanko, Dranove, Shanley, & Schaefer, 2004; Esty & Ghemawat, 2002).

This high-profile example illustrates the fundamental strategic trade-off between commitment and flexibility that managers face when deploying firm resources to establish product-market positions. Commitment and flexibility lie on opposite ends of a firm's investment spectrum, and scholars have historically been divided as to which of the two strategies is the main driver of investment value. On the one side, Stigler's early contribution (1939) and recent research on real options (Adner & Levinthal, 2004; Dixit & Pindyck, 1994; Kogut, 1991; Kulatilaka & Perotti, 1998; Luehrman, 1998; McGrath, 1997, 1999; McGrath, Ferrier, & Mendelow, 2004; Trigeorgis, 1996) have largely emphasized the value of flexibility. As demand or technical uncertainty increases, keeping options open by postponing strategic investments and waiting for uncertainty to subside may be the optimal strategy. On the other side, work coming from mainstream economics and strategy has stressed the value of inflexibility (Dixit & Pindyck, 1994; Fudenberg & Tirole, 1983; Ghemawat, 1991; Gilbert & Lieberman, 1987; Lieberman, 1987a; Spence, 1979). The argument in this stream of research is that making early irreversible commitments may secure future market space and discourage rivals from investing; the inflexibility of such commitment has value by shaping rivals' future behavior. Given these two

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opposing views, it is often not obvious which of the two drivers—flexibility or inflexibility—will ultimately prevail in imperfectly competitive and uncertain business situations.

Interestingly, this debate has overlooked the impact of resource accumulation on the trade-off between commitment and flexibility, despite the substantial attention resource accumulation has received in the resource-based view literature (e.g., Barney, 1991; Dierickx & Cool, 1989). In our initial example, would Airbus management have committed so early to the risky A380 project if aircraft development took six months instead of ten years?

Intuitively, the time required to accumulate resources should impact the relative attractiveness of flexible strategies. The more time it takes to accumulate resources prior to entry into a market, the more slowly firms will enter that market. Thus, if managers decide not to invest ex ante and there is demand ex post, their firms will have relinquished profits for the period in which they were out of the market. In such a circumstance, waiting or postponing investments in order to remain flexible becomes a less valuable option. Indeed, longer periods of resource accumulation may offset uncertainty, leading more firms to invest earlier in new market opportunities. Thus, contrary to conventional wisdom, competition may be fiercer in industries in which firms accumulate resources more slowly. Certainly this view is consistent with systematic empirical evidence of chronic excess supply in industries such as commercial real estate, electricity generation, and bulk chemicals, in each of which it takes a long time to accumulate resources and bring investments on line (Ghemawat, 1984; Henderson & Cool, 2003b; Kling & McCue, 1987; MacRae, 1989).

In this study, we examined the role of resource accumulation in an effort to better understand the commitment versus flexibility trade-off. In particular, we looked at how the time-consuming nature of resource accumulation (one of the most fundamental principles of the resource-based view) impacts the decision to invest and the value of the "option to wait." By doing so, we directly extend the existing literature on real options and strategic commitment (for a review, see Besanko et al. [2004: 232–258]).

The empirical setting is the global petrochemical industry during the period 1975–95. In this industry, managers must make frequent, important decisions about whether to invest in plants to expand capacity in the midst of demand uncertainty. As a result, petrochemical firms are particularly prone to the commitment-flexibility dilemma. Furthermore, the time it takes to plan and bring investments (such as new plants) on line is publicly reported and varies substantially over regions and product categories.

THEORY AND HYPOTHESIS DEVELOPMENT

Resource accumulation is a central tenet of the resource-based view of the firm. According to this view, a firm's sustainable competitive advantage stems not from privileged product-market positions, but from valuable and rare firm-specific resources deployed to support those product-market positions (Barney, 1991). These firm-specific resources cannot be bought on strategic factor markets; they must be internally accumulated by firms *over time* (Barney, 1986; Dierickx & Cool, 1989; Grant, 1991; Peteraf, 1993; Rumelt, 1984). For example, to implement product-market strategies, firms need employees with firm-specific skills and specialized labor that cannot be rented on the market but have to be developed through on-the-job learning and training (e.g., Schroeder, Bates, & Junttila, 2002).

The period of sustainability of a firm's competitive advantage depends on the extent to which these firm-specific resources are difficult for competitors to imitate. Rivals' attempts to catch up by spending money to develop a strategic resource quickly are often unsuccessful because of time compression diseconomies, resource "stickiness," causal ambiguity, or lack of complementary resources (Barney, 1991; Dierickx & Cool, 1989; Lippman & Rumelt, 1982; Mishina, Pollock, & Porac, 2004; Reed & DeFillippi, 1990).[1] These barriers to imitation lead to extensive periods of resource accumulation, which in turn sustain competitive advantage (Cohen, Nelson, & Walsh, 2000; Lieberman & Montgomery, 1988, 1998).

In summary, the time firms take to internally accumulate firm-specific resources to follow prod-

[1] Time compression diseconomies imply that speeding up resource accumulation more than proportionately increases costs (Mansfield, 1971; Pacheco-de-Almeida & Zemsky, 2007; Scherer, 1967). Preliminary estimates of time compression diseconomies have suggested that a 1 percent reduction in the time taken to develop a resource may inflate development costs up to 2 percent (Graves, 1989). Resource accumulation may also slow down with resource stickiness (Mishina, Pollock, & Porac, 2004; Penrose, 1959; Szulanski, 2003). If resources are sticky, their specialized nature makes them less useful if the task at hand changes. Therefore, firms cannot leverage their existing resource bases and quickly convert resource slack to alternative uses. In other words, adjusting an organization's stocks of sticky factors takes time.

uct-market strategies is central to the field of strategy and to the ex post sustainability of a firm's competitive advantage. Yet understanding of how *time-consuming* resource accumulation affects firms' ex ante strategic decisions, in particular investment *timing*, is much more limited. We focus on this question in this section, and begin by defining resource accumulation lags.

Resource Accumulation Lags

We define a *resource accumulation lag* as the time a firm takes, on average, to accumulate the resources to produce one unit of output in a product-market of interest.[2] There are two reasons to adopt this functional definition of resource accumulation lags. First, it links internal resource development to external product-market positioning, answering recent calls in the resource-based view literature for an integrated analysis of resources and products (Barney, 2001; Priem & Butler, 2001a, 2001b). Second, the definition obviates the measurement problem associated with most resource accumulation processes: their ongoing, unstructured, intangible, and seldom empirically observable nature (Hall, 1992; Itami, 1987; Villalonga, 2004). The accumulation of resources *with the purpose of producing a certain quantity of output in a product-market* tends to be limited in time, carefully planned, and often externally visible (Cool, Almeida Costa, & Dierickx, 2002; Dierickx & Cool, 1994). For example, investments in new production facilities are externally visible because they often require a substantial commitment of both physical and intangible resources to an industry and are often indicative of new market entry (e.g., Lowe, 1979). The case in point in this article is the petrochemical industry, where all firms' investments in new plants are systematically reported in the *Oil and Gas Journal* (*OGJ*), the industry's main trade journal.

The *OGJ* follows stage-by-stage the development of every plant construction project. It also includes information on delayed, suspended, and abandoned expansions. Investments in new chemical production facilities usually undergo four main phases: study, planning, engineering, and construction. According to the *OGJ*, the first two phases (study and planning) capture the accumulation of intangible resources such as managerial and technological knowledge, demand information, competitive intelligence about rivals' planned investments, government support, and employee operational expertise. This capital investment in intangibles represents the investment in organizational capabilities (Maritan, 2001; Schroeder et al., 2002). The third and fourth phases of investment in new production facilities (engineering and construction) pertain mostly to the accumulation of physical resources immediately prior to production (e.g., equipment and plant facilities). Firms deploy all these intangible and physical resources accumulated during the investment process to product-markets when production and market operations commence. Table 1 provides an overview of each of these plant expansion phases and their average length based on information collected by the *OGJ* for plants built in the United States, Europe, and Japan during the period 1975 to 1995.

In most manufacturing industries, the time firms take to plan and build new production facilities is empirically observable and clearly defined. Frequently, it also includes the intraorganizational accumulation of both intangible and physical resources required to enter and compete in a certain market. Therefore, the "time-to-build" of a new plant (also referred to as the "investment lag") is a good proxy for empirical measurement of resource accumulation lags.

Time-to-build is the product of multiple factors, typically including access to suppliers, governmental policies, technology and product features, and other industry structural characteristics (Porter, 1980). In prior studies, preliminary data on time-to-build has varied widely across industries (Koeva, 2000; Krainer, 1968; Mayer, 1960; Mayer & Sonenblum, 1955), ranging from two years for a new plant in the petrochemical industry (Lieberman, 1987b), to as many as ten to develop a new aircraft (Esty & Ghemawat, 2002), to almost immediate set-up in some Internet-based businesses. Koeva (2000) found that time-to-build can be as low as 13 months for simple, commodity products such as rubber and more than double that for more technologically advanced goods (e.g., 28 months for transport equipment). These results, although based on a small number of time-to-build observations per industry (five data points, on average), suggest that resource accumulation lags may differ substantially over industries.

Despite their empirical importance, resource accumulation lags have been underexamined in strategy research. Dierickx and Cool's (1989) study is probably the only seminal work that directly discusses the impact of time lags on the ex post sustainability of competitive advantage. Moreover, very little has been said about the effect of resource accumulation lags on managers' ex ante strategic

[2] We use one unit of output as an (arbitrary or normalized) point of comparison between industries.

TABLE 1
Plant Expansion Phases in the Petrochemical Industry[a]

Project Phase	Average Time to Build: Months	Percentages	Phase Description
1. Study	1.5	5	Market and competitive information analysis Financing, capital budgeting and risk management Securing government approval
2. Planning	9.1	31	Technology R&D or technology supplier selection Schematic and developed project design Preliminary schedule and permitting
3. Engineering	5.5	19	Detailed engineering and process design System specifications (electrical, mechanical, piping) Final cost estimates
4. Construction	13.3	45	Procurement, bid analysis, equipment purchase orders Material fabrication Physical construction of the plant
Total	29.4	100	

[a] Source: *Oil and Gas Journal* information on plants built in the United States, Europe, and Japan 1975–95.

decisions.[3] In particular, analyses of managers' investment *timing* decisions have not accounted for *time-consuming* resource accumulation. We now turn to this ex ante investment problem by revisiting the commitment versus flexibility debate.

Resource Accumulation Lags Favoring Commitment

Intuitive interpretations of extant theory would suggest that resource accumulation lags decrease the likelihood of commitment. According to resource-based and organization theory, such lags slow down imitation and increase inertia, which hinders firms' investments in new market opportunities (Barney, 1991; Dierickx & Cool, 1989; Hannan & Freeman, 1984; Hannan, Polos, & Carroll, 2004). According to the real options literature, uncertainty will exacerbate the negative effect of time lags on investment (e.g., Trigeorgis, 1996). The general real options perspective is that longer investment projects are inherently highly uncertain (i.e., have a high probability of producing extreme future market outcomes), which discourages firm investment. However, in this subsection we contest each of these two conventional views one at a time, starting with the resource-based/organization theory perspective. Given the small amount of research to be found in the strategy and management literatures on resource accumulation lags and investment timing, we draw substantially on the financial economics literature to complement our understanding of firms' investment timing decisions.

Two theoretical modeling papers have studied the impact of resource accumulation on the relative benefits of commitment and flexibility (Bar-Ilan & Strange, 1996; Pacheco-de-Almeida & Zemsky, 2003). Their findings suggest that time-consuming resource accumulation has *two* fundamental implications for managers' investment decisions that are robust to alternative theoretical model specifications (e.g., different types of industries and varying degrees of strategic interaction between firms).

First, in industries in which it takes a long time to accumulate resources, managers are unable to quickly adjust their strategies to new market and competitive information. When making an investment decision, managers weigh the benefits and

[3] Exceptions include prior work on strategic flexibility, which is defined as the capability to *quickly* respond to changing competitive conditions (Hitt, Keats, & DeMarie, 1998; Shimizu & Hitt, 2004). On a similar note, other authors have "referred to this ability to [quickly] achieve new forms of competitive advantage as 'dynamic capabilities'. . . . The term 'dynamic' refers to the capacity to renew competences so as to achieve congruence with the changing business environment . . . required when time-to-market and timing are critical, the rate of technological change is rapid, and the nature of future competition and markets difficult to determine" (Teece, Pisano, & Shuen, 1997: 515). One could argue that the ability to rapidly accumulate resources is one type of dynamic capability.

costs of early investment. The opportunity cost of waiting is the forgone income from a project, which depends on the price the product commands during the delay. If a firm can enter a market immediately in situations of strong demand or high prices, the opportunity cost of waiting to invest is limited. However, if there is an interval of time between a decision to invest and receipt of a project's first revenues, the opportunity cost of postponing investment can be substantially higher, including the profits forsaken while the firm is accumulating resources to enter the desired market (Bar-Ilan & Strange, 1996; Pacheco-de-Almeida & Zemsky, 2003). Indeed, long resource accumulation lags are known to create barriers to imitation and sustain competitive advantages (Barney, 1991; Dierickx & Cool, 1989). These resource accumulation lags create a grace period with mild competition and extraordinary rents for early mover firms as their late rivals struggle to catch up. If an early mover's market strategy proves to be winning (e.g., if there is market demand), a price premium is expected during the resource accumulation lag because competition and supply are low. Ultimately, the anticipation of such favorable ex post conditions, which are amplified by longer investment lags, triggers early investment.

To summarize, as resource accumulation lags increase in length under a *constant* (low or high) level of uncertainty, firms may be more likely to invest, contrary to popular wisdom. The following hypothesis expresses this main direct effect of time on the likelihood of investment:

Hypothesis 1. Ceteris paribus, resource accumulation lags have a positive effect on a firm's likelihood of investment.

Second, in industries in which resource accumulation is more time consuming, strategic investment decisions must be based on projections and forecasts for a more distant future. This requirement increases uncertainty, or the likelihood of extreme future market outcomes. However, firms also have more time to exercise the option of abandoning their investment projects; thus, their profits are better safeguarded in unfavorable market conditions. As a result, longer resource accumulation lags increase the profit potential of an investment project more than its loss potential. This relationship has been shown to increase the overall expected value of ex ante investment (Bar-Ilan & Strange, 1996), propelling managers to invest under uncertainty with a higher probability and suggesting a positive interaction effect between uncertainty and time lags. Stated differently, the ability to abandon a project and exit a market when prices are low means the downside of the investment is truncated. An increase in uncertainty, therefore, raises the expected profits over the period of the delay and may lead to earlier investment. This effect should be more salient when investment lags are longer, as managers necessarily make projections for a more distant and, thus, more uncertain future. In short, time is expected to have a moderating effect on the negative impact of uncertainty on investment:

Hypothesis 2. Ceteris paribus, resource accumulation lags reduce the main negative effect of uncertainty (the option value of waiting) on a firm's likelihood of investment.

Hypotheses 1 and 2 may explain the hypercompetitive behavior and chronic excess capacity observed in capital-intensive industries that experience long resource accumulation lags (e.g., commercial real estate, electricity generation, petrochemicals, semiconductors). They may also shed light on the aggressive investment policy described by Intel's CEO Andy Grove, of "building factories two years in advance of needing them, before . . . having the products to run in them, and before . . . knowing the industry's going to grow" (Kirkpatrick, 1997: 61). In addition, the reasoning leading to our hypotheses may influence firms' patterns of investment in new markets.[4]

Resource Accumulation Lags Favoring Flexibility

As an industry's resource accumulation lags increase, at the limit, two mechanisms may reduce or even reverse the aforementioned positive effect of resource accumulation lags on investment (commitment), making waiting (flexibility) more likely.

First, since resource accumulation lags enhance firms' disposition toward investing (Hypotheses 1 and 2), very long lags may ultimately generate widespread "bandwagons," wherein a large number of firms in an industry simultaneously invest early (Pacheco-de-Almeida & Zemsky, 2003). If a high number of firms invest early, it will be more difficult for any particular company to get ahead of

[4] Hypotheses 1 and 2 also formalize the following intuition expressed by Porter: "Long lead times [in investment] require firms to base their decisions on projections of demand and competitive behavior far into the future or pay a penalty in not capitalizing on opportunity if demand materializes. Long lead times increase the penalty to the firm who is left behind without capacity, and hence may cause risk-averse firms to be more prone to invest even though the capacity decision itself is risky" (1980: 329).

the competition by making an investment large enough to preempt rivals. In other words, the synchronicity of early investments reduces the opportunity for timing- and volume-based first mover advantages such as large strategic commitments to block competitors (Ghemawat, 1991). Therefore, with very long resource accumulation lags, managers have more incentives to make smaller-scale investments (Pacheco-de-Almeida & Zemsky, 2003) or to wait to invest. Indeed, the prospect of widespread investment bandwagons may eventually discourage investment altogether as managers anticipate problems of industry overcapacity (Henderson & Cool, 2003b). As a result, waiting is favored.

Second, the rate of return required to make an investment worthwhile may be higher for projects with very long resource accumulation lags because of short-term stock market pressures. Indeed, a substantial amount of research in finance and economics (e.g., Narayanan, 1985a, 1985b; Stein, 1988, 1989) has suggested that incentive schemes or the fear of losing control often lead the managers of publicly traded companies to overemphasize the importance of their firms' short-run stock price movements. These short-term objectives may ultimately lead to underinvestment in very long-run projects. If amassing the resources required to pursue market opportunities takes an extremely long time, managers may prefer not to invest and instead may turn to alternative projects with shorter payback periods. Projects that yield quick cash recovery enhance the reinvestment possibilities for firms (Ross, Westerfield, & Jaffe, 1996). As a result, the rate of return required to render longer-term projects economically attractive tends to be higher than the comparable rate for short-term projects (Ainslie & Haslam, 1992), making long-term investment less likely. It has been empirically shown that such short-term bias increases exponentially with time lags, an effect that naturally imposes an inflection point on the positive effect of time for very long resource accumulation lags (Miles, 1993).

Hypothesis 3. Ceteris paribus, very long resource accumulation lags have a negative effect on a firm's likelihood of investment.

In conclusion, the likelihood of commitment is expected to increase with resource accumulation lags (Hypotheses 1 and 2). This effect will be curbed or even reversed for very long resource accumulation lags (Hypothesis 3), making flexibility more likely.

RESEARCH DESIGN

Sample Data

The empirical analysis was carried out in the petrochemical industry in the United States, Europe, and Japan during the period 1975–95. The industry spans several industrial classification codes and includes numerous products, such as commodity chemicals, plastic resins, synthetic rubber, and fibers (for a basic review, see Chapman [1991]).

Several traits make the petrochemical industry a particularly appropriate setting for studying the effect of resource accumulation lags on strategic investment. First, industry players make constant capacity expansion decisions and are thus consistently faced with the commitment versus flexibility dilemma. Second, resource accumulation lags in the form of the time it takes firms to plan and bring investments (such as new plants) online are publicly reported and vary substantially over regions and product categories. Third, the various regions and products (i.e., petrochemical subindustries) can be studied simultaneously while maintaining a homogeneous sample. Finally, there is a large body of empirical work in strategy available on the petrochemical industry, which we are able to build upon.

The industry evolution can be divided into three main life cycle periods: 1850–1950, 1950–1975, and 1975–2005. The most recent period was the most suitable for our study for multiple reasons (our data set covers the years 1975–95). By this late stage, firms' expansion decisions were mainly determined by purely profit-maximizing criteria, as governments offered fewer subsidies to render uneconomic projects financially viable. In addition, this third stage of the industry life cycle is when the assumptions behind the (game-) theoretical models that generate our hypotheses hold the best. As the following quotation from an industry periodical suggests, during this period "information asymmetries" (and "expectation asymmetries") among firms about future market conditions and competitors' moves were reduced to their lowest level since the industry's birth: "Demand forecasts now reflect a strong consensus, there being a difference between the highest and lowest of less than 10%. This compares with the 100% difference which was prevalent in the 1970s" (*Chemical Insight*, 1987: 2) The period also saw improved communication and information about the investment plans and strategic commitments of different players in the industry.

Two data sets were used in this article. The first consists of 556 total time-to-build observations corresponding to 556 plant construction projects (i.e., expansions) that we manually collected from trade journal articles in the *Oil and Gas Journal* (*OGJ*) and complemented with field interviews.[5] We used these data only to generate measures of resource accumulation lags. All other data on firms' investments came from our second data set, which we built from multiple data sources, including the Tecnon Consulting Group, Datastream International, *Chemical Insight*, Compustat, Moody's, the Organisation for Economic Cooperation and Development (OECD), DeWitt & Company, and Chem Systems. This is a very rich data set containing performance and investment information at both the firm and product-market levels (Henderson, 1998). In this study, we employed data on product-market capacity at the firm level and data on production and consumption at the product-market level. Our subsample included a total of 5,848 investment observations on 879 different plant construction projects.

Both data sets used in this study included information on nine major commodity petrochemicals (ethylene, HDPE, LDPE, LLDPE, PP, styrene, PS, PVC, and VCM), which together account for over 50 percent of the industry's total sales volume.[6] The time-to-build and investment data sets included 166 and 116 firms, respectively, with most firms present in both sets. Eleven firms exercised the option to abandon, leaving 13 plant construction projects uncompleted; most decisions to abandon projects already underway took place in Europe. Table 2 summarizes the observations in both data sets for each of the petrochemical subindustries.

The purpose of this study was not to match or merge the two data sets, but to use the time-to-build observations to construct accurate measures of industry average resource accumulation lags that, in turn, could help explain the investment patterns evidenced in the second database. Merging the two databases would have been further unadvisable because a substantial number of investment observations, lacking corresponding time-to-build data, would be lost. Indeed, the time-to-build data on individual construction projects proved the most difficult piece of information to collect: data were available for 63 percent of the 879 investment projects reported in the larger investment data set.

Dependent Variable

Our hypotheses concern the impact of resource accumulation lags and uncertainty on firms' likelihood of investment. We operationalized firms' investments in capacity expansion in the petrochemical industry as has been done in prior work on the topic (Gilbert & Lieberman, 1987; Henderson & Cool, 2003a, 2003b; Lieberman, 1987a, 1987b). For a given observation year, *investment* was equal to 1 for all observations in which a firm expanded either by adding a new "greenfield" plant or by increasing at least one existing plant's production capacity by more than 10 percent. Otherwise, it was equal to 0. Debottlenecking, representing only 0–10 percent of capacity expansion per year, does not reflect a major capacity expansion decision; thus, it was not included in the analysis.

Explanatory Variables

Resource accumulation lag. In the second section of this article, we argued that the time firms take to plan and build new production facilities is generally a good proxy for resource accumulation lags. The times-to-build of plants are empirically observable, clearly defined, and frequently include the intraorganizational accumulation of both intangible and physical resources prior to market entry. This is certainly the case in the petrochemical industry. Therefore, we used the time-to-build of plants to measure the firms' resource accumulation lags. Our data set contained 556 time-to-build observations.

We calculated the time-to-build of each individual project as follows. The official start (end) of a plant expansion was assumed to be the date on which the project was first (last) reported in the *OGJ* minus (plus) 90 days. The 90-day lag resulted from the fact that the *OGJ* only reports the status of each plant expansion twice per year, in April and October. Thus, if a plant expansion appeared for the first time in one issue of the journal, we could only infer that the project started sometime after the prior issue and before the current one. For simplicity, we assumed that each plant expansion started exactly in between the two consecutive issues of the *OGJ* and thus used the 90-day lag (three months). A similar logic applied to the official end date of the plant expansion, unless an expected completion date for the project was reported, in which case the latter was assumed to be the official end date of the expansion.

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[5] Twice per year (in April and October), the *OGJ* reports on the development of every plant construction project. On average, each project was reported 3.1 times in the *OGJ* during its lifetime, which added up to a total of 1,721 data points. Therefore, our time-to-build data set contained 1,721 *single* observations (or data entries), but only 556 project *time-to-build* observations.

[6] The product names were abbreviated as follows: HDPE is high-density polyethylene; LDPE is low-density polyethylene; LLDPE is linear low-density polyethylene; PP is polypropylene; PS is polystyrene; PVC is polyvinyl chloride; and VCM is vinyl chloride monomer.

TABLE 2
Observations Included in the Two Data Sets

Product	Region	Number of Observations: Time-to-Build Data	Number of Observations: Investment Data	Number of Expansions: Time-to-Build Data	Number of Expansions: Investment Data	Number of Firms: Time-to-Build Data	Number of Firms: Investment Data	Total Capacity (10^3 MT/year)[a]
Ethylene	United States	164	315	64	39	28	19	1,040
HDPE	United States	68	221	25	51	14	14	435
LDPE	United States	42	182	20	12	11	11	295
LLDPE	United States	12	63	5	16	4	8	281
PP	United States	124	220	47	38	24	13	327
PS	United States	45	227	13	39	9	14	193
PVC	United States	64	252	25	38	13	15	432
Styrene	United States	32	170	15	15	13	10	537
VCM	United States	37	157	12	16	9	10	632
Ethylene	Europe	249	404	73	57	39	24	901
HDPE	Europe	137	264	31	64	20	16	311
LDPE	Europe	73	281	24	35	17	18	400
LLDPE	Europe	29	71	14	21	9	8	164
PP	Europe	168	276	55	85	25	16	401
PS	Europe	53	314	17	53	13	20	187
PVC	Europe	98	284	23	54	19	17	383
Styrene	Europe	43	174	13	19	11	11	570
VCM	Europe	19	270	19	18	15	16	500
Ethylene	Japan	82	221	14	27	9	13	585
HDPE	Japan	23	176	5	28	3	9	168
LDPE	Japan	29	173	5	14	5	10	174
LLDPE	Japan	9	64	3	10	2	7	73
PP	Japan	58	220	15	43	12	13	186
PS	Japan	21	267	6	29	5	16	114
PVC	Japan	8	193	3	24	3	12	135
Styrene	Japan	19	150	6	21	6	9	326
VCM	Japan	15	239	4	13	4	14	187
Total		1,721	5,848	556	879			

[a] 1995 data.

Using these 556 individual project time-to-build observations, we measured the resource accumulation lag variable as product-region averages per unit of output. Since larger petrochemical projects take longer to build, simply averaging times-to-build without adjusting for an equivalent amount of capacity would have generated industry average resource accumulation lag measures that were not comparable for the purposes of this study. In other words, we were interested in *how long, on average, it took firms to accumulate resources to produce one unit of output in each petrochemical subindustry*. Several alternative operationalizations of the resource accumulation lag variable can be found in the robustness checks section; all measures produced similar final econometric results. Thus,

$$\textit{Resource accumulation lag} = \sum_{e=1}^{n} \frac{(T_e/K_e)}{n},$$

where T_e represents the time-to-build of expansion e in the petrochemical subindustry defined by one product-region combination, K_e is the expansion capacity, and n is the total number of expansions in that subindustry over 1975–95. We standardized resource accumulation lag to reduce multicollinearity between its main and squared terms in the final estimated regression model.

Table 3 summarizes the average resource accumulation lags for the 27 petrochemical subindustries (i.e., product-region combinations) that we studied. These are time-to-build averages in months. For simplicity of interpretation, all measures were scaled up to 100,000 metric tons (MT) per year of equivalent capacity (the median capacity expanded in the time-to-build data set). Several interesting empirical patterns emerge from this data. First, the average time-to-build of a plant is approximately 29 months, 36 percent consisting of intangible resource accumulation (the study and planning phases of each investment project) and 64 percent, of physical asset accumulation (the engineering and construction phases). Second, resource accumulation takes, on average, 17 percent longer

TABLE 3
Average Resource Accumulation Lags in Months per 100,000 Metric Tons per Year of Capacity

Product	United States	Europe	Japan
Ethylene	14.7	19.6	17.7
HDPE	24.3	34.1	34.2
LDPE	15.3	29.3	51.6
LLDPE	13.8	26.2	41.4
PP	29.3	28.5	40.6
PS	40.1	47.0	71.1
PVC	30.4	40.0	37.7
Styrene	13.8	24.9	25.3
VCM	8.5	20.3	14.9

in Japan than in Europe, and 49 percent longer in Europe than in the United States. European countries and Japan are typically more stringent about environmental issues than the United States, which slows down plant approval and construction. Third, resource accumulation is faster for some petrochemical products than for others. Average time-to-build ranges from a minimum of 8.5 months to a maximum of 71.1 months and is shorter for primary and intermediate chemicals such as ethylene, VCM, and styrene than for commodity plastics such as HDPE, LDPE, PVC, PS, or PP. These geographic and product differences are all statistically significant (all p's $< .01$).

Demand uncertainty. The second explanatory variable we sought to operationalize was uncertainty, which usually is the variance of a variable. In this study, we focused on the most prominent driver of uncertainty in the petrochemical industry: demand. The corresponding measure was defined as the standard deviation of four years' worth of industrial production prior to the year under consideration. The four-year period prior to the focal year was chosen to match the operationalization of similar variables in prior empirical work in this industry (e.g., Lieberman, 1987a). We computed demand uncertainty for each geographic region (U.S., Europe, and Japan). This measure was standardized.[7]

Control Variables

The controls consisted of a few theoretically relevant variables that prior empirical studies of firms' investment decisions in the petrochemical industry have repeatedly shown to be significant and signed as predicted. These variables can be divided into two distinct categories: nonstrategic and strategic. Independently of rivals' competitive moves, three variables matter for firms' expansion decisions: historical demand growth rate, investment "lumpiness," and industry capacity utilization/excess capacity. Two strategic investment variables should also be considered: relative market share and rivals' expansion. These variables are defined below in this same order.

Demand growth. Predictably, the demand growth rate has been shown to have a positive impact on the probability of expansion (Gilbert & Lieberman, 1987; Henderson & Cool, 2003a, 2003b; Lieberman, 1987a, 1987b). *Demand growth* was the four-year historical compound annual growth rate of production for a product-region. Although firm-level growth in production would have been more indicative of demand, data were not available. Prior work has used this product-region proxy.

Excess capacity. As has been observed in previous studies, *excess capacity* discourages further capacity expansions (Gilbert & Lieberman, 1987; Henderson & Cool, 2003a, 2003b; Lieberman, 1987a, 1987b). It was measured as the amount of oversupply, taken as a percentage of total industry capacity, which is the inverse of capacity utilization. Capacity utilization was calculated as a product-market average rate of capacity utilization over the two previous years.

Investment lumpiness. Like excess capacity, *investment lumpiness* hinders investment (Gilbert & Lieberman, 1987; Henderson & Cool, 2003a, 2003b; Lieberman, 1987a, 1987b). The larger the plant size required to reach the minimum efficient scale (MES), the fewer incentives firms have to expand. This is because large amounts of capacity are riskier to add than small ones. Lumpiness should be calculated as the percentage of the market capacity covered by the capacity of an MES plant, but data were not available. Instead, we constructed a proxy: average plant size divided by total product-market production.

Market share. A firm's market share is expected to have a strongly positive effect on its expansion probability (Gilbert & Lieberman, 1987; Henderson & Cool, 2003a, 2003b). For multiple reasons, larger petrochemical firms may have a competitive advantage in capacity expansion over smaller firms (e.g., more investment experience, better access to suppliers, stronger brand name). At the same time, expansions for larger firms represent smaller increments of their total capacity. *Market share* was a firm's share of total product-market capacity.

[7] Standardization reduces multicollinearity with the control variable demand growth. Multicollinearity results from the fact that demand growth and demand uncertainty were defined as the mean and the variance of the same empirical measure (industrial production) and simultaneously included as independent variables in the model.

Rivals' expansion. Finally, rivals' expansion should also have a clear, positive impact on the probability of investment: firms have been found to be more likely to invest when they see their rivals investing (for a review, see Henderson and Cool [2003a, 2003b]). This may happen because of management myopia, defective corporate governance systems, or information asymmetries between firms, whereby competitors' expansions signal expectations about future market conditions. The variable *rivals' expansion* was constructed as the percentage of total capacity added simultaneously by rivals in a product-market during an observation year.

Estimation Methods

A logit regression analysis tests the hypotheses about the effect of industry resource accumulation lags on firms' likelihood of investment. The model is estimated using both random and fixed effects (firm, product, region, and year) in the following general form:[8]

$$\begin{aligned} P(investment = 1|X, \varepsilon) = \Lambda[\alpha \\ + \beta_1 demand\ growth + \beta_2 excess\ capacity \\ + \beta_3 investment\ lumpiness + \beta_4 market\ share \\ + \beta_5 rivals'\ expansion \\ + \beta_6 demand\ uncertainty \\ + \beta_7 resource\ accumulation\ lag \\ + \beta_8 (resource\ accumulation\ lag \\ \times demand\ uncertainty) \\ + \beta_9 (resource\ accumulation\ lag^2) + \varepsilon]. \end{aligned}$$

RESULTS

Descriptive Statistics

Table 4 summarizes the key statistics for the central variables used in the estimations. All of them show substantial variation. On average, approximately 15 percent of the firms in the sample invested in capacity in any given year, if one assumes projects are equally distributed among firms. Incremental expansions accounted for about 71 percent of these new investments, with an average of 63,295 MT per year in capacity. Greenfield projects represented the remaining 29 percent of investments, with an average of 151,800 MT per year in capacity. Total capacity added was approximately 81,090 MT per year, with a maximum of 680,000 MT per year for a new ethylene cracker. The historical demand growth rate was positive at some points and negative at others, and the industry's excess capacity varied widely, both reflecting the strong industry cyclicality experienced during the 1975–95 period. The table presents the descriptive statistics for the uncertainty and resource accumulation lag variables prior to standardization. The peak of uncertainty was reached at 4.19 standard deviations above the mean, an occurrence with less than 2.85 percent probability in a two-tailed distribution (after standardization according to Chebyshev inequality). Finally, variation in the accumulation lag measure is also considerable, as predicted.

TABLE 4
Descriptive Statistics, Selected Variables[a]

Variables	Mean	s.d.	Minimum	Maximum
Capacity expansion	0.15		0	1
Greenfield expansion	0.04		0	1
Incremental expansion	0.11		0	1
Total capacity added	81.09	107.23	1	680.00
Demand growth	3.54	4.19	−7.33	28.98
Excess capacity	17.16	12.13	0	58.99
Investment lumpiness	4.38	2.70	1.10	18.75
Market share	0.83	0.83	0	6.37
Rivals' expansion	3.77	3.86	0	24.85
Demand uncertainty[b]	3.39	1.47	1.48	9.55
Resource accumulation lag[b, c]	29.59	13.22	8.52	71.10

[a] $n = 5{,}848$.
[b] Nonstandardized variable.
[c] Months per 100,000 metric tons per year.

Logit Analysis

This study examined the influence of time-consuming resource accumulation on firms' investment strategies on the trade-off between commitment and flexibility. Accordingly, our logit regression analysis addressed the extent to which firms exploit the simplest type of flexibility—the option to wait—by delaying investment.

Table 5 summarizes the results for the random- and fixed-effects models. As is conventional, we performed a likelihood ratio test comparing the restricted or pooled with the unrestricted logit regressions to determine the joint significance of all possible fixed effects (firm, product, region, and year). All dummies came out significant (regions:

[8] The function $\Lambda(.)$ denotes the logistic cumulative distribution.

TABLE 5

Results of Logit Analysis of Expansion Probability[a]

Variables and Mean Values	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Constant	−0.24*** (0.12)	−0.24*** (0.12)	−0.24*** (0.12)	−0.24*** (0.12)	−0.22*** (0.12)	−0.22*** (0.12)	−0.23*** (0.12)	−0.22* (1.06)
Demand growth (0.04)	0.62*** (0.01)	0.67*** (0.01)	0.58*** (0.01)	0.64*** (0.01)	0.54*** (0.01)	0.54*** (0.01)	0.59*** (0.01)	0.51*** (0.01)
Excess capacity (0.17)	−0.05 (0.00)	−0.04 (0.00)	−0.08* (0.00)	−0.07† (0.00)	−0.11** (0.00)	−0.11** (0.00)	−0.10* (0.00)	−0.10* (0.00)
Investment lumpiness (0.04)	−0.75*** (0.02)	−0.77*** (0.02)	−0.59** (0.02)	−0.62** (0.02)	−0.43* (0.02)	−0.44* (0.02)	−0.47* (0.02)	−0.38† (0.02)
Market share (0.83)	0.02*** (0.05)	0.02*** (0.05)	0.02** (0.05)	0.02*** (0.05)	0.02*** (0.05)	0.02*** (0.05)	0.02*** (0.05)	0.01** (0.05)
Rivals' expansion (0.04)	0.78*** (0.01)	0.79*** (0.01)	0.77*** (0.01)	0.78*** (0.01)	0.71*** (0.01)	0.70*** (0.01)	0.71*** (0.01)	0.65*** (0.01)
Demand uncertainty (0)		−0.01* (0.04)		−0.01† (0.04)			−0.01† (0.04)	−0.00 (0.04)
Resource accumulation lag (0)			0.02** (0.04)	0.01** (0.04)	0.03*** (0.06)	0.03*** (0.06)	0.03*** (0.06)	0.03*** (0.06)
Resource accumulation lag squared (1)					−0.01*** (0.03)	−0.01*** (0.03)	−0.01*** (0.03)	−0.01*** (0.03)
Resource accumulation lag × demand uncertainty (0.02)						0.01† (0.04)	0.01* (0.03)	0.01† (0.04)
Number of observations	5,848	5,848	5,848	5,848	5,848	5,848	5,848	5,590
Log-likelihood chi-square	−2,389.90	−2,379.00	−2,376.30	−2,374.70	−2,368.50	−2,367.00	−2,365.00	−2,249.13
Chi-square for model	147.86***	150.77***	155.57***	158.05***	169.21***	171.82***	173.55***	335.77***
Chi-square for firms								Significant

† $p < .10$
* $p < .05$
** $p < .01$
*** $p < .001$

$\chi^2[2] = 16.53$; products: $\chi^2[8] = 37.73$; years: $\chi^2[16] = 73.09$; firms: $\chi^2[98] = 168.48$).[9]

The firm dummies were included in the estimations and are reported in the last column of Table 5. Although the year, product, and region dummies were also significant, their inclusion in the estimation rendered much of the analysis uninteresting. With the year dummies, the variables capturing cyclicality (excess capacity and demand uncertainty) unsurprisingly turned insignificant. Since there was no other loss in significance in the variables of interest and the control variables adequately captured the circumstances unique to particular points in time, the time dummies were not kept in the estimations. The product and region dummies naturally absorbed part of the variance in the dependent variable explained by the product-region accumulation lag measures (and demand uncertainty), which countered the purpose of this study. As a result, although we carefully examined them during estimation, we do not report these aggressive fixed-effect models below.

The first column in Table 5 lists the independent variables and their values at the sample mean. The other columns report the parameter estimates and standard errors. Each parameter estimate is the partial derivative of the probability of expansion with respect to the independent variable, with the logistic cumulative distribution evaluated at the sample means of the data.[10] Under model 1, the base model, we only report the estimates for the control variables. In models 2, 3, and 4 we add the main effects of uncertainty and accumulation lag. Models 5 and 6 introduce the squared and interaction effects of resource accumulation lag on the likelihood of investment. Model 7 is the full model. Finally, although models 1–7 are random-effects models, model 8 reports the estimation results with firm fixed effects. The usual tests for multicollinearity, heteroscedasticity, and serial correlation were performed. No major problems were found, and the estimation proceeded via the conventional regression techniques described above.[11]

Table 5 deserves several comments. First, the chi-square tests for the models are significant, allowing us to reject the null hypothesis that all coefficients with the exception of the intercept are zero. Second, the control variables are generally significant and with the expected signs. Rapid demand growth signals the need for investment in additional plant capacity and, thus, has a positive impact on investment likelihood. The level of idle or excess capacity in the industry was expected to dissuade investment since it is often associated with industry oversupply, price declines, and incumbent retaliation responses to new market entry. Accordingly, the corresponding coefficient is consistently negative and significant in the random-effects models. The effect of investment lumpiness is also straightforward: if capacity can only be added in large increments, firms have fewer incentives to invest. The likelihood of investment depends positively on firms' relative market shares, reflecting the idea that large firms have a competitive advantage over small firms. A strong case for investment bandwagon behaviors can also be made, with a positive and significant coefficient for rivals' expansion, the percentage of total capacity added simultaneously by rivals.

Third, supporting the conventional option theory view of investment, demand uncertainty does hinder investment in the random-effects models, as expected.

Fourth, the logit analysis indicates clear support for all the hypotheses on resource accumulation lags favoring commitment developed herein. Indeed, the coefficient associated with the main resource accumulation lag variable is consistently positive and significant in all the estimated models, as predicted in Hypothesis 1. In particular, model 7 suggests that a marginal six-month increase over the mean in the average time it takes firms to accumulate resources (from 29.59 to 35.59 months)—an increase that may be due, for instance, to the introduction of stricter governmental regulation or more complex technologies—raises firms' predicted likelihood of investment by 1.24 percent (from 12.50%

[9] In the degrees of freedom, three years and 17 firms were dropped because of perfect collinearity.

[10] Following Ai and Norton (2003), we computed the magnitude of the interaction effect. We found that there was not, in fact, much difference between the marginal effect of the interaction term (reported in Table 5) and its magnitude.

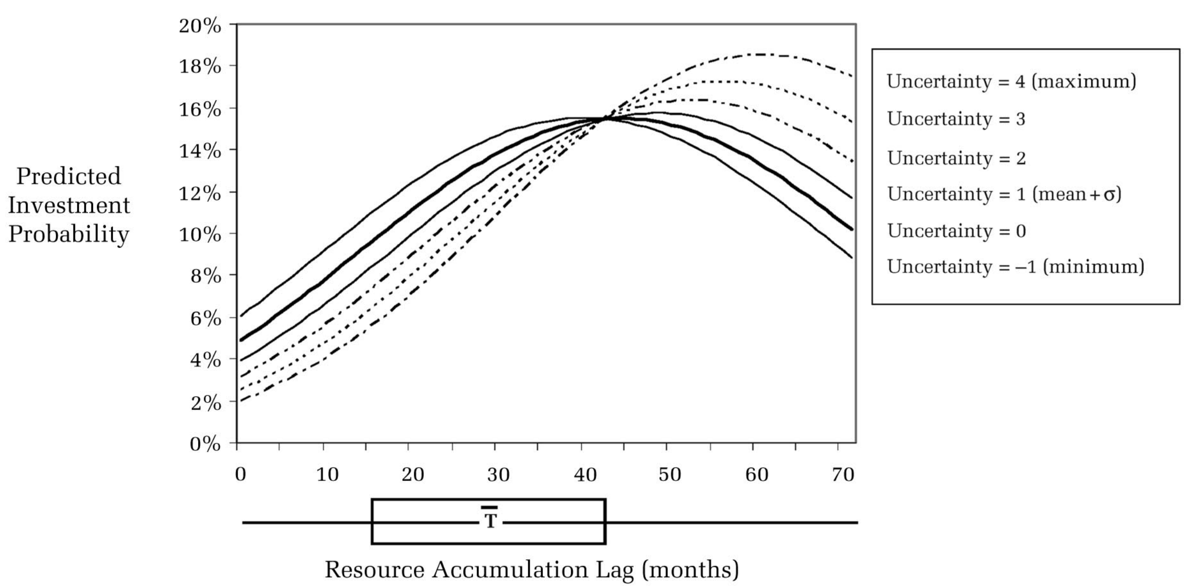
[11] See Appendix B for the Pearson correlation coefficients. The unstructured within-panel error correlation matrix did not suggest any discernible AR1 pattern. For heteroscedasticity, we assumed that the coefficients were biased and thus estimated the models using the sandwich or robust estimator of variance (i.e., when the source of the bias is unknown). Four estimations of the full model were conducted: the original model; robust standard errors for the whole sample; robust standard errors within each region, company, product combination; and robust standard errors within each company cluster of observations. However, the changes to the standard errors were minor, leaving the significance of the coefficients intact.

to 13.74%). This increase corresponds to five new firms investing each year, resulting in at least 89 new projects during the period of analysis (i.e., a 10 percent increase in the total number of capacity expansions recorded in the database, assuming that investment projects are equally distributed among firms). These numbers are particularly striking in a mature industry with chronic excess capacity such as petrochemicals. These results reflect the fact that longer resource accumulation lags decelerate firms' reactions to new market and competitive information, increasing the potential forgone profits if firms wait to invest, and thereby inducing them to commit. Furthermore, the coefficient associated with the interaction between resource accumulation lag and demand uncertainty is consistently positive and significant, as predicted in Hypothesis 2. Contrary to conventional wisdom, in industries with sufficiently time-consuming resource accumulation, an increase in uncertainty may ultimately encourage, rather than dissuade, investment. An increase in uncertainty raises the expected profits over the period of delay because of firms' greater ability to abandon an investment with longer resource accumulation lags, which leads to commitment. For example, since the main and interaction terms of demand uncertainty have similar coefficients of opposite signs in model 7, if the resource accumulation lag variable is greater than 1 (greater than 42.37 months prior to standardization), increasing uncertainty raises the probability of investment.

Fifth, the data also support Hypothesis 3, on resource accumulation lags favoring flexibility. In industries in which resource accumulation is very time-consuming, the risk of widespread investment bandwagons and industry overcapacity is especially high. Also, short-term stock market pressures discourage investment in long-run projects that reduce firms' cash recovery and reinvestment possibilities. The negative and highly significant coefficient of the squared resource accumulation lag variable confirms that, if it takes very long to amass resources prior to market entry (more than 42.83 months for a mean level of uncertainty in model 7), firms start requiring higher expected rates of return on investment and, in turn, they favor waiting.

Figure 1 is a graphical representation of the joint effect of industry resource accumulation lags and uncertainty on the predicted probability of investment, using the coefficients estimated in model 7. Within (at least) one standard deviation away from the mean (29.59 ± 13.22 months), slower resource accumulation lags have a positive impact on investment likelihood, after which this effect is curbed. Uncertainty, through its interaction with investment lags, skews the probability curve to the left: uncertainty encourages investment when firms have enough time to exercise the option of abandoning a project (i.e., when accumulation lags are sufficiently slow). In particular, with uncertainty at its maximum (level 4 in figure 1), slowing down the speed of resource accumulation almost always increases firms' investment probability, and the fac-

FIGURE 1
Industry Resource Accumulation Lags and Predicted Investment Probability[a]



[a] Graph depicts logit model 7.

tors curbing the effect of time only kick in for extremely long resource accumulation lags (greater than 63.42 months with level 4 uncertainty).[12]

These results are robust to the alternative estimation with firm fixed effects (model 8). All coefficients had the expected sign and, with the exception of uncertainty (which had a negative, insignificant coefficient), they were significant. One possible explanation for this finding is that most of the uncertainty variance is region-based and firms tend to invest within a single region (the United States, Europe, or Japan). Hence, including firm dummies serves as a natural surrogate for uncertainty's role in capturing region-based variance. This conjecture finds some support in the fact that including region dummies produces a similar outcome on the uncertainty coefficient.

Robustness Checks

Several checks confirmed the robustness of our findings. First, pooled and population-averaged logit models produced identical results. Second, using an alternative operationalization of demand uncertainty, four years' worth of production of petrochemicals (also standardized), did not change the estimations.

Third, three other possible measures of the resource accumulation lag variable (see Appendix A) left the sign and significance of the model coefficients intact, with the exception of the squared term of resource accumulation lag, as follows. The squared term coefficient was only negative and significant for the alternative measure of the resource accumulation lag variable that also included data for the petrochemical subindustry with the slowest speed of resource accumulation (71.1 months in the subset for polystyrene in Japan). With the two other operationalizations (where data were missing for this subindustry), the squared term came out insignificant. The reason for this result is that the squared *resource accumulation lag* term curbs the positive effect of time lags precisely for observations on the upper tail of the distribution (e.g., the Japanese polystyrene subindustry). Note, however, that all four resource accumulation lag measures are highly correlated ($\rho = 0.8$). All these results remain unchanged if we use the industry-average time-to-build for the average amount of capacity added in each subindustry instead of averages per unit of output.

Fourth, other operationalizations of the control variables (for a review, see Henderson [1998]) were tested with no major impact on the estimation results.

Finally, several robustness checks were run on different, though related, dependent variables: (1) the total number of investments per year (excluding the rivals' expansion independent variable, for obvious reasons), (2) the total amount invested in capacity (in a Tobit regression), and (3) the likelihood of investment in different types of capacity expansions (in an ordered logit regression).[13] Findings were identical.

DISCUSSION AND CONCLUSIONS

This study is the first in the strategy field to give a systematic empirical account of resource accumulation lags. According to the resource-based view, the speed at which firms accumulate resources is an important determinant of the length of imitation lags, the scope of lead-time advantages, and the sustainability of competitive advantage. Borrowing the control variables of the solid empirical work on the petrochemical industry (Gilbert & Lieberman, 1987; Henderson & Cool, 2003a, 2003b; Lieberman, 1987a, 1987b), we tested the robustness of a novel set of competitive strategy hypotheses concerning the effect of time-consuming resource accumulation on firms' investments under uncertainty and, in particular, the trade-off between commitment and flexibility.

All the hypotheses we developed in this study found support in the data. Industry resource accumulation lags were found to have a nontrivial impact on firms' strategies. The longer it takes, on average, to

[12] All curves in Figure 1 intersect when industry resource accumulation lags are such that changes in uncertainty have no impact on the predicted probability of investment. Because the main and interaction effects of demand uncertainty have similar coefficients of opposite signs, the overall effect of uncertainty cancels out when the resource accumulation lag measure is close to 1 (i.e., one standard deviation above the mean). More precisely: $\beta_6 + \beta_8 \times$ *resource accumulation lag* $= 0 \Leftrightarrow$ *resource accumulation lag* $= -\beta_6 / \beta_8 = 0.97$ (or 42.37 months prior to standardization; coefficients from model 7).

[13] In the petrochemical industry, firms can expand capacity in two main ways: by adding a greenfield plant or by adding a new incremental unit to an existing plant. In the investment data set, greenfield and incremental expansions represented 29 and 71 percent, respectively, of the total 879 plant construction projects observed in 1975–95. Expansion type was set equal to 1 if a firm expanded incrementally in a given year and equal to 2 if, alternatively, that firm expanded with a greenfield plant in that same year. Otherwise, the variable assumed the value 0. The ordered logit estimation confirmed the results of the logit analysis.

accumulate resources to compete in a certain market, the more likely firms are to invest under uncertainty. This is because slower resource accumulation decelerates firms' reactions to new market or competitive information, thereby increasing the potential forgone profits if firms wait to invest and market conditions turn out to be favorable. At the same time, with longer resource accumulation lags, investment decisions depend on projections for a more distant future, a condition that not only increases the likelihood of extreme future market outcomes, but also gives managers more time to exercise the option of abandoning their investment projects. Profits become more effectively safeguarded under poor business conditions (e.g., demand or prices are low), and the net present value of investing ex ante increases, propelling firms to commit (invest).

A more subtle consequence of this line of reasoning also found empirical support: with extremely long resource accumulation lags, the anticipation of sufficiently large forgone profits ex post increases the risk of early widespread investment bandwagons, making it more difficult for any particular company to get ahead of the competition by making an investment large enough to preempt rivals. This situation ultimately reduces the incentives for commitment and, thus, makes flexibility (waiting) more likely. Short-term stock market pressures reinforce this effect: if it takes too long to amass resources prior to market entry, managers will consider not investing as alternative projects with shorter payback periods may be more financially attractive. Indeed, projects that yield quick cash recovery enhance the reinvestment possibilities for firms. The positive effect of resource accumulation lags on commitment is thereby curbed, and the probability of flexibility is increased, as evidenced in the data. These empirical findings are consistent with prior theoretical work (Bar-Ilan & Strange, 1996; Narayanan, 1985a, 1985b; Pacheco-de-Almeida & Zemsky, 2003; Stein, 1988, 1989).

In short, resource accumulation lags generally favor commitment; flexibility is only preferred in situations in which resource accumulation is very time-consuming (more than one standard deviation above the mean in our sample).

Strategy Implications

Time is an important element of industry structure. Often the structural characteristics of an industry dictate the speed of firms' resource accumulation; clearly, in some industries firms can accumulate resources faster than in others. The reason to measure resource accumulation lags in a study of industry analysis à la Porter (1980) is threefold.

First, in industries with lengthy resource accumulation lags, competitive advantage may be hard to attain. Contrary to conventional wisdom, competition may be fiercer in markets in which firms accumulate resources slowly than in those in which accumulation is relatively rapid. Long resource accumulation lags generally offset uncertainty and reduce inertia, inducing firms to commit and start racing for new market opportunities early. In addition, because time-consuming resource accumulation sustains competitive advantage (Barney, 1991; Dierickx & Cool, 1989), firms face a critical trade-off: competitive advantage is harder to create precisely in those industries in which it is easier to sustain. In other words, the benefits of slow imitation and lead time advantages in industries with long resource accumulation lags are partly offset by the risk of stiff competition. This finding is consistent with systematic empirical evidence of chronic excess supply in industries characterized by long investment lags, such as commercial real estate, electricity, and chemicals (Ghemawat, 1984; Henderson & Cool, 2003b; Kling & McCue, 1987; MacRae, 1989).

Second, our results contradict the view that uncertainty is always a strong disincentive for investment. We have shown empirically that an increase in uncertainty may encourage rather than dissuade commitment, owing to the positive moderating effect of resource accumulation lags on uncertainty. Indeed, the longer it takes to plan and bring new investments online, the more time firms have to learn about conditions in a market (demand, prices, competition, technology, regulation, etc.) before commencing operations in that market. Long resource accumulation lags are often associated with staged investment projects that, should new unfavorable market information be revealed, firms can abandon before moving into the next stage of the investment. Because the investment can be abandoned at multiple stages, its downside is truncated. An increase in uncertainty, therefore, augments the upside potential of a project more than its downside, boosting its expected profits ex ante and leading not only to a greater but also to an earlier likelihood of investment.

Third, the nonlinear inverted U-shaped effect of resource accumulation lags on commitment implies that flexibility is more valued in industries in which resource accumulation is either very time-consuming or virtually instantaneous. In these settings, managers are more likely than they are in other settings to exploit the option to wait, postponing investments; thus, preemptive strategies are less frequent.

Several normative managerial implications can be derived from these empirical results. Contrary to conventional wisdom, our study suggests that *slowing down*, rather than *accelerating*, firms' resource accumulation may lead to hypercompetition. Slower resource accumulation reduces imitation pressures, but it also substantially increases the number of competitive investments in an industry. Managers should carefully weigh this trade-off between the pace of imitation and the intensity of competition when deciding whether to enter slow- or fast-moving industries. Managers of industry-incumbent firms should also anticipate the competitive effects of structural changes on the pace of an industry. For instance, stricter governmental regulations or more complex technologies often slow down firms' resource accumulation, thereby increasing competition.

In addition, to the extent that the patterns our results reveal influence firms' investment in new markets, the study suggests that first mover advantages may be *easier* to establish in fast-moving industries. With faster resource accumulation, more firms follow a wait-and-see strategy by postponing investments if initial market uncertainty is high and quickly catching up when market conditions are favorable. This pattern of investment concedes a (small) timing advantage to the few firms that decide to enter an industry early. These early entrants can preempt quick imitation by late movers by investing in excess capacity, patenting, and product proliferation. Preemptive strategies are less effective in slow-moving industries because more firms enter the market early.

These implications for strategic management also apply in the context of international diversification, as it is reasonable to expect substantial differences in resource accumulation lags across countries, likely related to variation in regulatory environment. Governments have a major influence on firms' total times-to-market and, thus, can critically influence the level of competition (e.g., overcapacity) in some industries over time.

Generalization and Limitations

The aforementioned implications of our results do not apply uniformly to every industry. We studied the petrochemical industry, a mature industry with chronic excess capacity, and the reported effects of resource accumulation lags on firms' investment strategies may be typical of such industries. In emergent and growing markets, potential forgone profits from delaying investment tend to be greater, and the positive impact of resource accumulation lags may be even stronger. It is unclear how other structural characteristics of an industry (e.g., level of product differentiation, rate of technological breakthroughs, degree of investment secrecy) change the effect of time lags on firms' strategies under uncertainty. This observation may motivate future work.

Another interesting direction for future research would be to examine how differences in firm speed within one industry change our key results regarding investment strategies. More data on time-to-build would need to be gathered, to increase variation in resource accumulation lags among firms and over time.

Finally, finding measures of the resource accumulation lag other than the time needed to build production facilities might capture aspects of resource accumulation that this study has overlooked. In manufacturing industries with relatively homogeneous products, establishing a production facility is often all a firm needs to compete in existing markets. The key elements of firms' strategies (such as technological innovation and production efficiency) are usually important components of the investment process. In contrast, in some service industries, the construction of "production facilities" is not as vital for firms' strategies; in such industries, strategies might depend on the long-term cultivation of intangible assets such as corporate reputation or brand image. For some industrial contexts, therefore, the time-to-build of new plants is obviously a less appropriate proxy for resource accumulation lags, and alternative measures need to be identified.

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APPENDIX A

Alternative Measures of Resource Accumulation Lag

Different projects were initially reported in the *OGJ* in varying stages of completion.[14] Directly averaging a project's time-to-build per product-region irrespective of the phase during which the project was first reported would have biased the industry averages. Observations for projects that were initially in the study or planning phase were more complete than those in which time-to-build was not measured until the expansion had reached the engineering or construction stages. A "right-censoring" problem in the time-to-build measures was associated with the 257 projects first reported in the engineering and construction phases. Classifying these right-censored data as missing observations was also not advisable: the missing subsample was not random, and several time-to-build data points would have been lost.[15] Hence, we computed several measures of the resource accumulation lag, values for which are shown in the tables below. We used (1) only the 97 time-to-build observations first

TABLE A1
Resource Accumulation Lags for Projects First Observed at a Study or Planning Stage

Product	United States	Europe	Japan
Ethylene	20.5	19.6	52.8
HDPE	21.0	65.1	57.6
LDPE	28.3	40.1	82.9
LLDPE	8.9	23.2	39.3
PP	61.4	64.4	43.5
PS	43.7	124.2	
PVC	29.1	48.5	73.0
Styrene	5.0	34.4	24.8
VCM	8.4	30.8	33.2

TABLE A2
Resource Accumulation Lags for All Projects with Initial Information on Project Status, with Adjustment for Right Censoring

Product	United States	Europe	Japan
Ethylene	22.1	22.0	16.0
HDPE	22.4	48.5	49.6
LDPE	18.3	38.2	51.6
LLDPE	16.2	32.5	41.4
PP	36.1	38.4	48.8
PS	66.6	51.1	71.1
PVC	59.7	53.2	96.2
Styrene	22.7	30.0	28.6
VCM	10.1	27.6	20.4

TABLE A3
Resource Accumulation Lags for the Fitted Values of a Right-Censored Regression

Product	United States	Europe	Japan
Ethylene	29.9	40.9	27.5
HDPE	61.4	81.1	97.4
LDPE	25.3	67.4	83.4
LLDPE	33.8	23.0	46.5
PP	37.6	57.6	67.1
PS	43.7	103.5	
PVC	71.6	78.9	96.2
Styrene	21.4	30.2	27.7
VCM	10.1	30.9	34.0

APPENDIX B

Pearson Correlation Coefficients of the Independent Variables

Variable	1	2	3	4	5	6
1. Demand growth						
2. Excess capacity	−.15*					
3. Investment lumpiness	.17*	.07*				
4. Market share	−.06*	.04*	−.06*			
5. Rivals' expansion	.33*	−.16*	.07*	−.07*		
6. Demand uncertainty[a]	.20*	.08*	.08*	.04*	.06*	
7. Accumulation lag[b]	.02*	.20*	−.16*	.02	−.02	.02

[a] Standardized variable; no multicollinearity problems with the interaction or squared terms.
[b] Months per 100,000 MT/year.
* $p < .05$

[14] The *OGJ* reports on projects twice per year. When the 556 expansion projects were reported in the *OGJ* for the first time, 97 were under study or being planned, 85 in the engineering stage, and 172 already under construction. Of the remaining 202 expansions, only 28 included some information on project status in a later issue of the journal.

[15] A dummy variable with two groups, cases with right-censored time-to-build observations and cases with clean time-to-build observations, was constructed. We performed parametric and nonparametric tests of mean differences for the remaining continuous data set variables; results allowed us to reject the null hypothesis of equal means. Thus, the right-censored subsample was not random, and omitting the limit observations would have created biases.

reported when they were in study or planning phases (Table A1) and then (2) only the 354 time-to-build observations in which we adjusted the 257 right-censored data points by adding the average time spent in the study and planning stages in the corresponding subindustry (Table A2). The third measure calculated was the one discussed in the body of the article and reported in Table 3; it consists of the complete 556 time-to-build observations in which the 257 right-censored observations were corrected in the same way as those in Table A2. A final, fourth data sample included the 354 fitted values of a right-censored exploratory regression of the determinants of time-to-build at the firm level (Table A3).[16] For simplicity, all measures were scaled up to 100,000 MT/year of capacity.

[16] The regression equation used the 354 under-study, planned, engineering, and construction observations. We regressed time-to-build on a measure of project capacity and other controls (firm expansion experience, expansion type, a year trend, and product-region dummies, among others), taking into account which observations were right-censored and that the true censoring value was unknown and could change from observation to observation. This regression was run using the "intreg" command in Stata 8.2.

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