The Effect of Market-Entry Timing on a Firm's Speed and Cost of Entry

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This paper examines the effect of market-entry timing on a firm's speed and cost of entry in a setting where a firm needs to build a plant for market entry. Based on our developed analytical model, we provide seven scenarios of the market-entry timing effect on a firm's entry speed and cost. We test hypotheses in the liquefied natural gas (LNG) industry. We use Wooldridge's three-step instrumental variable (IV) approach to account for endogeneity bias. We find that a late entrant has (1) a shorter time-to-build and (2) a higher cost-to-build relative to an early entrant. Further, (3) the late entrant positively moderates the negative relationship of time-to-build and cost-to-build (i.e., the negative relationship of time-to-build and cost-to-build becomes less negative for the late entrant). These empirical results are consistent with the prediction of when both revenue effect (i.e., revenue curve shift) and cost effect (i.e., cost curve leftward shift) exist.

Keywords: market entry, entry timing, entry speed, entry cost, time compression diseconomies

INTRODUCTION

Entry timing is one of the key strategic variables involving a tradeoff between costs and benefits. Acting early increases the costs that stem from limited information and learning opportunities. Early entrants face a lack of market and technological information and market and technological insights observed from other firms. With limited information and precedents, early entrants are more likely to incur costs by making mistakes in irreversible investments regarding the type of product, business model, or operations (Glazer, 1985; Lieberman & Montgomery, 1988, 1998; Mitchell, 1989, 1991; Mitchell *et al*., 1994). In contrast, late entrants may benefit from the option value of waiting because increased information and learning opportunities from waiting can help late entrants avoid irreversible and costly mistakes (Argote *et al*., 1990; Dixit, 1992; Ingram & Baum, 1997; Kim & Miner, 2007; Mitchell *et al*., 1994; Pindyck, 1991; Shaver *et al*., 1997; Zimmerman, 1982).

Countering the costs of acting early are the potential benefits of preemption. For example, early entrants can preempt inputs such as scarce natural and human resources, increase consumer-switching costs, and build technological lock-in. These entrants thus can preempt critical resources, which restrict late entrants or at least severely limit their range of action (Dixit, 1992; Ghemawat, 1991; Kim & Miner, 2007; Lieberman & Montgomery, 1988, 1998; Mitchell et al., 1994; Pindyck, 1991; Rumelt, 1984). An additional benefit of early-market entry is that it can enable profitable follow-on investments (i.e., growth options) to be exercised sooner to enhance the firm's NPV (Tong & Li, 2011; Trigeorgis, 1996).

Although market-entry timing is a critical strategic variable, a firm does not complete the entry process immediately with its decision to enter the market. Most market-entry processes take time. In the current research, we focus on the setting where a firm needs to build a plant to enter the market and view time-to-build a plant as market entry speed. In particular, a firm's market-entry timing refers to the moment when the firm initiates market entry. In contrast, its time-to-build is the time lag between the firm's initiation and completion of its market entry. Specifically, time-to-build refers to the firm's time lag between initiating a plant's construction and the plant's commercial operation.

A firm's time-to-build choice is also strategic because it involves a tradeoff. On the one hand, decreasing time-to-build is beneficial because firms that are slow to execute investment projects (e.g., slow-to-build plants) often incur substantial revenue losses (D'Aveni, 1994; Eisenhardt, 1989; Smith & Reinertsen, 1998; Stalk & Hout, 1990; Teece *et al*., 1997). Clark (1989) estimates that each day of delay in introducing a new model represents a $1 million profit loss for a $10,000 car. This revenue loss of slower speed in the execution of investment projects also has a direct impact on a firm's market value: delay announcements in new product introduction decrease the firm market value by 5.25% (or $-119.3 million in 1991 dollars) on average (Hendricks & Singhal, 1997). On the other hand, the firm may significantly raise its costs when it compresses its time-to-build (Boehm, 1981; Dierickx & Cool, 1989; Graves, 1989; Mansfield, 1971; Scherer, 1967, 1984). Early estimates of this time-cost tradeoff indicate that, on average, a 1% acceleration in project development time inflates investment costs by 1.75% (Mansfield, 1971). Mansfield's (1988) elasticity estimate of a time-cost tradeoff in the electrical and instruments industry of 4.3 percent implies that a two-week schedule compression of Intel's 386 microprocessor development would have resulted in an $8.6 million increase in costs (Graves, 1989), for a review on empirical estimates of the acceleration-cost trade-off). Several influential management works emphasize strategy's timing dimension, including Fine (1998) on industry clock speed and Stalk (1988) on time-based competition. Specifically, in the context of the current study, the firm's time-cost tradeoff concerns the non-linear increase in a firm's cost as it speeds up the time-to-build its plant (e.g., a one percent decrease in a firm's time-to-build its plant typically requires more than a one percent increase in the firm's costs).

However, the extant literature often views the time-to-build as an exogenous capability moderating the entry-timing effects without considering the firm's time-cost tradeoff. When it is considered an endogenous choice involving a time-cost tradeoff, it typically does not consider market-entry timing (e.g., Pacheco-de-Almeida & Zemsky, 2007). The current study maintains that we can better explain and predict the relationship between market-entry timing and time-to-build when we take time-to-build as a strategic choice involving a time-cost tradeoff in the context of market-entry timing. The current study pays particular attention to market conditions at entry. It contributes to this research by joining the firm's market-entry timing with its entry speed and cost (Teece et al., 1997). In particular, the current study considers the tradeoffs of benefits and costs in explaining and predicting the firm's time-to-build and cost-to-build in response to market conditions at the time of market entry.

Re-framing the firm's strategic decision enables us to incorporate time-to-build as a strategic choice in response to demand conditions (which impacts revenue curves) and as a learning outcome of the market-entry timing decision (which impacts cost curves). Specifically, the current research's analytical model develops our understanding of the market-entry timing effect on time-to-build and cost-to-build. This study's analytical model derives the seven scenarios from combinations of revenue and cost effects of market-entry timing. Distinctive empirical predictions are anticipated for each scenario, allowing us to discern whether the revenue and cost effects are substantially at play in the context of the global liquefied natural gas (LNG) industry.

The model captures the tradeoff concerning the firm's time-to-build by considering the firm's increases in costs that result from its decision to decrease its time-to-build vis-à-vis the firm's revenues deferment resulting from its decision to allow its time-to-build to be longer. The model focuses on the firm's choice of time-to-build, conditional on its entry timing. In particular, the early and late entrants discount their expected flow of revenues until they make their entry decision. Because of the posited reduction in the uncertainty of the discounted revenue streams over time, the outcome results in differential time-to-build for the two entrants.

In terms of revenues, firms entering the market late when demand uncertainty is reduced in ways that increase the probability of the high-demand scenario have a greater incentive to decrease their time-to-build because higher revenue flow is expected to occur sooner, which can more than compensate for any additional costs incurred in decreasing the time-to-build. Therefore, the decreased time-to-build for late entrants is a profit-maximizing decision. In this case, the greater cost-to-build of the late entrant is a result of this shorter optimal time-to-build under the time-cost tradeoff.

In terms of costs, firms entering the market late have additional opportunities for experiential learning from the early-market entry (i.e., learning-by-doing) or vicarious learning (i.e., learning by observing) (Huber, 1991). This benefit of learning by the late entrant enables it to shorten the time lag to build its plants at the same cost. The shifting cost curve in the model captures this reasoning.

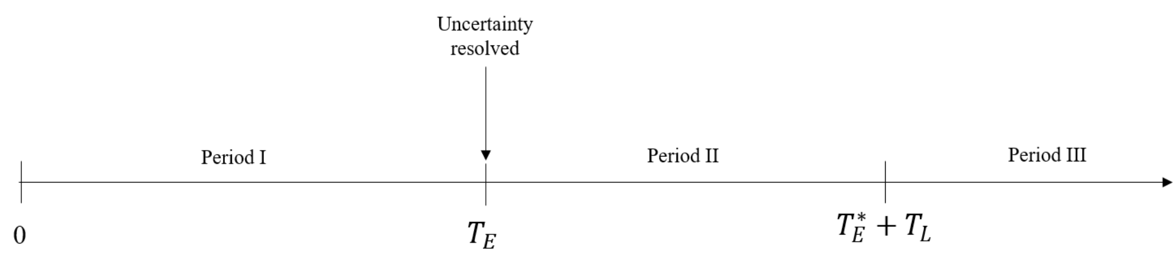
We test the development theory in the context of the global liquefied natural gas (LNG) industry from 1996 to 2007. To account for endogeneity bias from self-selection, we use Wooldridge's three-step instrumental variable (IV) approach, using 'price uncertainty' as an instrumental variable. We find that the late entrant has (1) a shorter time-to-build and (2) a higher cost-to-build relative to the early entrant. Moreover, (3) The negative relationship between cost-to-build and time-to-build is positively moderated by the late entrant (i.e., the negative relationship between cost-to-build and time-to-build gets less negative for the late entrant). These empirical results are consistent with the prediction when the revenue curve in response to better demand conditions and the cost curve leftward shift as an outcome of learning.

MODEL

Model Setting

We model two firms competing in a homogenous output market. We denote the early entrant by E and the late entrant by L. There are three time periods designated by I, II, and III. Figure 1 depicts the three time periods within this developed model, described below.

FIGURE 1
THE TIMING OF THE MODE



The early entrant makes investments in period I. We denote the early market entrant by E and the late market entrant (i.e., those firms that invest in period II) by L. We label the time-to-build of the early entrant by T_E and the late entrant by T_L. A key contribution to the extant research literature is that this model captures the real-world feature that managers will typically consider time-to-build as a *strategic* choice in the context of entry-timing decisions. The early entrant invests in period I with a strategic choice in their time-to-build T_E^* that maximizes its net present value (NPV). In this model, we posit demand uncertainty to be resolved fully at $t = T_E^*$. Note that once the early entrant calculates its T_E^* , it has determined its calendar time for investment completion (and for starting its operations). The late entrant enters the market with T_L^* that maximizes its NPV. Note that once the late entrant calculates its T_L^*, the calendar time for investment completion (and for starting operations) of the late entrant is also fully determined.

The model is in continuous time, denoted by t > 0. We posit that the investments are irreversible for both the early and late entrants. Each firm incurs costs, receives revenues, and seeks to maximize its discounted cash flows (i.e., its respective NPVs) for a common discount rate $\delta \in (0, 1)$, which reflects the firm's capital cost. If the late entrant does not develop the resource, the current study sets $T_L = \infty$.

Expected Revenue and Cost for the Early Entrant

Expected Revenues for the Early Entrant

When demand uncertainty is not yet resolved (at $\mathrm{t} = 0$), firms have their subjective expectation concerning output market demand. Firm *i* has the expected flow of revenues for good demand and bad demand with its probability for each case. When the demand is good, the expected flow of revenues is r_G and its probability is p_i. When the demand is bad, the expected flow of revenues is r_B and its probability is $1 - p_i$ where $\mathrm{r}_G > \mathrm{r}_B$. Firms having better market demand expectations and anticipating that their NPV will be positive become firm *E* by entering the market in period I (i.e., $p_E > p_L$). The model captures the possibility that a firm entering the market in period I can also enter the market in period II.

The present value of the expected revenue flows that the early entrant faces at the time of market entry is then

$$R_E(T) = \int_{T_E}^{\infty} r_E e^{-\delta t} d \tag{1}$$

Expected Costs for the Early Entrant

A firm's total construction cost for its plant is a function of time-to-build under a time-cost tradeoff. In the current study, the time-cost tradeoff is captured as: a one percent decrease in a firm's time-to-build its plant typically requires more than a one percent increase in the firm's total construction cost for its plant (Boehm, 1981; Graves, 1989; Mansfield, 1971; Scherer, 1967, 1984). As will be shown later, this time-cost tradeoff is observed in our data from 1996 to 2000.

We denote the early entrant's cost function of time-to-build its plant by $C_E(\mathrm{T})$:

$$C_E(T) = c(T) + k \; for \; k \; is \; constant \tag{2}$$

In the model, a sufficient condition for the time-cost tradeoff is $c'(T) < 0$, $\lim_{T \to 0} c'(T) = -\infty$, $\lim_{T \to \infty} c'(T) = 0$, and $c''(T) > 0$. For the case where the late entrant does not develop the resource, $T_L = \infty$.

The early entrant seeks to maximize the NPV of its cash flows as given by:

$$\prod\nolimits_E = R_E - C_E(T) \tag{3}$$

Expected Revenue and Cost for the Late Entrant

Expected Revenues for the Late Entrant

When demand uncertainty is resolved (at $\mathrm{t} = T_E^*$), firm *L* has the expected revenues flow r_G with probability one. Early entrant *E* and late entrant *L* are assumed to be identical except for their probability for demand p_i before the demand uncertainty is resolved.

The expected flow of revenues of the early entrant *E* is denoted by r_E and the expected flow of revenues of the late entrant *L* by r_L. Since each entrant E and L will have $\mathrm{r}_E = \mathrm{r}_G \times p_E + \mathrm{r}_B \times (1 - p_E)$ and $\mathrm{r}_L = r_G \times 1 + \mathrm{r}_B \times 0$, r_E and r_L satisfy $0 < r_E < r_L$. The late entrant makes an investment decision with the expected revenue flow of r_L when the early entrant completes its plant construction (and starts operation) at $\mathrm{t} = T_E^*$.

The present value of the expected revenue flows that the late entrant faces at the time of market entry is then:

$$R_L(T) = \int_{T_L}^{\infty} \mathrm{r}_L e^{-\delta t} dt \tag{4}$$

Note that the starting point of integration for the late entrant is T_L, not $T_E^* + T_L$. Because this late entrant makes its entry decision at time $\mathrm{t} = T_E^*$, the expected revenue flows are discounted up to T_E^*.

Expected Costs for the Late Entrant

For the late entrant, the total construction cost for its plants is still a function of time-to-build under a time-cost tradeoff. The late entrant's *ratio* of lower time-to-build and increased cost is assumed to be the same as the early entrant. That is, the shape of a cost curve for the late entrant is the same as for the early entrant. However, regarding absolute costs, the late entrants might have a shorter time-to-build for the same cost-to-build because of experiential learning from the early-market entry (i.e., learning-by-doing) or s learning (i.e., learning by observing). Three cost-curve shifts capture this benefit of learning by the late entrant: downward shift, leftward shift, and downward & leftward shift. We denote the early entrant's cost function of time-to-build its plant by C_L(T) in the model.

(a) For the case of cost-curve downward shift by γ_1 ($\gamma_1 \geq 0$):

$$C_L(T) = c(T) + k - \gamma_1 \tag{5}$$

(b) For the case of cost-curve leftward shift by γ_2 ($\gamma_2 \geq 0$):

$$C_L(T) = c(T + \gamma_2) + k \tag{6}$$

(c) For the case of cost-curve downward shift by γ_1 & leftward shift by γ_2 ($\gamma_1 \geq 0$, $\gamma_2 \geq 0, |\gamma_1 - \gamma_2| \cong 0$):

$$C_L(T) = c(T + \gamma_2) + k - \gamma_1 \tag{7}$$

In the model, the late entrant seeks to maximize the NPV of its cash flows as given by:

$$\prod_L = R_L(\mathrm{T}) - C_L(T) \tag{8}$$

RESULTS FROM THE MODELS

The Effect of Late-Market Entry in Revenue Shift Only

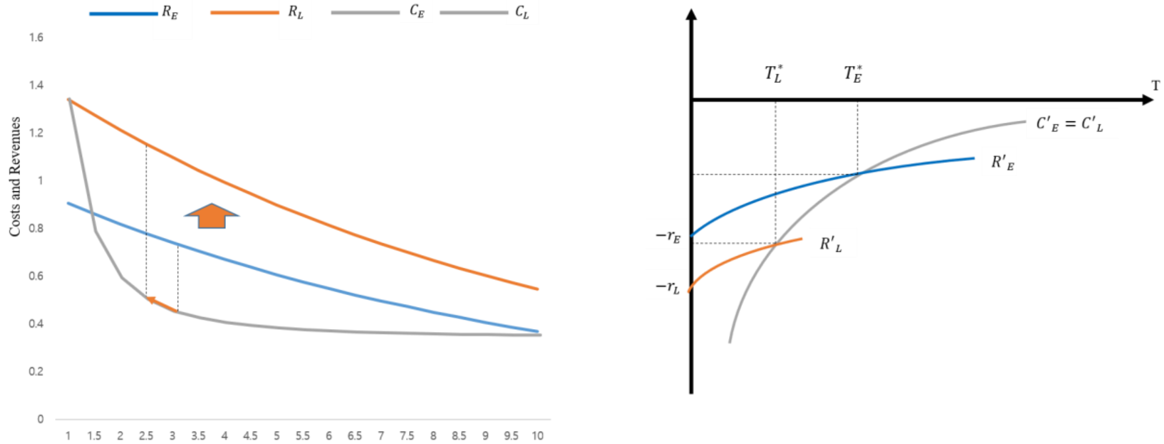
Figure 2(a) illustrates the expected discounted revenue flows for the early entrant (R_E), the expected discounted revenue flows of the late entrant (R_L), and the costs (C). The cost curve captures a time-cost tradeoff. Since the late entrant faces steeper increases in revenue as time-to-build decreases, the optimal time-to-build of the late entrant (T_L^*) is shorter than that of the early entrant (T_E^*), (i.e., $T_L^* < T_E^*$). The late entrant has higher cost-to-build relative to the early entrant (i.e., $C_{T_E^*} < C_{T_L^*}$) to decrease its time-to-build T_E^* by increasing costs higher because of the time-cost tradeoff.

Figure 2(b) illustrates a first derivative of expected revenue flows for the early entrant (R'_E), a first derivative of expected revenue flows for the late entrant (R'_L), and a first derivative of costs (C'). The optimal time-to-build of the late entrant (T_L^*) is shorter than that of the early entrant (T_E^*), (that is, $T_L^* < T_E^*$) and the late entrant's shorter time-to-build T_E^* is achieved by increasingly higher costs because of time-cost tradeoff (i.e., $C' < 0$ and $\left|\mathrm{C}'_{T_E^*}\right| < \left|\mathrm{C}'_{T_L^*}\right|$).

We report one first-order derivative for the remaining sections.

FIGURE 2
EFFECT ON TIME-TO-BUILD AND COST-TO-BUILD ON THE REVENUE SIDE ONLY

(a) Net present value (NPV) **(b) First-order derivative from the model**



The Effect of Late-Market Entry in Cost Shift Only

Cost Curve Downward Shift

Figure 3(a) illustrates the effect of late-market entry when cost curve shifts downward. As shown in Figure 3(a)i, the optimal time-to-build of the late entrant (T_L^*) does not change relative to that of the early entrant (T_E^*), (i.e., $T_L^* = T_E^*$). However, the late entrant has lower cost-to-build relative to the early entrant (i.e., $C_{T_E^*} > C_{T_L^*}$). 3(a)ii also shows that the optimal time-to-build of the late entrant (T_L^*) does not change relative to that of early entrants (T_E^*), (i.e., $T_L^* = T_E^*$). It predicts no moderating effect of late-market entry on the negative relationship between cost-to-build and time-to-build.

Cost Curve Leftward Shift

Figure 3(b) illustrates the effect of late-market entry when cost curve shifts leftward. As shown in Figure 3(b)i, the optimal time-to-build of the late entrant (T_L^*) is shorter than that of early entrants (T_E^*), (i.e., $T_L^* < T_E^*$). The late entrant has slightly higher cost-to-build relative to the early entrant, but almost negligible (i.e., $C_{T_E^*} \cong C_{T_L^*}$). Figure 3(b)ii shows that the optimal time-to-build of the late entrant (T_L^*) is shorter than that of the early entrant (T_E^*), (i.e., $T_L^* < T_E^*$). It also shows that the negative relationship between cost-to-build and time-to-build gets less negative for the late entrant (i.e., a positive moderating effect of late-market entry on the negative relationship between cost-to-build and time-to-build).

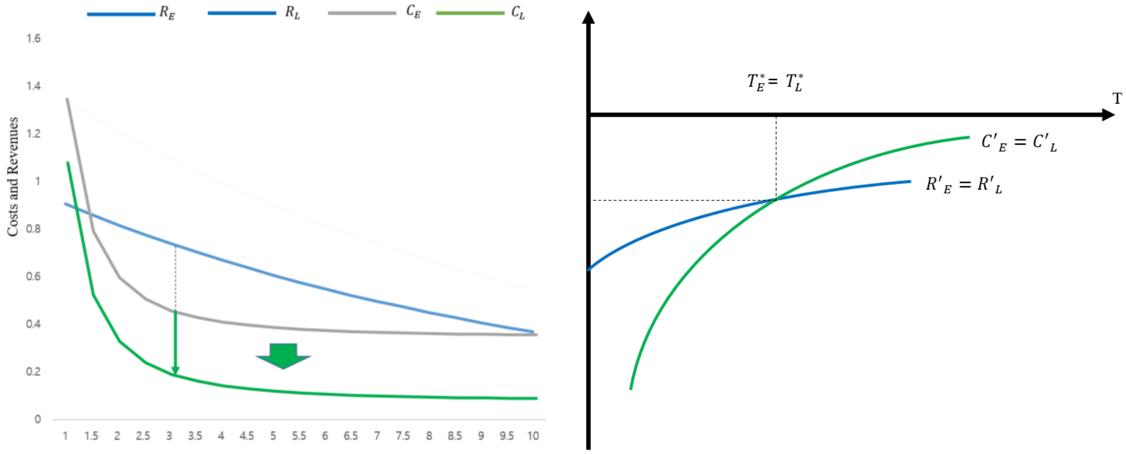
Cost Curve Downward & Leftward Shift

Figure 3(c) illustrates the effect of late-market entry when cost curve shifts down- & leftward. As shown in Figure 3(b)i, the optimal time-to-build of the late entrant (T_L^*) is shorter than that of early entrants (T_E^*), (i.e., $T_L^* < T_E^*$). The late entrant has lower cost-to-build relative to the early entrant (i.e., $C_{T_E^*} > C_{T_L^*}$). Figure 3(b)ii shows that the optimal time-to-build of the late entrant (T_L^*) is shorter than that of early entrants (T_E^*), (i.e., $T_L^* < T_E^*$). It also shows that the negative relationship between cost-to-build and time-to-build gets less negative for the late entrant (i.e., a positive moderating effect of late-market entry on the negative relationship between cost-to-build and time-to-build).

FIGURE 3
EFFECT ON TIME-TO-BUILD AND COST-TO-BUILD ON THE COST SIDE ONLY

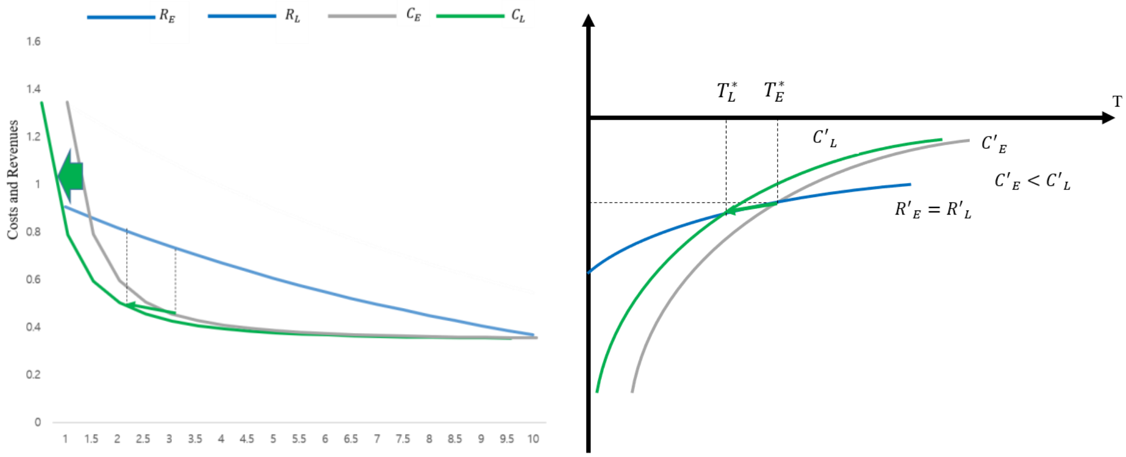
(a) Cost-curve downward shift

i. Net present value (NPV) ii. First-order derivative



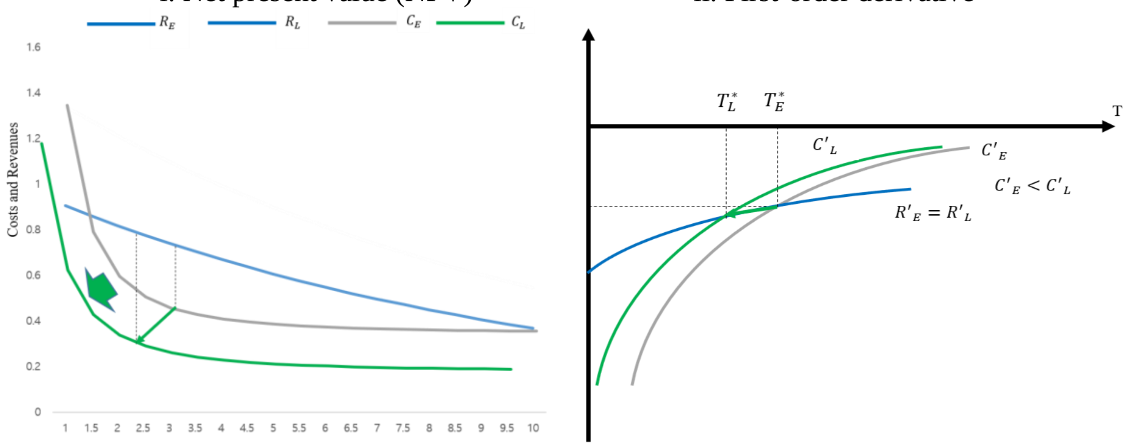
(b) Cost-curve leftward shift

i. Net present value (NPV) ii. First-order derivative



(c) Cost-curve downward & leftward shift

i. Net present value (NPV) ii. First-order derivative



Effect of Late-Market Entry on Both Revenue Side and Cost Side

Revenue Curve Shift & Cost Curve Downward Shift

Figure 4(a) illustrates the effect of late-market entry when the revenue curve shifts upward and cost curve shifts downward. As shown in Figure 4(a)i, the optimal time-to-build of the late entrant (T_L^*) is shorter than that of early entrant (T_E^*), (i.e., $T_L^* < T_E^*$). The late entrant's cost-to-build relative to the early entrant is indeterminable and varies depending on the relative impact of each curve. Figure 4(a)ii also shows that the optimal time-to-build of the late entrant (T_L^*) is shorter than that of early entrant (T_E^*), (i.e., $T_L^* < T_E^*$). It also shows that the negative relationship between cost-to-build and time-to-build gets less negative for the late entrant (i.e., a positive moderating effect of late-market entry on the negative relationship between cost-to-build and time-to-build).

Revenue Curve Shift & Cost Curve Leftward Shift

Figure 4(b) illustrates the effect of late-market entry when the revenue curve shifts upward and cost curve shifts leftward. As shown in Figure 4(b)i, the optimal time-to-build of the late entrant (T_L^*) is shorter than that of early entrant (T_E^*), (i.e., $T_L^* < T_E^*$). The late entrant has higher cost-to-build relative to the early entrant (i.e., $C_{T_E^*} < C_{T_L^*}$). Figure 4(b)ii shows that the optimal time-to-build of the late entrant (T_L^*) is shorter than that of early entrants (T_E^*), (i.e., $T_L^* < T_E^*$). It also shows that the negative relationship between cost-to-build and time-to-build gets less negative for the late entrant (i.e., a positive moderating effect of late-market entry on the negative relationship between cost-to-build and time-to-build).

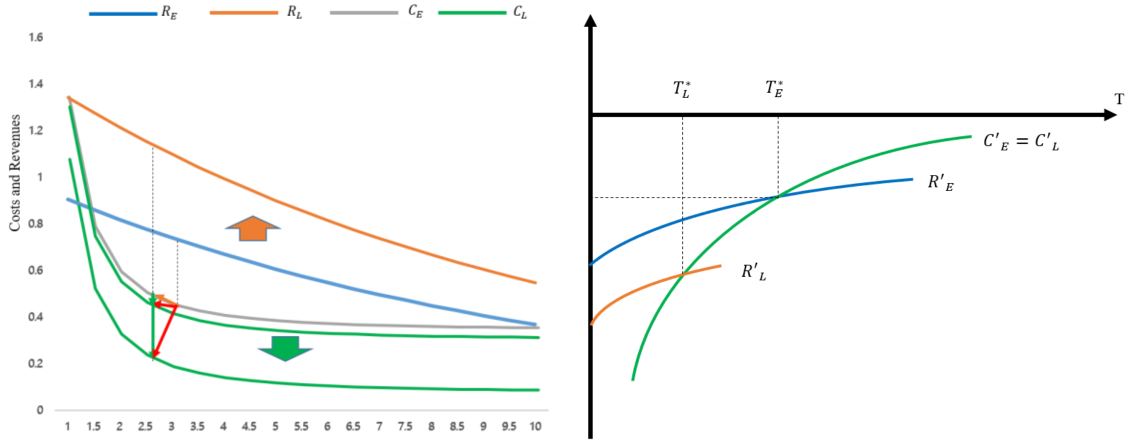
Revenue Curve Shift & Cost Curve Downward and Leftward Shift

Figure 4(c) illustrates the effect of late-market entry when the revenue curve shifts upward and cost curve shifts downward and leftward. As shown in Figure 4(c)i, the optimal time-to-build of the late entrant (T_L^*) is shorter than that of the early entrant (T_E^*), (i.e., $T_L^* < T_E^*$). The late entrant's cost-to-build relative to the early entrant is indeterminable and varies depending on the relative impact of each curve. Figure 4(c)ii shows that the optimal time-to-build of the late entrant (T_L^*) is shorter than that of early entrant (T_E^*), (i.e., $T_L^* < T_E^*$). It also shows that the negative relationship between cost-to-build and time-to-build gets less negative for the late entrant (i.e., a positive moderating effect of late-market entry on the negative relationship between cost-to-build and time-to-build).

FIGURE 4
EFFECT ON TIME-TO-BUILD AND COST-TO-BUILD IN BOTH REVENUE SIDE AND COST SIDE

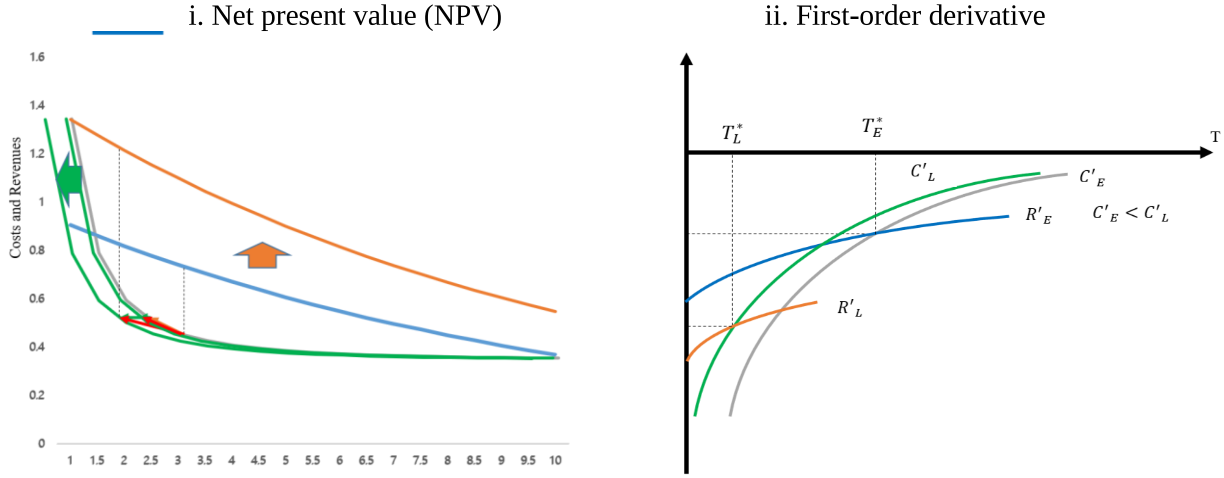
(a) Revenue-curve shift and cost-curve downward shift

i. Net present value (NPV) ii. First-order derivative



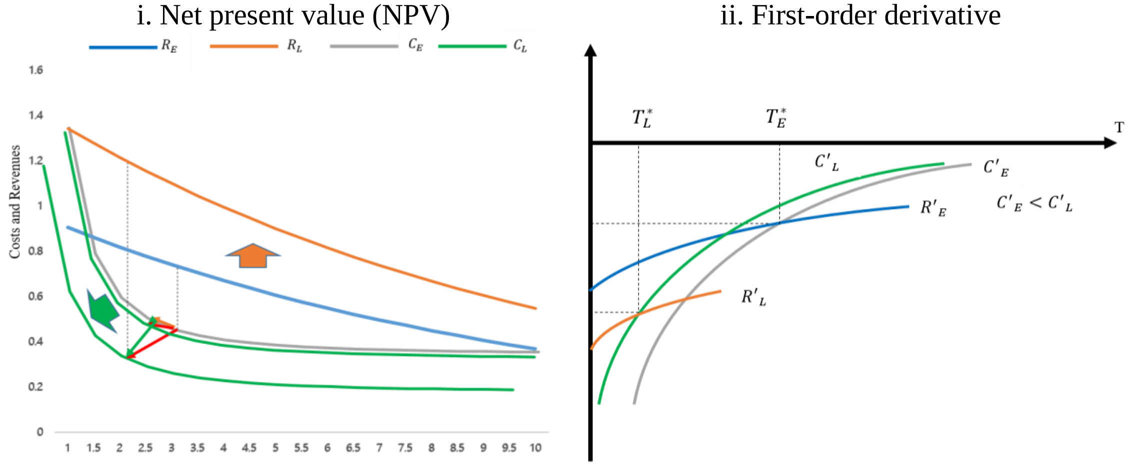
(b) Revenue-curve shift and cost-curve leftward shift

i. Net present value (NPV) ii. First-order derivative



(c) Revenue-curve shift and cost-curve downward & leftward shift

i. Net present value (NPV) ii. First-order derivative



Summary

Table 1 summarizes empirical predictions for each scenario of revenue shift curve and cost curve shifts. As shown in Table 1, each scenario produces specific predictions regarding the market-entry timing effect on time-to-build and cost-to-build. Even though it is an empirical question of which scenario will be observed, we anticipate the scenario when both the revenue and cost curves shift (i.e., scenarios 5, 6, or 7 Table 1).

This section makes contributions to the study of market-entry timing and time-to-build. The extant literature views the time-to-build as an exogenous capability moderating the entry-timing effects without considering the firm's time-cost tradeoff or as an endogenous (i.e., strategic) choice involving a time-cost tradeoff without considering market-entry timing. The current study views firms' time-to-build as a strategic choice involving time-cost tradeoff while considering market-entry timing. This perspective enables us to incorporate time-to-build as a strategic choice in response to demand uncertainty (which impacts revenues) and as a learning outcome of the market-entry timing decision (which impacts costs). We provide specific empirical predictions for each case of the revenue and cost-effect combinations. Distinctive empirical predictions are anticipated for each scenario, allowing us to discern whether the revenue effect (i.e., revenue curve shift) and the cost effect (i.e., cost curve shift) are substantially at play in the global LNG industry context.

TABLE 1
EMPIRICAL PREDICTIONS SUMMARY FOR THE COMBINATIONS OF COST SIDE AND REVENUE SIDE

Case of combination	Empirical prediction (a) $time = \alpha_2 late + \alpha_3 cost$ $time = \alpha_1 late \times cost + \alpha_2 late + \alpha_3 cost$ (b) $cost = \beta_2 late + \beta_3 time$ $cost = \beta_1 late \times time + \beta_2 late + \beta_3 time$					
	α_1	α_2	α_3	β_1	β_2	β_3
(1) Revenue side only: Revenue curve upward shift	0	−	−	0	+	−
(2) Cost side only: cost-curve downward shift	0	0	−	0	−	−
(3) Cost side only: cost-curve leftward shift	+	−	−	+	0	−
(4) Cost side only: cost-curve downward & leftward shift	+	−	−	+	−	−
(5) Revenue curve upward shifht & cost-curve downward shift	0	−	−	0	±, 0	−
(6) Revenue curve upward shift & cost-curve leftward shift	+	−	−	+	+	−
(7) Revenue curve upward shifht & cost-curve downward & leftward shift	+	−	−	+	±, 0	−

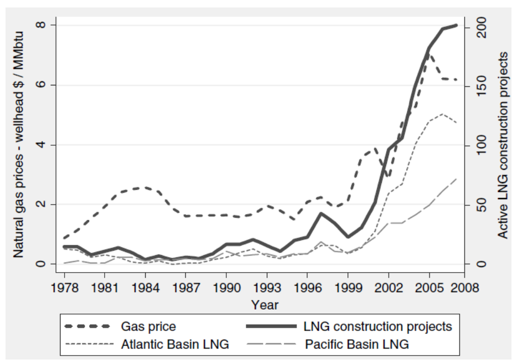
+: positive effect
−: negative effect
±: can be either positive or negative
0: no effect

EMPIRICAL CONTEXT AND RESEARCH DESIGN

Sample

The current study examines the effect of the market-entry timing on firms' time-to-build and cost-to-build in the context of the Atlantic Basin LNG submarket of the global LNG industry from 1996 to 2007. We choose the sample period from 1996 to 2007 for ease of comparison to Hawk *et al.* (2013), which uses the same periods to test the time-to-build effect on a firm's entry timing. In addition, natural gas price begins to decline after 2007. A post-2007 period does not fit into the growth stage, but into the shakeout stage of the industry life cycle. We do not use a pre-1996 period because it is hard to identify relevant data before 1996. This context is attractive because the empirical pattern of the emergence of the Atlantic Basin sub-market is consistent with previous studies on industry evolution (Agarwal & Gort, 1996; Gort & Klepper, 1982). Further, a firm's plant-construction investment decision is strategic and informed by existing knowledge regarding price level, uncertainty, and other firm characteristics. Moreover, we can empirically observe a key construct in the strategy field: time compression diseconomies.

FIGURE 5
GLOBAL LIQUEFIED NATURAL (LNG) INDUSTRY, 1996-2007



Hawk et al., 2013

Industry evolution literature divided the early stage of industry into two phases. In Phase I, entry is slow and steady. In Phase II, entry accelerates until reaching a peak. 'A sharp increase in the entry rate of new competitors into the industry' (Gort & Klepper, 1982, p.631) usually determines the boundary between Phase I and II. This increase in the entry is typically related to new information 'emanating from sources outside the set of current producers' (Gort & Klepper, 1982, p. 632). As shown in Figure 5, the empirical pattern of construction activity in the LNG industry is consistent with the patterns studied in industry evolution literature. Entry happened very slowly before late 2000 until natural gas prices remained low and steady historically, representing high market uncertainty. In the winter of 2000, an energy market liberalization and increased demand were driven by gas power plants. Natural gas prices rose to more than five times the typical price level, and a consensus of uncertainty reduction was made. Entry dramatically accelerates in the LNG industry until the end of our sample. Following these empirical observations, we partitioned the entry based on the change in LNG pricing in 2000: a pre-2000 regime corresponds to Phase I, and a post-2000 regime corresponds to Phase II with an empirically validated and exogenously determined uncertainty reduction. The current study does not consider the technological change (as in Gort & Klepper, 1982) as the boundary between Phases I and II because the LNG industry relies on a standardized technology, and entry is not constrained by proprietary technology or technology innovation. For more details about the industry, refer to the appendix of Hawk et al. (2013).

The current study's empirical context is also consistent with the setting of the mathematical model presented in the previous section, in which the late entrant faces a higher price relative to the early entrant when output market demand uncertainty is resolved.

In addition, a firm's plant-construction investment decision is strategic and informed by existing knowledge regarding price level, price uncertainty, and other firm characteristics. As shown in column I in Table 2, (1) a firm's entry is positively associated with price level, (2) negatively associated with price uncertainty, and (3) associated with other firm characteristics.

Moreover, we can empirically observe a time-cost tradeoff. As shown in column II in Table 2, for a 1% increase in the cost (per ton capacity), time-to-build per ton capacity decreases by 0.596% during the early period of the sample. Although this time-cost tradeoff is not statistically significant in Column III during the late period of the sample, it is possible because it includes firms with heterogeneous capabilities (Hawk & Pacheco-de-Almeida, 2018).

TABLE 2
REGRESSION WITH CONTROL AND TIME COMPRESSION DISECONOMIES

	I Entry into Global LNG Probit	II ln(time-to-build per ton capacity) 1996-2000 / OLS	III ln(time-to-build per ton capacity) 2001-2007 / OLS
ln(cost-to-build per ton capacity)		-0.596*** (0.073)	-0.132 (0.112)
Price	0. 119** (0. 037)	-0.004+ (0.002)	-0.001 (0.003)
Price uncertainty	-0.018** (0. 006)	-0.001 (0.001)	0.000 (0.000)
Firm Size	0.069** (0.026)	0.006 (0.004)	-0.001 (0.008)
Age	-0.062 (0.051)	0.008 (0.007)	-0.005 (0.018)
Age^2	0.018 (0.030)	0.000 (0.004))	-0.007 (0.008)
Experience	0.092*** (0.019)	-0.005 (0.006)	0.001 (0.003)
Oil & Gas Production	-0.094* (0.046)	-0.008* (0.004)	0.015 (0.010)
Oil & Gas Reserves	0.082+ (0.044)	0.011** (0.003)	-0.005 (0.011)
Industry dummies	Y	Y	Y
N	6,924	910	2,758
Log-L	-668.026		
Prob>chi^2 (or F)	0.0000	0.0000	0.0011
Pseudo R^2 (or R^2)	0.1089	0.7571	0.1882

*** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$ + $p < 0.1$

Results reported in Column I are from estimating the probit model of a firm's entry into the LNG industry from 1996 to 2007. Results reported in Column II are from estimation of ordinary least squares on time-to-build in the LNG industry from 1996 to 2000. Results reported in Column III are from estimating an OLS model on time-to-build in the LNG industry from 2001 to 2007. Industry dummies and a constant are included in the regressions, but results are not reported in the table. Standard errors are robust to clustering by the firm in all Columns. Because the original time-to-build per ton capacity and cost-to-build per ton capacity capture relative characteristics and contain negative values, we used shifted time-to-build and cost-to-build, resulting in positive values only. Results are consistent for the different magnitudes of shifts (i.e., from the minimum value of measures to 10,000).

Data

To obtain our dataset, we first identify the proposed LNG construction projects from the *Oil & Gas Journal* (OGJ), Tusiani and Shearer's (2007) LNG: *A Non-technical Guide*, firm Web sites, Web searches, and other sources. We hand-collect other plant-level data, such as plant costs, plant quality, construction start date, commercial operation date, and delay events. Through this process, we identify 72 LNG plant construction projects that started construction in our sample period. In most cases, multiple firms conduct each project. We then use this project dataset to construct firm panel data and a firm's operational efficiency in building a plant.

We define entry as the 'construction' of a liquefaction or gasification plant because the construction involves the highest sunk-cost commitment among the firm's other decisions in executing this project. Such a commitment is credible for the following reasons. First, the firm's plant construction does not begin until the board of directors makes its final investment decision, which entails contractual obligations and is thus costly to reverse. Second, the firm has little ability to change its plant construction plans after construction begins and is thus "locked in" to its planned course of action (Department of Energy, 2016: 95). The commitments investigated in the current study qualify as strategic in the sense that they involve (staged) irreversible investments under uncertainty (Dixit & Pindyck, 1994; Trigeorgis, 1996). After the firm's early design stage, an estimate of the LNG plant cost typically has a substantial uncertainty in its cost estimate of 30-40%. After the design stage, the uncertainty in the cost estimate is 15-25%. After the engineering procurement construction contract, the cost estimate has an uncertainty of 10-15% as the firm gathers more information and does progressively more design work. Following Ghemawat (1991), this dissertation considers the timing of commitment (i.e., the timing of an irreversible investment) as a critical component of what it means for a firm to be "strategic." Thus, this study focuses on the category of substantial irreversible investment, in which 72 out of 306 plants in our sample resulted in actual construction from 1996 to 2007.

These plant-level data are matched into the firm-month, parent company-level panel data using the ownership information collected during our data work. We matched these data with hand-collected firm-level data such as Oil & Gas Productions and Reserves and financial information. OGJ100/200 (the OGJ's survey of the 100 leading U.S.-based and leading international oil and gas companies), company annual reports and 10-Ks, and *Compustat* are used for these data. After deleting observations due to missing data for needed variables, our final panel data set covered over 12 years, from 1996 to 2007, and produced a sample of 3,759 firm-month records corresponding to 46 firms. It is warranted to claim that this data set comprises a fairly comprehensive panel data set covering most of the entrants into the LNG industry with available and useable data for covariates.

Measures

Independent Variable: Late Entrant

Following the partition between Phase I and II in the industry life cycle, we create a late entrant variable that equals '1' for a post-2000 period in the firm panel data and '0' for a pre-2000 period.

Dependent Variable: Time-to-Build and Cost-to-Build (Per Ton Capacity)

This study defines the construct of "time-to-build" (per ton capacity) as the time lag between the construction beginning and commercial operation (per ton capacity). Further, this study defines the construct of "cost-to-build" (per ton capacity) as the construction cost (per ton capacity). Because the mathematical model we introduced in the previous section above relies on *ceteris paribus* assumptions, the firm's time-to-build its plant and its cost are (by the parsimonious model construction) directly comparable between the early entrant and the late entrant. That is, in the tradition of industrial organization economics, the current study's developed mathematical model posits identical firms working on identical plants in an identical market.

However, an essential element that often distinguishes the industrial organization approach from the strategic management approach, primarily based on the resource-based view, is that firms are posited as *heterogeneous* (e.g., Barney, 1991; Mahoney & Pandian, 1992; Rumelt, 1984). Thus, the empirical testing will need to parse out (heterogeneous) plants, firms, and markets influence the firm's strategic choice of time-to-build. In our empirical setting, we anticipate that firms will have heterogeneous capabilities in their time-to-build (per ton capacity). Thus the empirical testing will need to parse out how plant, firm, and market effects influence the firm's time-to-build decision.

To obtain comparable time-to-build per ton capacity and cost-to-build per ton capacity, we take several steps below following the approach of Pacheco-de-Almeida et al. (2015). Regarding time-to-build per ton capacity, the first step is to collect time-to-build per ton capacity for each plant. In the second step, we adjust the nominal time-to-build for plant- and market-level variables. Since a project often consists of plural firms, we do not control for firm-level variables in this step but rather in the final regression of market entry. In the third step, we standardize residuals from the second step within each region subgroup for each year. In the fourth step, we average the standardized residuals from the third step for each firm's projects beginning in the month. Finally, in the fifth step, we map the monthly average to a panel of firm observations. We carry this measure to future months when no new information is available. Regarding cost-to-build per ton capacity, we first collect the cost per ton capacity for each plant. As outlined above, we repeat the steps from the second to the fifth step.

First, we hand-collected data to identify the construction beginning and commercial operation dates to help determine the nominal time-to-build per ton capacity. When the construction beginning date was unavailable, but the construction duration and commercial operation date were identified, we calculated the construction start date from them. When the construction start date and duration were unclear, we used the Engineering-Procurement-Construction (EPC) contract award date as a proxy for the construction beginning date. If the EPC contract award date was unavailable, we used the board of directors' final investment decision (FID) date as the next best proxy for the construction beginning date and then calculated nominal time-to-build. We calculate the average months between EPC and construction calendar dates when both are observable in the current study's s data set. Months of difference on average is 1.6 months. We also calculate the average months between FID and construction calendar dates when both are observable in the current study's s data set. Months of difference on average is 2.5 months. The average time-to-build is 41.2 months, with a standard deviation of 13.9 months. We divide a plant's nominal time-to-build by ton capacity to obtain the nominal time-to-build per ton capacity. In order to get nominal cost-to-build per ton capacity, we hand-collected the plant construction cost estimate in millions of US dollars (USD). The cost estimate is typically available when the EPC contract is awarded or the construction is completed. When several cost estimates are available over time, we use the most updated publicly available information concerning a particular plant. When the currency unit is not USD, we used the yearly-averaged exchange rate to convert other currency units into USD. We deflated the cost estimate in USD to 1996 prices using the yearly-averaged consumer price index (CPI). We divide this deflated plant cost estimate by ton capacity to get the nominal cost-to-build per ton capacity. We explain time-to-build per ton capacity only since we repeat the rest of the steps for the cost-to-build per ton capacity.

Second, we adjust nominal time-to-build per ton capacity for plant-level variables (e.g., plant size, usage, quality, and types) and market-level variables (e.g., demand growth, geography, and year). In this approach, we decompose the time-to-build per ton capacity of each plant into a systematic component (i.e., average time-to-build in the sample) and a plant-specific component (corresponding to the degree to which a firm has s shorter or a longer time-to-build per ton capacity than the average time-to-build in the sample). Specifically, we pull plant-level data from all firms for all facilities (indexed by *f*), all geographic regions (indexed by *l*), and all years (indexed by *t*) in our sample by running the following regression:

$$\ln T_{f,l,t} = \beta_1 \ln E_{f,l,t} + \beta_2 \ln {E_{f,l,t}}^2 + \beta_3 P_{f,l,t} + \beta_4 Q_{f,l,t} + \beta_5 NDUM_{f,l,t} + \beta_6 \ln \overline{\Delta}_{l,t} + \beta_7 \mathrm{LDUM}_l + \beta_8 \mathrm{YDUM}_t + \theta_{f,l,t} \tag{9}$$

where T is the nominal time-to-build per ton capacity, E is the ton capacity of a plant, P is the plant usage dummy, Q is the plant quality dummy, NDUM is the plant type dummies, $\overline{\Delta}$ is the proxy for the local demand growth, and LDUM and YDUM are geographic region dummies and year dummies respectively.

The ton capacity of a plant can affect time-to-build per ton capacity due to economies of scale (captured by $\ln E_{f,l,t}$) and diseconomies of scale (captured by $\ln E_{f,l,t}{}^{2}$). The ton capacity of a plant is measured as capacity figures in million tons per year. Plant usage can also influence the time-to-build due to the different usage specificity. Plant usage is measured as 1 if a plant is a liquefaction plant and 0 if a plant is a regasification plant. Quality can also influence the time-to-build per ton capacity since plant time-to-build can be shorter at the expense of the plant quality. Alternatively, bad plant management may lead to poor quality and longer time-to-build, so poor quality and longer time-to-build can be positively correlated. Plant quality is measured as 1 if a plant is shut down for maintenance within a year of commercial operation. Plant types such as new, expansion, or revamp can influence time-to-build per ton capacity. We include dummy variables for plant type. Local demand growth ($\overline{\Delta}_{l,t}$) is proxied by the yearly growth rate in real GDP in the plant's country from the World Bank Development Indicators database. In addition, we include geographic region and year dummy variables to capture year-specific and geography-specific effects (i.e., bureaucratic delays). We use the following: Asia and the Pacific; Eastern Europe; Former USSR; Japan; Latin America and the Caribbean; North Africa and the Middle East; North America; Sub-Saharan Africa; and Western Europe.

The estimated residual $\theta_{f,l,t}$ associated with a plant for a given firm (denoted $\theta^{j}_{f,l,t}$ for firm *j*) from our estimation of Equation 1 represents the plant-specific component of the time-to-build that is uncorrelated with the systematic determinants of time-to-build associated with plant ton capacity, quality, usage, types, demand condition, time fixed effects, and geography fixed effects. A positive residual indicates that the plant was finished slower than average, whereas a negative residual implies the plant was finished faster than average.

Third, for comparability, we standardize the measure within each region subgroup for each year. We calculate the mean and standard deviation of $\theta^{j}_{f,l,t}$ within each region subgroup for each year, where the mean is calculated as $\bar{\theta}_{l,t} = \frac{\sum_j \sum_f \theta^{j}_{f,l,t}}{n_{l,t}}$ and the standard deviation is calculated as $\sigma_{l,t} = \left[\frac{\sum_j \sum_f \left(\theta^{j}_{f,l,t} - \bar{\theta}_{l,t}\right)^2}{n_{l,t} - 1}\right]^2$. We then standardize each observation of $\theta^{j}_{f,l,t}$ using $\bar{\theta}_{l,t}$ and $\sigma_{l,t}$ as follows: $\tilde{\theta}^{j}_{f,l,t} = \frac{\theta^{j}_{f,l,t} - \bar{\theta}_{l,t}}{\sigma_{l,t}}$.

Fourth, we build our measure of time-to-build per ton capacity for firm *j* by summing up the standardized plant time-to-build per ton capacity $\tilde{\theta}^{j}_{f,l,t}$ for all of the plants that firm *j* begin in month t and taking the average.

Finally, we map our averaged, standardized time-to-build per ton capacity measure from fourth step into a panel of firm-month observations. We aim to have a firm time-to-build per ton capacity measure over time. Thus, we take the following approach. We carry forward our time-to-build per ton capacity measure to future months when no new information is available. In the robustness check, we replace the missing time-to-build per ton capacity observations by zeroes for years before any time-to-build per ton capacity information is available for a firm in our panel. Results are consistent. The effect on time-to-build is negative and statistically significant for Wooldridge's three-step IV estimation with a p-value less than 0.05. The effect on cost-to-build is positive and statistically significant for Wooldridge's three-step IV estimation with a p-value less than 0.1.

For the other dependent variable, cost-to-build per ton capacity, we replace time-to-build per ton capacity with cost-to-build per ton capacity in equation 1 of the second step and repeat the rest of the steps above.

Control Variables

Market characteristics within each stage of the industry life cycle matter. Because price is a crucial factor indicating market conditions in the oil & gas industry, we control for price and price uncertainty as market characteristics. *Price* is measured using monthly U.S. natural gas wellhead price data from the Energy Information Administration of the U.S. Department of Energy. *Price uncertainty* is the conditional variance of U.S. natural gas prices estimated from the ARCH process (Episcopos, 1995; Huizinga, 1993).

Numerous firm characteristics (Fuentelsaz et al., 2002; Mitchell, 1989, 1991)—such as firm size, age, prior experiences, and the possession of complementary assets—may affect the time-to-build and cost-to-build a plant. *Firm Size* is the natural log of the average total sales of the firm from 1996 to 2007, deflated to 1996 prices using the CPI and averaged over the sample. *Age* is the difference between the year of incorporation for the firm and the plant construction year, and *Age*^{2} is included to account for possible non-linear effects. To reduce potential multicollinearity between the age and age-squared terms, we standardize the age measures. Results do not change substantially with the exclusion of the age squared term. *Experience* is a count variable measuring the number of prior LNG plant construction a firm has participated in throughout the LNG industry in the current panel data set. We include several measures of relevant complementary assets for the LNG industry. We create *Oil and Gas Production* and *Oil and Gas Reserves* as the natural log of the average oil and gas production and reserves of the firm from 1996 to 2007, respectively, measured in millions of barrels of oil equivalent (MMboe). We also include a set of industry dummies to account for any systematic differences in entry incentives across parent industry categorization. These include Oil and Gas Extraction (SIC code 13), Petroleum and Coal Products (SIC code 29), Electric and Gas Services (SIC code 49), and Others.

Statistical Method: Wooldridge's Three-Step Instrumental Variable (IV) Approach

Entry timing is considered a strategic choice and, thereby, is endogenous. Thus, the empirical approach to employ multivariate techniques, such as using OLS to regress our dependent variables (i.e., time-to-build, cost-to-build) on discrete entry timing, potentially suffers from endogeneity bias due to self-selection. Further, entry timing and time-to-build might be co-determined or have reciprocal causality. The time to build a plant may affect the firm's entry timing, and its strategic choice may affect its time to build the plant. In order to account for this potential endogeneity problem, we employ both Wooldridge's three-step instrumental variable (IV) approach (Wooldridge, 2010, pp.939-945) because this method does not require that causality is unidirectional (Basinger & Ensley, 2010). Wooldridge's three-step instrumental variable (IV) approach is also supported by Angrist and Pischke (2009: 191).

Before correcting for the self-selection bias, we first test the selection model of being a late entrant with the controls of the market and firm characteristics. Market characteristics such as price level and uncertainty may affect entry timing (Folta & O'Brien, 2004; Kellogg, 2014). Numerous firm characteristics–such as firm size, age, prior experiences, and the possession of complementary assets–may affect entry timing (Fuentelsaz et al., 2002; Mitchell, 1989, 1991). Time-to-build (Hawk *et al*., 2013) and cost-to-build can influence entry timing. In order to mitigate endogeneity concerns, a two-stage least squares (2SLS) estimation is adopted, which uses delay during construction caused by a natural disaster as an instrumental variable for time-to-build and cost-to-build individually. We use delays during construction caused by natural disasters (i.e., hurricanes) as our instrumental variable. An instrumental variable (1) should be highly correlated with the independent variables, and (2) should be uncorrelated with other unobserved factors related to entry decisions into the LNG market. The first criterion is easily met because delay during construction caused by natural disasters is directly associated with the time-to-build per ton capacity and time-to-build per cost. For the second criterion, a firm can hardly anticipate that the plant construction project would experience a natural disaster in the moment of entry decision because natural disaster is intrinsically unpredictable. It might be possible that a firm has its subjective expectation about the chance of natural disaster and their effect on the project, and a firm's subjective expectation influences the entry decision or other unobserved factors related to entry decisions. Even in that case, however, if a firm goes through delays during construction due to a natural disaster, it means that the effect of the natural disaster is still beyond the firm's prediction in the moment of entry decision, and the event is a sudden surprise to the firm. The fact that firms commonly use a *force majeure* clause in plant construction contracts also corroborates that delays during construction caused by natural disasters meet the second criterion for instrumental variables in practice. The delay event during construction caused by natural disasters also passes the empirical test of weak instrument and identification in the next section. *A natural disaster* is a dummy variable if a plant experiences a delay during construction due to a hurricane. We map these dummy variables to a panel of firm observations for the plant that underwent delays caused by natural disasters.

To account for endogeneity bias from self-selection, we first use Wooldridge's three-step IV approach using price uncertainty as an (excluded) instrumental variable. Price uncertainty is an excluded instrumental variable in Wooldridge's three-step IV estimation. A theoretical reason for price uncertainty as an exclusion variable is that construction costs incurred are substantially irreversible in this context because of the low redeployability of the plant. Thus, the price uncertainty becomes less of a concern for time-to-build and cost-to-build once construction begins. In contrast, price uncertainty is still under consideration until the firm makes its construction decision. A technical reason for price uncertainty as an exclusion variable is that time-to-build and cost-to-build measures are constructed as the deviation from systematic components of time-to-build and cost-build considering market-level characteristics, which means those measures are, by construction, orthogonal components of market-level characteristic such as price uncertainty.

Step 1 is a probit regression of the endogenous dummy variable (i.e., entry timing) on the exogenous variables and the exclusion restrictions (i.e., price uncertainty). Step 2 is a least squares regression of the endogenous treatment variable on the exogenous variables and the predicted probabilities from Step 1. Step 3 is a least squares regression of the outcome variable (i.e., time-to-build and cost-to-build) on the exogenous variables and the predicted values from Step 2. The second step uses first-step predicted probabilities as its exclusion restrictions, and the intermediate step allows the researcher to employ a non-linear probability for the assignment of the treatment but does not impose a specific distributional assumption for the probability model (Basinger & Ensley, 2010).

EMPIRICAL RESULTS

Summary statistics and a correlation matrix for the data set show that the dependent and independent variables demonstrate substantial variation. Some of the statistics suggest the potential for multicollinearity problems. Using variance inflation factors (VIFs) to examine potential collinearity, we found that the collinearity issue that may be of concern is with Oil Gas Reserves, Firm Size, Oil Gas Production, and Price Level (VIF of 140.39, 110.93, 71.49, and 40.43 respectively). We expected potential collinearity issues with these variables since they both capture year-specific characteristics of the firm that may affect investment incentives. Our regression analysis produces statistically significant results despite the high VIFs of these variables in general. Although some firm characteristics variables are sometimes omitted when we include firm fixed effects, our results did not change substantially. We provide the results from the firm's random- and fixed-effect models.

TABLE 3
SELECTION MODEL ON BEING A LATE ENTRANT

	I Probit	II 2SLS / RE	III 2SLS / FE	IV 2SLS / RE	V 2SLS / FE
Time-to-build	-0. 040	-0.389*	-0.829+		
per ton capacity	(0.276)	(0.197)	(0.442)		
Cost-to-build	0.502+			0.789	0.749*
per ton capacity	(0.302)			(0.844)	(0.301)
Price level	0.738***	0.174***	0.033*	0.185***	0.065***
	(0.073)	(0.025)	(0.015)	(0.030)	(0.014)
Price uncertainty	0.224***	-0.010***	-0.005**	-0.009***	-0.006***
	(0.028)	(0.001)	(0.002)	(0.003)	(0.001)
Firm Size	-0.348*	-0.011		0.073	
	(0.160)	(0.020)		(0.112)	

Age	-0.001	0.003	4.102***	-0.093	3.043***
	(0.264)	(0.070)	(0.754)	(0.146)	(0.613)
Age^2	0.182	-0.019	-0.555	0.036	-0.208
	(0.155)	(0. 035)	(0.367)	(0.060)	(0.285)
Experience	0.608***	0.024*	-0.024	-0.024	-0.039+
	(0.131)	(0.011)	(0.018)	(0.057)	(0.022)
Oil & Gas	0.214	0.059		0.079	
Production	(0.250)	(0.036)		(0.078)	
Oil & Gas	-0.149	-0.022		-0.086	
Reserves	(0.252)	(0.029)		(0.096)	
Industry dummies	Y	Y	Y	Y	Y
N	3,668	3, 666	3, 666	3, 668	3, 666
Prob > F (or Chi^2)	0.0000	0.0000	0.0000	0.0000	0.0000

*** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$ + $p < 0.1$

Results reported in Column I are from estimation of probit regression. Results reported in Columns II through V are from 2SLS using ivreg2 and xtivreg2 stata commands for each. Standard errors are robust to clustering by the firm. Industry dummies and a constant are included in the regressions, but results are not reported in the table.

Table 3 provides results regarding the selection model for being a late entrant. As seen in the table, market-level characteristics, such as price level and price uncertainty, and firm-level characteristics, such as firm time-to-build per ton capacity, cost-to-build per ton capacity, age, and so on, influence being a late entrant. Especially, Columns II and III show that a firm with a shorter time-to-build per ton capacity is more likely to enter the uncertain market later. Column V shows that a firm with a higher cost-to-build per ton capacity is more likely to enter the uncertain market late. However, the coefficient in Column IV is not statistically significant.

TABLE 4
EFFECT ON TIME-TO-BUILD PER TON CAPACITY

	I Time-to-build Per ton capacity RE	II Time-to-build Per ton capacity FE	III Cost-to-build Per ton capacity RE	IV Cost-to-build Per ton capacity FE
Late entrant	-0.477**	-0.436*	0.401**	0.435*
($\boldsymbol{\alpha_2}, \boldsymbol{\beta_2}$)	(0.155)	(0.199)	(0.151)	(0.181)
Cost-to-build per ton	-0.112	-0.076		
capacity ($\boldsymbol{\alpha_3}$)	(0.096)	(0.129)		
Time-to-build per ton			-0.096	-0.057
capacity ($\boldsymbol{\beta_3}$)			(0.086)	(0.099)
Price level	0.009	-0.006	-0.046*	-0.036**
	(0.027)	(0.011)	(0.023)	(0.014)
Hurricane	0.388+	0.200	-0.122	-0.262
	(0.227)	(0.234)	(0.250)	(0.167)
Extreme weather	0.838***	0.711**	-0.410*	-0.520*
	(0.166)	(0.244)	(0.172)	(0.207)
Firm Size	0.014		-0.108*	
	(0.054)		(0.044)	
Age	0.066	2.031*	0.098	-0.643
	(0.083)	(0.923)	(0.106)	(0.789)

Age^2	-0.072	-0.675*	-0.048	0.243
	(0.049)	(0.351)	(0.063)	(0.325)
Experience	0.013	-0.031	0.050*	0.063*
	(0.029)	(0.039)	(0.024)	(0.031)
Oil & Gas Production	0.011		-0.026	
	(0.064)		(0.082)	
Oil & Gas Reserves	0.029		0.068	
	(0.062)		(0.063)	
Industry dummies	Y	Y	Y	Y
N	3, 668	3, 666	3,668	3,666
Prob > F (or Chi^2)	0.0000	0.0004	0.0000	0.0044

*** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$ + $p < 0.1$

The results are from estimating Wooldridge's three-step IV approach using ivreg2 and xtivreg2 stata commands for each. In Column I, II, III, and IV, standard errors are robust to clustering by the firm, and standard errors are corrected for the two-step. Industry dummies and a constant are included in the regressions, but results are not reported in the table.

Table 4 presents results regarding the effect of late entrants on time-to-build per and cost-to-build (ton capacity). Regarding the effect of the late entrant on time-to-build (per ton capacity), Columns I and II provide the results from Wooldridge's three-step IV estimation. The coefficients for the late entrant are negative and statistically significant when self-selection bias is corrected. Therefore, we find that late entry (after the end of 2000) is related to shorter time-to-build per ton capacity. Regarding the effect of the late entrant on cost-to-build (per ton capacity), Columns III and IV provide the results from Wooldridge's three-step IV estimation. The coefficients for the late entrants are positive and statistically significant when self-selection bias is corrected. Therefore, we find that late entry (after the end of 2000) is related to higher cost-to-build per ton capacity.

TABLE 5
MODERATING EFFECT OF THE LATE ENTRANT ON THE RELATIONSHIP BETWEEN TIME-TO-BUILD AND COST-TO-BUILD (PER TON CAPACITY)

	I Time-to-build Per ton capacity RE	II Time-to-build Per ton capacity FE	III Cost-to-build Per ton capacity RE	IV Cost-to-build Per ton capacity FE
$late \times cost\ (\boldsymbol{\alpha_1})$	0.611***	0.615**	0.593***	0.417**
	(0.170)	(0.192)	(0.157)	(0.152)
Late entrant	-0.291*	-0.178	0.223	0.248
	(0.147)	(0.199)	(0.148)	(0.201)
Cost-to-build per ton capacity	-0.634***	-0.610**		
	(0.143)	(0.232)		
Time-to-build per ton capacity			-0.619***	-0.417*
			(0.146)	(0.173)
Price level	0.006	-0.006	-0.034	-0.035*
	(0.026)	(0.011)	(0.023)	(0.014)
Hurricane	0.375	0.125	-0.085	-0.239
	(0.237)	(0.236)	(0.243)	(0.169)
Extreme weather	0.865***	0.807**	-0.425*	-0.503*
	(0.171)	(0.262)	(0.174)	(0.217)

Firm Size	0.004		-0.091*	
	(0.056)		(0.046)	
Age	0.014	1.606*	0.125	-0.140
	(0.086)	(0.766)	(0.095)	(0.863)
Age^2	-0.052	-0.415	-0.052	0.129
	(0.051)	(0.373)	(0.057)	(0.299)
Experience	0.009	-0.034	0.044+	0.056+
	(0.029)	(0.035)	(0.025)	(0.031)
Oil & Gas Production	-0.010		-0.036	
	(0.071)		(0.080)	
Oil & Gas	0.062		0.066	
Reserves	(0.068)		(0.062)	
Industry dummies	Y	Y	Y	Y
N	3, 668	3, 666	3,668	3,666
Prob > F (or Chi^2)	0.0000	0.0000	0.0000	0.0004

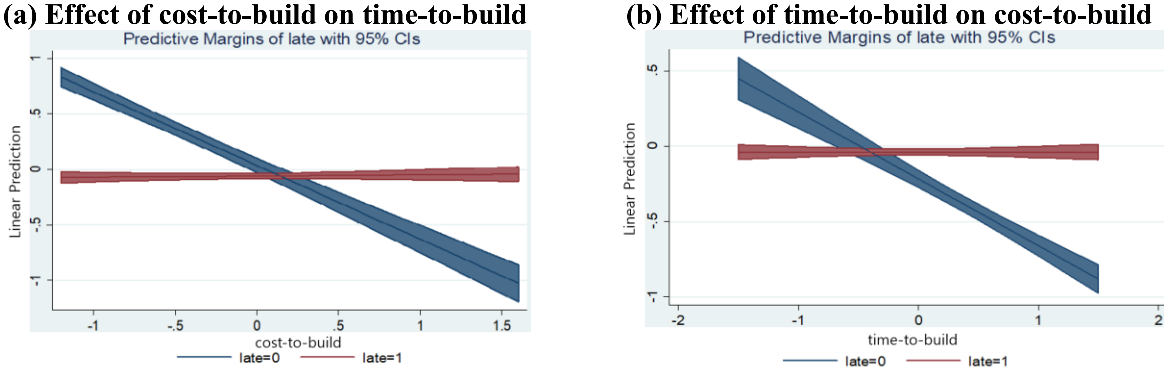
*** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$ + $p < 0.1$

The results are from estimating Wooldridge's three-step IV approach using ivreg2 and xtivreg2 stata commands for each. In Column I, II, III, and IV, standard errors are robust to clustering by the firm, and standard errors are corrected for the two-step. Industry dummies and a constant are included in the regressions, but results are not reported in the table.

Table 5 presents results regarding the moderating effect of the late entrant on the negative relationship between time-to-build and cost-to-build. The results from Wooldridge's three-step IV estimation. In all Columns, the coefficients for the late entrant are positive and statistically significant. Therefore, we find that late entry (after 2000) positively moderates the negative relationship between time-to-build and cost-to-build (i.e., the negative relationship between time-to-build and cost-to-build becomes less negative for the late entrant). Figure 6 illustrates the late entrant's positive moderating effect on the negative relationship between the time-to-build and the cost-to-build.

FIGURE 6
MODERATING EFFECT OF THE LATE-ENTRANT ON COST-TO-BUILD AND TIME-TO-BUILD

(a) Effect of cost-to-build on time-to-build   **(b) Effect of time-to-build on cost-to-build**



In sum, the late entrant has (1) a shorter time-to-build and (2) a higher cost-to-build relative to the early entrant. Moreover, (3) The negative relationship of cost-to-build and time-to-build is positively moderated by the late entrant (i.e., the negative relationship of cost-to-build and time-to-build gets less negative for the late entrant). These empirical results are consistent with the prediction when the revenue curve shifts upward and the cost curve shifts leftward (i.e., case 6 in Table 1).

DISCUSSION AND CONCLUSIONS

We develop a theory to explain and predict why a firm would be expected to choose its time-to-build strategically based on its market-entry timing decision in leveraging a new market opportunity. When firms enter the uncertain market late, the late entrant decreases its time-to-build and incurs higher cost-to-build even if the benefit of learning in the cost curve exists, relative to the early entrant, which will have, on average, a longer time-to-build, but incur lower cost-to-build. Using firm-level entry data from the LNG industry, these results were corroborated using delay during construction caused by natural disasters as an instrumental variable while controlling for firm characteristics and market features. They also withstand extensive robustness checks.

The current study has implications for both management scholars and practitioners. For scholars, it contributes to strategy research focused on time-to-build and market-entry timing. Our empirical results show time-to-build as a firm's strategic choice, endogenous to market-entry timing. We extend our understanding of the relationship between market-entry timing and time-to-build. Although the extant literature's recognition of the effect of time-to-build on market-entry timing provides a good starting point, the current study maintains that we can explain and predict even better if we consider that time-to-build is endogenous.

Practitioners will benefit from viewing time-to-build as a strategic choice. When a firm decides its market-entry timing, it faces a tradeoff in costs and benefits. On the one hand, early entrants can preempt inputs such as scarce natural and human resources, increase consumer-switching costs, or build technological lock-in. On the other hand, early entrants are more likely to incur costs by making mistakes in irreversible investments regarding the type of product, business model, or operations of product, business model, or operations due to limited information and learning opportunities. Once a firm decides its market-entry timing, it faces another tradeoff of time-to-build on its costs and revenues. On the one hand, decreasing time-to-build is beneficial because firms that are slow to build plants often incur substantial revenue losses. On the other hand, decreasing time-to-build often increases the firm's cost due to time compression diseconomies. It is important for practitioners to recognize the (interfirm) tradeoff of the market-entry timing and the (intrafirm) tradeoff of time-to-build and to understand how to make the most use of these tradeoffs.

Limitations

An alternative explanation for the shorter time-to-build of the late entrant is that the firm's time-to-build is an outcome of learning about the specialized suppliers in the factor market. The specialized suppliers' shorter time-to-build as an outcome of learning can also explain the higher cost-to-build of the late entrant if the suppliers for the late entrant ask for more rewards for the decrease in time-to-build. However, it is an empirical question of how much proportion of the value creation results from the decreased time-to-build that suppliers capture. Further empirical study concerning the labor supply would help disentangle the mechanism (e.g., by showing suppliers' increased cost-to-build for the same periods and whether the late entrant's effect on cost-to-build is still significantly controlling for the suppliers' cost-to-build).

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REFERENCES

Agarwal, R., & Gort, M. (1996). The evolution of markets and entry, exit, and survival of firms. *Review of Economics and Statistics*, *78*(3), 489–498.

Angrist, J.D., & Pischke, J.S. (2009). *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton, NJ: Princeton University Press.
Argote, L., Beckman, S.L., & Epple, D. (1990). The persistence and transfer of learning in industrial settings. *Management Science*, *36*(2), 140–154.
Barney, J.B. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, *17*(1), 99–120.
Basinger, S.J., & Ensley, M.J. (2010). *Endogeneity problems with binary treatments: A comparison of models*. Working Paper.
Boehm, B.W. (1981). *Software Engineering Economics*. Englewood Cliffs, NJ: Prentice Hall.
Clark, K.B. (1989). Project scope and project performance: The effect of parts strategy and supplier involvement on product development. *Management Science*, *35*(10), 1247–1263.
D'Aveni, R.A. (1994). *Hypercompetition*. New York: The Free Press.
Department of Energy of United States. (2016). *Understanding Natural Gas and LNG Options*.
Dierickx, I., & Cool, K. (1989). Asset stock accumulation and sustainability of competitive advantage. *Management Science*, *35*(12), 1504–1511.
Dixit, A.K. (1992). Investment and hysteresis. *Journal of Economic Perspectives*, *6*(1), 107–132.
Dixit, A.K., & Pindyck, R.S. (1994). *Investment under Uncertainty*. Princeton, NJ: Princeton University Press.
Eisenhardt, K.M. (1989). Making fast strategic decisions in high-velocity environments. *Academy of Management Journal*, *32*(3), 543–576.
Episcopos, A. (1995). Evidence on the relationship between uncertainty and irreversible investment. *Quarterly Review of Economics and Finance*, *35*(1), 41–52.
Fine, C.H. (1998). *Clockspeed*. Reading, MA: Perseus Books.
Folta, T.B., & O'Brien, J.P. (2004). Entry in the presence of dueling options. *Strategic Management Journal*, *25*(2), 121–138.
Fuentelsaz, L., Gomez, J., & Polo, Y. (2002). Followers' entry timing: Evidence from the Spanish banking sector after deregulation. *Strategic Management Journal*, *23*(3), 245–264.
Ghemawat, P. (1991). *Commitment: The Dynamic of Strategy*. New York: Free Press.
Glazer, A. (1985). The advantages of being first. *American Economic Review*, *75*(3), 473–480.
Gort, M., & Klepper, S. (1982). Time paths in the diffusion of product innovations. *Economic Journal*, *92*(367), 630–653.
Graves, S.B. (1989). The Time-cost tradeoff in research and development: A review. *Engineering Costs and Production Economics*, *16*(1), 1–9.
Hawk, A., & Pacheco-de-Almeida, G. (2018). Time compression (dis)economies: An empirical analysis. *Strategic Management Journal*, *39*(9), 2489–2516.
Hawk, A., Pacheco-De-Almeida, G., & Yeung, B. (2013). Fast-mover advantages: Speed capabilities and entry into the emerging submarket of Atlantic basin LNG. *Strategic Management Journal*, *33*(13), 1531–1550.
Hendricks, K.B., & Singhal, V.R. (1997). Delays in new product introductions and the market value of the firm: The consequences of being late to the market. *Management Science*, *43*(4), 422–436.
Huber, G.P. (1991). Organizational Learning: The Contributing Processes and the Literatures. *Organization Science*, *2*(1), 88–115.
Huizinga, J. (1993). Inflation uncertainty, relative price uncertainty, and investment in US manufacturing. *Journal of Money, Credit and Banking*, 25(3), 521–554.
Ingram, P., & Baum, J.A.C. (1997). Opportunity and constraint: Organizations' learning from the operating and competitive experience of industries. *Strategic Management Journal*, *18*(S1), 75–98.
Kellogg, R. (2014). The Effect of uncertainty on investment: Evidence from Texas oil drilling. *American Economic Review*, *104*(6), 1698–1734.

Kim, J.Y., & Miner, A.S. (2007). Vicarious learning from the failures and near-failures of others: Evidence from the U.S. commercial banking industry. *Academy of Management Journal*, *50*(2), 687–714.
Lieberman, M.B., & Montgomery, D.B. (1988, Summer). First–mover advantages. *Strategic Management Journal*, *9*, 41–58.
Lieberman, M.B., & Montgomery, D.B. (1998). First–mover (dis)advantages: Retrospective and link with the resource-based view. *Strategic Management Journal*, *19*(12), 1111–1125.
Mahoney, J.T., & Pandian, J.R. (1992). The Resource-based view within the conversation of strategic management. *Strategic Management Journal*, 13(5), 363–380.
Mansfield, E. (1971). *Industrial Research and Technological Innovation*. New York: Norton.
Mansfield, E. (1988). The speed and cost of industrial innovation in Japan and the United States: External vs. internal technology. *Management Science*, *34*(10), 1157–1168.
Mitchell, W. (1989). Whether and when? Probability and timing of incumbents' entry into emerging industrial subfields. *Administrative Science Quarterly*, *34*(2), 208–230.
Mitchell, W. (1991). Dual clocks: Entry order influences on incumbent and newcomer market share and survival when specialized assets retain their value. *Strategic Management Journal*, *12*(2), 85–100.
Mitchell, W., Shaver, J.M., & Yeung, B. (1994). Foreign entrant survival and foreign market share: Canadian companies' experience in United States medical sector markets. *Strategic Management Journal*, *15*(7), 555–567.
Pacheco-de-Almeida, G., & Zemsky, P.B. (2007). The timing of resource development and sustainable competitive advantage. *Management Science*, *53*(4), 651–666.
Pacheco-de-Almeida, G., Hawk, A., & Yeung, B. (2015). The right speed and its value. *Strategic Management Journal*, *36*(2), 159–176.
Pindyck, R.S. (1991). Irreversibility, uncertainty, and investment. *Journal of Economic Literature*, *29*(3), 1110–1148.
Rumelt, R.P. (1984). Toward a strategic theory of the firm. In R. Lamb (Ed.), *Competitive strategic management* (pp. 556–570). Englewood Cliffs, NJ: Prentice Hall.
Scherer, F.M. (1967). Research and development resource allocation under rivalry. *Quarterly Journal of Economics*, *81*(3), 359–394.
Scherer, F.M. (1984). *Innovation and Growth*. Cambridge, MA: MIT Press.
Shaver, J.M., Mitchell, W., & Yeung, B. (1997). The effect of own-firm and other-firm experience on foreign direct investment survival in the United States, 1987-92. *Strategic Management Journal*, *18*(10), 811–824.
Smith, P.G., & Reinertsen, D.G. (1998). *Developing Products in Half the Time.* New York: John Wiley & Sons, Inc.
Stalk, G. (1988). Time? The next source of competitive advantage. *Harvard Business Review*, *66*(4), 41–51.
Stalk, G., & Hout, T.M. (1990). *Competing Against Time*. New York: The Free Press.
Teece, D.J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*(7), 509–533.
Tong, T.W., & Li, Y. (2011). Real options and investment mode: Evidence from corporate venture capital and acquisition. *Organization Science*, *22*(3), 659–674.
Trigeorgis, L. (1996). *Real Options: Managerial Flexibility and Strategy in Resource Allocation*. Cambridge, MA: MIT Press.
Tusiani, M.D., & Shearer, G. (2007). *LNG: A Nontechnical Guide*. Tulsa, OK: PennWell.
Wooldridge, J.M. (2010). *Econometric Analysis of Cross Section and Panel Data* (2nd Ed.). Cambridge, MA: MIT Press.
Zimmerman, M.B. (1982). Learning effects and the commercialization of new energy technologies: The case of nuclear power. *Bell Journal of Economics*, *13*(2), 297–310.