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The Facts About Time-to-Build

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Abstract

This paper presents new empirical evidence about the process of plant investment. Using newspaper and trade journal articles, the author collects and analyzes time-to-build data for a sample of Compustat firms. These data suggest that the average construction lead time for new plants is around two years in most industries. Business cycle fluctuations do not affect the length of time-to-build. The investment lead times are generally not sensitive to the size of the projects. Only nine percent of the firms in the sample deviate from their investment schedules and delay or abandon their projects.

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Contents

I. Introduction

This paper presents new empirical evidence on the process of time-to-build. The data are compiled from the online system Lexis-Nexis which contains the full text of company news, published in newspapers and trade journals. Starting from a panel of 1175 Compustat firms, I construct a representative sub-sample of 106 companies and collect information on their investment projects.[2] The complete data consist of the name of the company, the industry, location, cost and schedule, as well as the starting and ending dates of the project.

The analysis of these data suggests the following results. First, the construction lead time for new plants is around two years in most industries. The average value of time-to-build is significantly different from two years in the utilities, rubber, industrial equipment, miscellaneous manufacturing and railroad transportation industries. Second, the use of different proxies for external economic conditions yields the same result--time-to-build is inflexible with respect to the business cycle. Third, the size of the project has a significant effect on the length of the construction lead time only for very large plants. For these projects, an additional expenditure of 100 million dollars increases the duration of time-to-build by 2.4 months. The business cycle variables remain insignificant even after controlling for the size of the project. Fourth, there were few delays and cancellations in the sample. Only ten projects were not finished on schedule. Five of them were in the utilities industry. The qualitative evidence from Lexis-Nexis suggests that most of the delays did not occur for economic reasons. I estimate a probit model which shows that utilities projects are thirty-nine percent more likely to be delayed than other investment projects. The external economic factors have an insignificant marginal effect on the probability of deviating from the investment schedule.

The rigidity of time-to-build can be attributed to technological and contractual factors. The necessity to perform construction tasks sequentially limits the scope of time-saving technological progress. The complexity of the contractual arrangements among the parties involved in the investment project makes any delay costly and undesirable.

The paper is organized as follows. Section 2 contains an overview of the theoretical and empirical research on time-to-build. Section 3 presents the new empirical evidence on time-to-build and describes the methodology used in the collection of the data. The main findings are reported in the next section. Section 5 discusses the empirical results and their possible explanations. The last section concludes.

[2] The initial Compustat sample is used in subsequent research.

II. Background

A brief overview of the history of economic thought shows that informal time-to-build models were developed as early as the beginning of this century. The concept of time-to-build was an important ingredient in some theories which attempted to explain economic fluctuations. Aftalion (1927), for example, claims that ``the chief responsibility for cyclical fluctuations should be assigned to one of the characteristics of modern technique, namely, the long period required for the production of fixed capital." In Pigou's work on fluctuations (1920), the lags in plant and equipment constructions give rise to errors in judgement which, in turn, bring about the expansion and contraction of industries. Kalecki's ``Macrodynamic Theory of Business Cycles" (1935) emphasizes the effect of time-to-build on investment and output oscillations.

In the context of general equilibrium, the interest in time-to-build was revived in the late 1970s and early 1980s, with the emergence of real business cycle theory. The objective of this literature has been to account for the existence of business cycles in perfectly competitive markets under the assumption of rational expectations. The dynamics of most real business cycle models are driven by exogenous technological shocks. Proponents of the theory have tried to identify important channels which propagate the technological disturbances in the model.

In their seminal paper on real business cycle theory "Time-to-Build and Aggregate Fluctuations," Kydland and Prescott (1982) emphasize the importance of time-to-build in creating a persistent response to shocks. The authors make the assumptions that the length of time-to-build is four quarters, the stream of investment expenditures is evenly distributed over the construction period, and the investment schedule cannot be altered once the project is started. Using the standard real-business cycle methodology, Kydland and Prescott demonstrate that the time-to-build model does better than the convex adjustment cost framework in terms of explaining aggregate fluctuations. Rouwenhorst (1991), however, points out that time-to-build plays a limited role in obtaining the above conclusions. His paper suggests that the main results in Kydland and Prescott (1982) are driven by the assumptions with respect to the non-separability of preferences and the process for technological shocks.

Nevertheless, the time-to-build specification in real-business cycle models has been modified and revisited by numerous authors. Park (1984), for example, allows for changes in the projects under construction and argues for a multi-period adjustment cost specification. Christiano and Todd (1996) extend and modify the work of Kydland and Prescott by introducing a planning phase in the investment process. The authors maintain that the presence of this planning stage of plant investment changes the dynamics and improves the performance of the Kydland-Prescott model. Altug (1989) uses different gestation periods for equipment and structures, but preserves the specification of the time-to-build technology adopted by Kydland and Prescott. Wen (1996), on the other hand, focuses on the persistent demand for investment goods which could arise from the multi-period construction of capital goods under an alternative specification of time-to-build. An important lesson from examining these general equilibrium models is that the specific assumptions made with respect to the characteristics of time-to-build cannot be ignored. Therefore, the proponents of real business cycle methodology would benefit from more definitive microeconomic evidence on the process of time-to-build.[3]

The significance of time-to-build has been assessed in partial equilibrium as well. In the context of the convex adjustment costs model, time-to-build can serve as a potential explanation for the observed persistence of investment which is usually attributed to convex adjustment costs. The dynamics of the investment in structures is particularly difficult to explain using the standard adjustment costs framework. Few papers address the significance of time-to-build in partial equilibrium. Taylor (1982) uses a neoclassical model with heterogeneous construction lags in order to examine the effect of government stabilization policy on investment. The focus of his paper is on the aggregate investment in structures. Taylor derives a simple accelerator model of investment from the optimization problem of the firm. The length of time-to-build and the investment weights across periods are among the structural coefficients in the model. Abel and Blanchard (1984), on the other hand, combine delivery lags with the standard convex adjustment costs approach in order to examine the relationship between investment and sales across industries. The monograph "Time-to-Build: Interrelated Investment and Labour Demand Modelling With Applications to Six OECD Countries" by Marga Peeters (1995) is the most comprehensive work on time-to-build. The emphasis is, however, on the interrelation among the different factors of production. Another limitation is the use of aggregate data.

In comparing the forecasting properties of different investment models, Oliner, Rudebusch and Sickel (1995) estimate an Euler equation which incorporates time-to-build using aggregate level investment data on equipment and structures. The results indicate that all of the considered models of investment (accelerator, neoclassical, modified neoclassical and Euler) fail to account for the investment dynamics in structures at the aggregate level. The authors point out that the use of firm-level investment data on structures would be preferred in the presence of aggregation problems.

The most recent development in the investment theory of the firm also offers models which incorporate time-to-build. Majd and Pindyck (1986), for example, discuss a model of time-to-build and irreversible investment in a single project. The environment is stochastic. In their framework, a firm incurs a sequence of capital expenditures and faces a maximum construction rate. The option to delay investment exists at each stage of the project. In this setting, the optimal policy rule is either to invest at the maximum rate every period or to wait

[3] The general criticism towards the real business cycle literature is expressed in the summary article by Stadler (1994). The author points out that "RBC models have difficulty in accounting for the dynamic properties of output because the propagation mechanisms they employ are generally weak" (p. 1751).

until the external conditions improve. The authors show that the negative effect of increased uncertainty on investment is stronger with time-to-build.

The interaction between time-to-build, uncertainty and irreversibility is also discussed by Bar-Ilan and Strange (1996). In their model, the conventional depressive effect of price uncertainty on investment could disappear in the presence of investment lags *and* the option to abandon the project. The intuition for this result is that the opportunity cost of waiting increases with uncertainty. The existence of long investment lags is important for the authors' conclusion that an increase in uncertainty could encourage investment. Again, the effect of time-to-build on uncertainty in the models of irreversible investment depends on the assumptions made with respect to the length and flexibility of the construction technology.

The papers mentioned above make different assumptions about the length and flexibility of the construction lags. However, little is known about the nature of time-to-build. The previous empirical work on the topic comes from the early 1960s. Mayer (1960) conducts a survey of 110 companies which undertook construction between January, 1954 and January 1955. The process of time-to-build is broken down into different stages. In the sample, the average length of time between the decision to build a plant and the completion of the project is twenty-one months. The sensitivity of time-to-build to the business cycle and the occurrence of delays or cancellations are not addressed in his paper.

In another article, Mayer and Sonenblum (1955) use defense records to recover the lead times for fixed investment in 108 four-digit industries during World War II and the Korean war. Their definition of time-to-build takes into account only the period between the starting and the estimated completion dates. The authors find that the average construction lag is three quarters. The paper contains little information about the nature of the projects and says nothing about delays and suspensions during the course of construction. Forty years later, Montgomery (1995) uses survey data collected by the U.S. Department of Commerce to construct the completion pattern for nonresidential structures during the 1961-83 period. He finds that the construction period has an average of less than six quarters.

The industrial organization literature also provides some estimates of time-to-build in various industries. For example, Lieberman (1987) reports that the construction lag in the chemical industry is approximately two years. Krainer (1968), on the other hand, studies twenty-five investment projects in a single industry. The emphasis of his paper, however, is on the path of expenditures during the investment process.

A careful overview of the theoretical and empirical literature suggests that the assumptions used in modeling time-to-build are crucial. The role of time-to-build in explaining the persistence of the investment in structures cannot be assessed without some knowledge of the determinants and characteristics of the process. In the next part of this paper, I present and analyze a new dataset on time-to-build.

III. New Evidence on Time-to-Build

Microeconomic evidence on time-to-build is scarce. The collection of reliable time-to-build data is often difficult and effort-intensive. The new dataset described in this section is compiled from newspaper and trade journal articles from the online system Lexis-Nexis. The methodology used in the process of data collection is outlined below. Before turning to the new evidence, however, I give a brief description of the mechanics of the process of investment in non-residential structures.

A. Definition

Building a new plant is a long and carefully planned process. The beginning of a project is marked by the decision of the firm to build a plant. The announcement of this decision is, however, often preceded by some preliminary analysis of the technical feasibility and the site of the project. The principal stages in the course of the project's development could be described as follows.

Design Phase

The project undergoes the stages of schematic and developed design. The architectural and engineering services required for these tasks could either be performed in-house or rented on the market. Most firms choose the latter option. In this case, the hired architecture and engineering (A & E) firm provides the owner with sketches, outline specifications of the project and its conceptual design. The design professional also has to make sure that the investment project is in line with the budget. Then the schematic design phase is over. The developed design phase requires the architects and their engineers, consultants and advisors to prepare detailed drawings and documentation which demonstrate how the plant would appear at the end. The arrangement of all electrical, mechanical and structural systems has to be laid out. The overall project design and another cost estimate are part of the requirements as well. With this documentation in hand, the firm which plans to build the plant can proceed to the next stage of bidding and contracting.

Bidding and Contracting Phase

At this stage, the firm and the architect select a general contractor. In the private sector, construction contracts are awarded by a process of competitive bidding, negotiation or a combination of the two. The project is usually advertised in trade papers. In practice, bids come from a limited list of invited bidders. The contract is awarded to the lowest bidder, although the firm has the right to reject all offers and negotiate afterwards. Once the general contractor is chosen, a formal notice of the award is made in the press. Subcontractors are selected as well. At the end of this stage, the firm authorizes the start of construction.

Construction Phase

The construction plan is part of most contracts between the firm and the general contractor. The time schedule of the project is an important element of the agreement. The ramifications of project delays are outlined in the contract as well. Plant construction is an involved process which consists of a large number of sequential tasks. Therefore, construction takes time. When the plant nears substantial completion, the firm can take occupancy. The final completion is established only after an inspection from the architect and the firm. The start of production follows. Typically, the end of the project is announced in the news media.

B. Methodology

In this paper, I exploit the fact that national, local and trade publications follow closely (stage-by-stage) the development of projects undertaken by large firms. The published reports on the status of projects allow me to construct the length of time which elapses between the decision to build a plant and the end of construction in various industries. I can also observe whether and when the project is delayed, suspended or abandoned. The exact procedure used in the collection of the time-to-build data is described below.

The sample of firms for whose projects I collected data on time-to-build comes from the Compustat universe. Compustat is one of the commonly used micro datasets in the investment literature. This database contains yearly and quarterly accounting data for a large number of firms. Large and medium-size companies are over-represented. Using the Compustat database, I formed a balanced panel of 1175 firms. The firms included in the sample have complete investment data from 1975 to 1996. In addition, their primary industry code is between 2000 and 5999, i.e. the sample includes both manufacturing and non-manufacturing firms.[4] A list of the industries in the sample is given in Table 1. Faced with the time constraints of collecting data for 1175 firms, I restricted by attention to a sub-sample of 106 observations. The smaller sample preserves the industry composition of the original sample. Within each industry, the firms in the sub-sample were drawn randomly from the Compustat sample.

The data on time-to-build are compiled from the online database system Lexis-Nexis. This source contains the full text of company news, published in national and regional newspapers. The Lexis-Nexis database also includes articles from specialized industry journals--*Nonwovens Industry, Automotive News, Rubber & Plastics News, Pulp & Paper, Oil & Gas Journal, Engineering News*, etc.

[4] Compustat reports the four-digit SIC code of each company.

The decision of a company to build a new plant is often announced in the press. The nature of the provided information depends on the news source. Local newspapers tend to discuss the effect of the new facility on the labor market in the area. In general, these articles are less likely to provide details about the length of the construction period or any other technicalities. They, however, invariably report the opening date of the new plant, as well as the occurrence of any delays along the construction process. The trade-journal coverage, on the other hand, is often short and formal. *Engineering News--Record*, for example, records the name of the company which plans to make the investment, the contractor's name, the location and the construction schedule of the project. In addition, industry publications tend to follow the construction progress and to inform the public of any delays and cancellations. Putting together the information presented by the different sources, I collected the firm-level data on the time-to-build process. The main advantage of using Lexis-Nexis as a data source is that one could obtain very comprehensive information about each company and the history of its investment projects.

To gather the data, I used the following procedure. Initially, I searched for any notice of new plant construction in the history of each company in the sample of 106 observations. In particular, I recorded the date when the company announced its intentions to build a plant. When this starting date was not available, I took the beginning-of-construction date instead. If the projected date of completion was mentioned, I checked whether the construction was finished on time. If the project was still in progress, I used the expected ending date. In several cases--mainly in the utilities industry--the plant construction was abandoned for ever. In the case of discrepancy between sources, I record the date which was less favorable to the time-to-build hypothesis. One striking feature of the constructed dataset is that only eight of the construction projects started in the 1970s. This pattern could be explained by the Lexis-Nexis incomplete coverage of the early period.

The following case illustrates how the time-to-build information was recovered from various sources. Nucor Corp is one of the four primary-metal companies in the sample. The initial search by the name of the company produced the records of 244 articles. The earliest article was published in January 1975, whereas the most recent one appeared in American Metal Market in August 1998. The search was narrowed to publications containing the key phrase **new plant**, and the number of articles was reduced to 31. The first relevant news brief was printed in *Engineering News*--Record, on February 19, 1987. The article reported that Nucor Corp--one of the largest U.S. steel companies--would spend over 200 million dollars on a new sheet-steel mill. Although the site of the new facility had not been selected, the construction was planned to start before the end of 1987. Following the news on the topic **sheet-steel mill**, I found a publication in the magazine Forbes from April 3rd, 1989. The two-page article, entitled "Nucor's Boldest Gamble" started with the news of the opening of Nucor Corp's mill during the same month in Crawfordsville, Indiana. The discussion of the technological features of the mill showed that the new facility was the same operation which *Engineering News--Record* had described in 1987. Thus I recorded the beginning and ending dates (February 1987 and April 1989, respectively), the size of the project ($200 million) and the location (Crawfordsville, Indiana) in the data sheet for the whole sample. The last piece of information needed is the occurrence of delays. In this particular case, I was not able to tell if the project was completed according to the initial schedule. The time-to-build information for the remaining companies in the sample was obtained in a similar way. The analysis of these data is presented in the next section.

IV. Main Findings

The main empirical findings can be described as follows. First, the average length of time-to-build is approximately two years in most industries. Second, I find little evidence that time-to-build is affected by the business cycle. Third, the size of a project has a significant effect on the length of the construction lead time only for large investment projects. Lastly (and most surprisingly), time-to-build is very inflexible ex-post--firms adhere closely to the initial schedules of their projects.

An important fact that is established in the data is that time-to-build is fairly long and uniform across industries. The actual distribution of the data is presented in Figures 1 and 2. Figure 1 plots all industries on the horizontal axis against the observed values of time-to-build in months for each industry on the vertical axis. The graph shows a significant dispersion of the observations in the utilities industry, as well as two outliers in the lumber and primary metals industries. The rest of the projects seem to be scattered around a two-year period of time-to-build. In Figure 2, the utilities industry is omitted in order to get a closer look at the data. The estimates of the average time-to-build across industries are given in Table 1. As suggested by Figures 1 and 2, the construction lead time is around two years in most industries. Regressing the length of time-to-build on the industry dummies, I find that the utilities, rubber, industrial equipment, manufacturing (other), railroad transportation and nondurable goods (wholesale) industries have mean values of time-to-build which are significantly different from two years.[5]

[5] The dropped dummy in the regression is the indicator for the textile products industry. The significance level is 5 percent.

Figure 1. Distribution of Time-to-Build, all industries

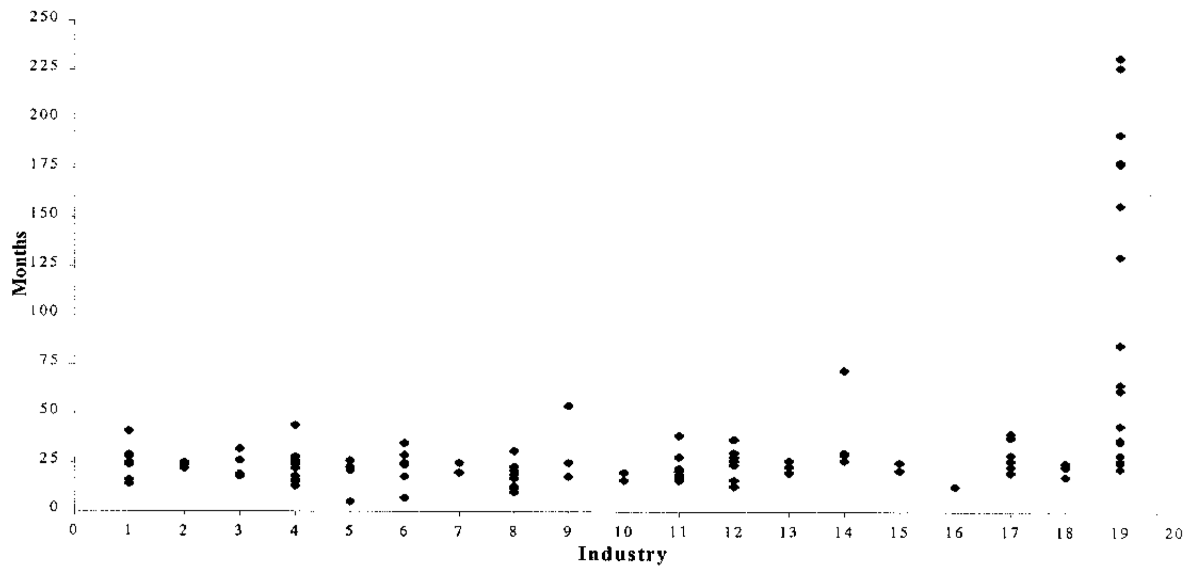
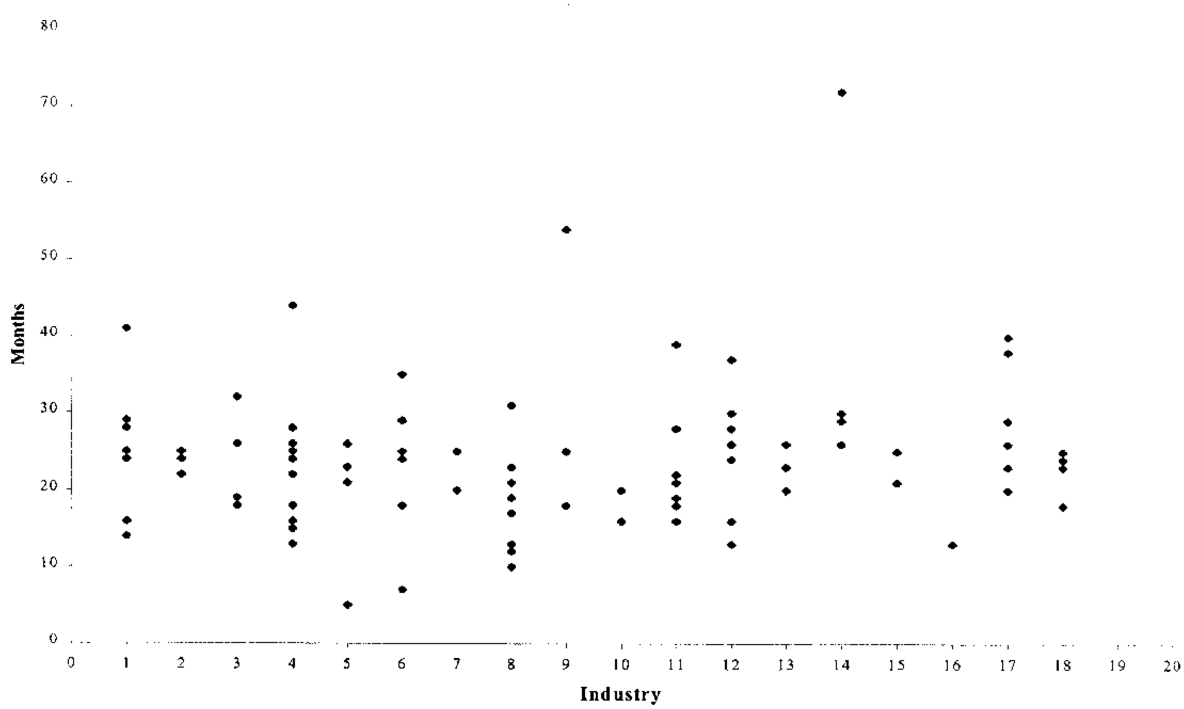


Figure 2. Distribution of Time-to-Build, no utilities



Industry Legend

1. Chemical products
2. Clothing
3. Communications
4. Electrical equip.
5. Fabricated equip.
6. Food products
7. Glass and stone
8. Industrial equip.
9. Lumber
10. Manufacturing, other
11. Measure
12. Paper products
13. Petrol products
14. Primary metals
15. Rubber
16. Shoe and leather
17. Transport equip.
18. Transportation
19. Utilities

Table 1. Average Time-to-Build Across Industries, in months

Industry	Lead time, in months
Food products	24
Textile products	24
Lumber	30
Paper products	23
Chemical products	23
Petrol products	23
Rubber	13
Leather	23
Glass and stone	18
Primary metals	37
Fabricated metals	14
Industrial equipment	18
Electrical equipment	24
Transport equipment	28
Measure	25
Manufacturing, other	18
Railroad transportation	18
Freight transportation	23
Water transportation	25
Transportation by air	24
Communications	24
Utilities	86
Nondurable goods, wholesale	37

Another question which the data could resolve is whether the length of time-to-build varies with the business cycle. The empirical results are shown in Table 2. The dependent variable in the regression analysis is the length of time-to-build in months. The first column contains a baseline specification which uses the industry dummies as the only regressors. The hypothesis that the industry dummies are jointly significant cannot be rejected (p-value =0.01). The second column includes a recession indicator which equals 1 if the project was underway during a recession and zero, otherwise. Among the hundred and six observations in the sample, fifteen projects were in progress during recessions. The coefficient estimate is negative, but statistically insignificant. The unemployment rate is another measure of the economy-wide fluctuations. The next two columns use the unemployment rate at the start and

Table 2. The Effect of the Business Cycle on the Length of Time-to-Build

	(1)	(2)	(3)	(4)
Industry Dummies	Yes	Yes	Yes	Yes
Recession	-	-0.5255 (3.8147)	-	-
Unemployment rate (start of project)	-	-	-1.0476 (2.7173)	-
Unemployment rate (end of project)	-	-	-	2.3806 (2.8461)
R-squared	0.38	0.38	0.41	0.39
Number of obs.	106	106	106	106

Notes: 1. The dependent variable is the length of time-to-build in months. 2. Column (1) contains a baseline regression of time-to-build on the industry dummies listed in Table 1. Columns (2)-(4) use different business cycle proxies. The indicator variable *Recession* equals one if the project was in progress during a recession. 3. The robust standard errors are reported in brackets.

the end of the project as proxies for the business cycle. Both specifications indicate that the effect of the business cycle on the length of time-to-build is not statistically significant.[6]

The empirical results presented in Table 2, however, do not control for the size of the investment projects. Such information is available for sixty-eight observations. The size distribution is shown in Figure 3. The largest category of projects contains plants which cost less than 50 million dollars. Five of the largest projects (over $750 million) come from the utilities industry. The rest of the plants are in the transportation, food-processing and electrical equipment industries.

[6] These negative results are not changed when the industry dummies are omitted. I have also experimented with using the local unemployment rate rather than the economy-wide one. Again, I find no evidence for a significant business cycle effect on the length of time-to-build.

The next table summarizes the empirical findings on the effect of the size of the project on the length of time-to-build. The first specification in Table 3 assumes that the marginal effect of size is the same regardless of the scale of the project. The coefficient

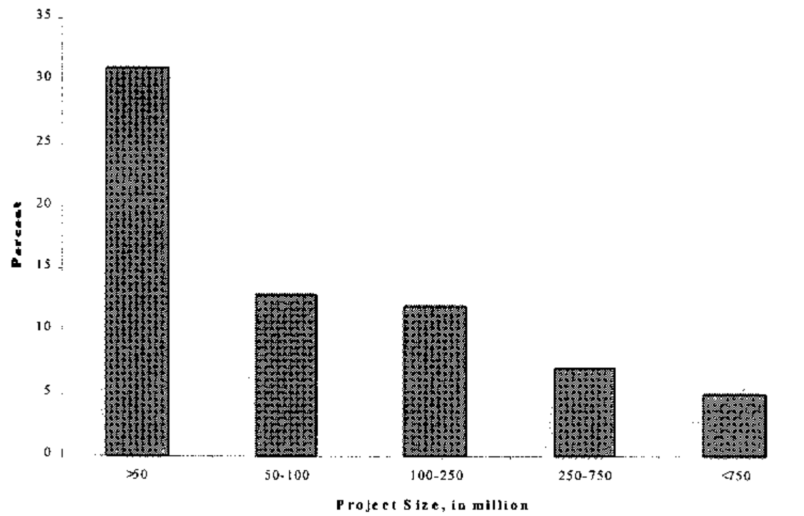
Table 3. The Effect of Project Size on the Length of Time-to-Build

	(1)	(2)	(3)	(4)
Size	0.0241	0.0241	-	-
	(0.0035)	(0.0035)		
Size1	-	-	-0.2037	-0.2024
			(0.6009)	(0.6057)
Size2	-	-	0.3571	0.3642
			(0.4734)	(0.4788)
Size3	-	-	-0.0376	-0.0318
			(0.2119)	(0.2161)
Size4	-	-	0.0699	0.0694
			(0.0706)	(0.0713)
Size5	-	-	0.0229	0.0228
			(0.0025)	(0.0025)
Unemployment	-	0.5061	-	-0.4601
		(1.0207)		(2.6017)
R-squared	0.65	0.65	0.66	0.66
Number of Obs.	68	68	68	68

Notes:

1. The dependent variable is the length of time-to-build in months.
2. The project size is measured in millions.
3. The regression specification in Columns (1)-(2) imposes the same slope for all project sizes. Columns (3)-(4) contain spline regressions. The threshold values are at the $20^{th,}$ 40^{th}, 60^{th} and 80^{th} percentiles.
4. The robust standard errors are reported in brackets.

Figure 3. Distribution of Projects by Size



estimate is highly significant. Its magnitude indicates that an additional expenditure of 100 million dollars increases the duration of time-to-build by 2.4 months. A more careful examination of the data, however, suggests that the above result may be driven by a few large projects in the sample. Conceptually, it is also unclear why the size effect should be linear. Prompted by these considerations, I estimated a spline regression which allows the relationship between time-to-build and size to be estimated as a piecewise linear function. The knots of the spline are taken at the 20th, 40th, 60th and 80th percentiles. The resulting coefficients are shown in the third column of Table 3. The slope for large projects (80th-percentile) has the same magnitude and level of statistical significance as the ones suggested by the previous specification. The remaining slope coefficients, however, are not statistically significant from zero.[7] Columns (2) and (4) suggest that the business cycle variables remain insignificant even after controlling for the size of the project.

The ex-post flexibility of the investment projects is the next issue addressed in the empirical analysis. The summary of the delays and cancellations in the data is presented in Table 4 below. Only ten projects were not finished on schedule. Not surprisingly, five of the plants were in the utilities industry. The other five cases are quite interesting. The start-up of a plant in the electrical equipment industry was postponed due to technical problems for four months. The project of the nickel producer Falconbridge was delayed due to problems at the design stage. Only one project outside the utilities industry was suspended and finally

[7] The spline regression imposes a set of linear restrictions in order to obtain a piecewise function which is continuous. Alternatively, one could allow for different intercepts as well. The resulting slope coefficients are quite similar to the estimates discussed above.

cancelled due to economic reasons. The chronology of the events is as follows. In the beginning of 1988, *Engineering News--Record* reported that the food processing company Kellogg Co. planned "to begin site preparation and detailed engineering later this year for a highly automated cereal plant near Memphis." In December 1989, the work on the plant was halted because of worsening market conditions. The project was finally cancelled in January 1991. The reason for the termination of the project, as explained by company officials, was the change in the demand conditions for the breakfast cereal market.

Table 4. Were Projects Completed as Scheduled?

No delay	83
Delay/cancellation	10
No information	13
Total	106

A more formal analysis of the data on delays and cancellations is presented in Table 5. Using a simple probit model, I investigate if the economic conditions during the gestation period affect the probability of delaying the completion of the project. The binary dependent variable in the regression equals 1 if the project was delayed or cancelled and 0, otherwise. The parameter estimates are presented as marginal probabilities.

Table 5. Probit Estimates

	(1)	(2)	(3)
Utility	0.3936	0.3902	0.3875
	(0.1532)	(0.1560)	(0.1550)
Recession	-	-0.0344	-
		(0.0567)	
Unemployment Rate	-	-	0.0128
			(0.0211)
Log-Likelihood	-26.41	-26.32	-26.24
Number of Obs.	93	93	93

Notes:

1/ The dependent variable equals 1 if the project was delayed and 0, otherwise.

2/ The unemployment rate variable is defined as the average local employment rate during the investment period.

3/ The robust standard errors are reported in brackets.

The results suggest that utilities projects are approximately thirty-nine percent more likely to be delayed than other investment projects. The external economic factors proxied by the occurrence of a recession and the average local unemployment rate during the construction period have an insignificant marginal effect on the probability of deviating from the investment schedule. Therefore, the empirical results are consistent with the qualitative evidence from Lexis-Nexis.

V. Discussion

What determines the length of time-to-build? Why are the construction lead times similar across industries? Is time-to-build a rigid technological constraint? Before turning to these questions, let us first examine the empirical findings of previous studies. The results from Table 1 could be compared to different estimates of time-to-build from the existing literature.

Mayer (1960) obtains an average time of 21 months between the decision to start a project until its completion. In another paper, Mayer and Sonenblum (1955) recover the construction time, defined as the period between the starting and estimated completion dates.[8] According to their estimates, the average industry lead time is slightly over three quarters.

More recently, Ghemawat (1984) reports that the construction lead time in the bulk chemicals industry is approximately four years. Lieberman (1987) mentions that ``in the chemical industry, there is, on average, a construction lag of about two years from the date when a decision is made to construct a new plant and the date when the plant becomes operational." In comparison, the chemical industry time-to-build from Table 1 is 23 months. Majd and Pindyck (1986) note that the projects such as the construction of a petrochemical plant take at least five years. MacRae (1989) observes that a power-generating plant usually takes between six and ten years to complete. From Table 1, the corresponding number for the utilities industry is 86 months. Therefore, the time-to-build estimates derived from Lexis-Nexis are consistent with the results found in the literature.

The proximity of the estimates of the average time-to-build found here and in Mayer's paper from 1960 is quite surprising. The length of time-to-build seems to be stable over time. In addition, the construction lead times are relatively insensitive to the choice of industry (with the exception of the utilities, rubber, industrial equipment, railroad transportation,

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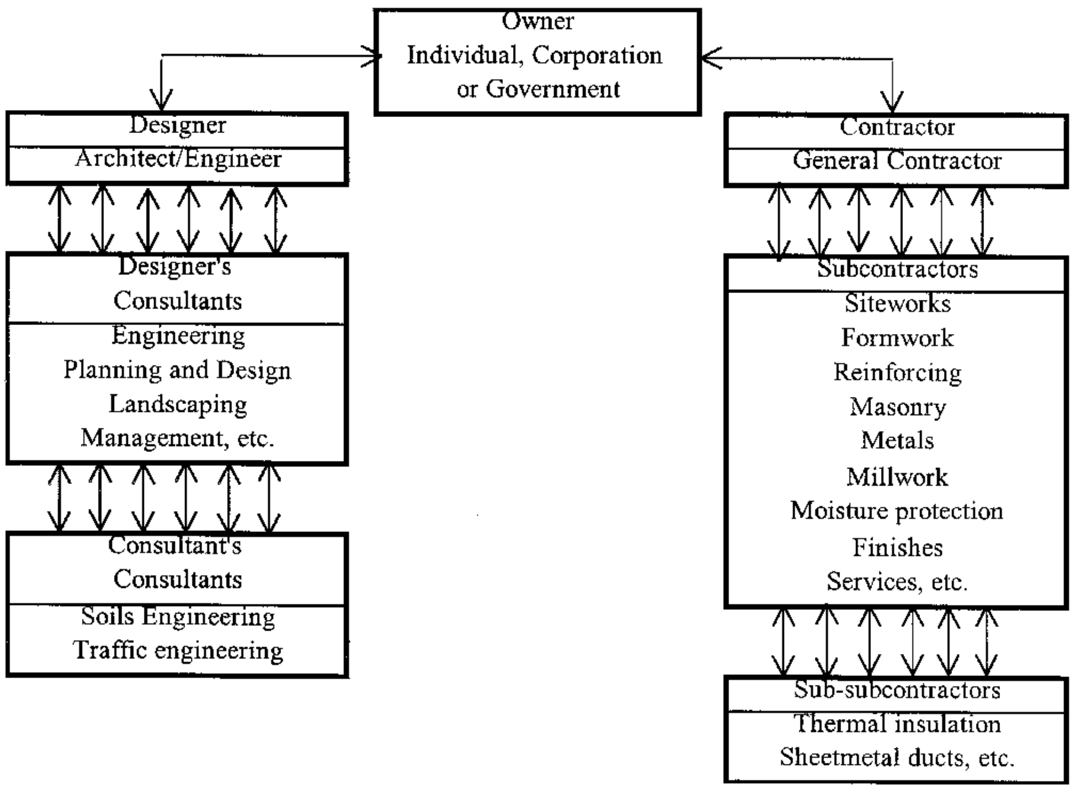
[8] Note that the period from the announcement of the project until the beginning of construction is excluded from the estimated lead time.

manufacturing, other and nondurable goods industries), and the size of the project.[9] These facts suggest that time-to-build is a technological parameter which cannot be easily altered.

Figure 4. Contractual Arrangements



Note: The arrows denote the presence of contracts.

The sequential nature of construction--most construction tasks cannot be performed out of order--limits the extent to which the process of building a plant can be speeded up. Builders have developed scheduling techniques which allow them to plan and utilize the construction time--bar charts, network diagrams, etc. An example of the scheduling tool called "the critical method path" (CMP). The contractors cannot, however, change drastically the technology in the construction industry and overcome the constraints of sequential building.

[9] The process of construction is the same regardless of the value of the installed machines. If plants are considered "large" because of the cost of the advanced technology embodied in them, then the size of the project may not have a large effect on the length of time-to-build.

Another fact which emerges from the previous section is that investment in large plants usually proceeds as planned in most industries (see Table 4). In other word, time-to-build is fairly inflexible ex-post. Outside the utilities industry, only one project was suspended due to an adverse change in the demand conditions. In addition, we have learned from the empirical results that time-to-build is insensitive to the business cycle.

The reluctance of companies to cause delays in their investment projects is also mentioned in one of the publications from Lexis-Nexis used for the collection of the data. In July 1982, an article in Chemical Week quotes an Amoco spokesman who says that "[the] company never interrupts construction once it has started, because any resulting delay would only drive up the cost." The article continues on to discuss the fact that some plants in the chemical industry have been completed and immediately mothballed.

What determines the observed inflexibility of time-to-build? A potential answer to this question can be found in the intricacy of the contractual arrangements which precede the start of a large investment project. The planning and construction of a plant involve many parties (the firm, the designer, the general contractor, the subcontractors, etc.) An example of contractual arrangements is presented in Figure 4, which illustrates the setup of the traditional construction contract. Other versions of the contractual relationship between the firm and the rest of the players are equally complicated. In this framework, the delay or suspension of the project could be very difficult and costly.[10]

The exact implications of delaying the project are set in the construction contract. On the contractor's side, delays are broken into excusable-nonexcusable and compensable-noncompensable categories. Any delay caused by the firm is classified as excusable and compensable. The firm has to acknowledge the delay and compensate the contractor under the terms of the contract. Otherwise, the two parties can invoke a costly contract dispute procedure.[11] Most contracts have suspension-of-work clauses which require the firm to reimburse the contractor.[12] Under these circumstances, the interruption of the investment project is very costly from the firm's point of view. Note that the contract between the firm and the general contractor is only one of the many agreements which have to be observed during the period of plant construction (see Figure 4). Since the interruption of the investment project affects each contract, the overall cost of the delay is substantial.

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[10] In the economics literature, the intricacy of the contractual arrangements in the construction industry has been emphasized by Bajari and Tadelis (1999).

[11] For example, Acret (1986) reports that "in a 1971 Montana Supreme Court decision, the contractor showed that it was an established and successful business, that it had always made a profit in years before the job in controversy, and that it had the opportunity to obtain other projects." As a result, the contractor was awarded the profits lost during the period of delay.

[12] The maximum suspension allowed under the typical contract is ninety days.

When interpreting the results from the previous section with respect to the length of time-to-build (see Table 1), one should keep in mind that the computations are based on a very small number of companies in some industries. These firms may not be representative of the larger sample of 1175 observations from Compustat. Another issue is that most of the companies which appear in the Compustat sample are large and well-established. The use of Lexis-Nexis is appropriate since this database is likely to contain information about the new projects of medium and large firms. The average company in the economy, however, may be quite different.[13]

Another potential concern is the measurement of time-to-build as described in Section 3.2. In this paper, I use the date of announcement of construction plans as the starting date used in the calculations.[14] Unfortunately, this information was not available in a few cases. Instead, I report the date when the project was mentioned for the first time as being under construction. In spite of these problems, I believe that the results presented in this paper capture some of the important features of the time-to-build process for nonresidential structures.

VI. Conclusion

The conclusions from this paper are clear. The new empirical evidence from Lexis-Nexis indicates that time-to-build is long and rigid. For most industries, the construction lead time for new plants is approximately two years. The length of time-to-build is not sensitive to the business cycle. Investment projects are rarely delayed or abandoned. The ex-ante and ex-post inflexibility of time-to-build is determined by technological and contractual factors.

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[13] The finding that time-to-build is inflexible mab not hold for small firms which are much more likely to face liquidity constraints, for example.

[14] Conceptually, one could argue that time-to-build starts from designing the new plant, which often precedes the announcement of the project. Another possibility is the starting date of construction.

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