Investment and Time to Plan: A Comparison of Structures vs. Equipment in a Panel of Italian Firms

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Summary

"Time to build" models of investment expenditures play an important role in many traditional and modern theories of the business cycle, especially for explaining the dynamic propagation of shocks. We estimate the structural parameters of a time-to-build model using firm-level investment data on equipment and structures. For equipment expenditures, we find no evidence of time-to-build effects beyond one period. For structures, by contrast, there is clear evidence of time to build in the range of 2-3 years. The contrast between equipment and structures is intuitively reasonable and consistent with previous results. The estimates for structures also indicate that initial-period expenditures are low, and increase as projects near completion. These results provide empirical support for including "time to plan" effects for investment in structures. More generally, these results suggest a potential source of specification error for Q models of investment and production-based asset pricing models that ignore the time required to plan, build and install new capital.

Keywords: Investment expenditures, Panel data, Italian firms, Time to build

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1 Introduction

Tobin's Q theory of investment observes that the ratio of the marginal value of capital to its marginal cost (Tobin's Q) ought to be unity for a value-maximizing firm. Deviations from one are explained by capital adjustment costs, and give rise to an equilibrium relationship between investment and Q. The theory assumes that capital is the sole endogenous state variable. Empirically, this is a strong assumption. In the presence of multiple capital types and/or time to plan, build and install capital (TTB), the model no longer predicts a simple relation between investment and Q. In our view, failure to account for these added margins is a leading explanation for the empirical shortcomings of the Tobin's Q model.

The Q theory generalizes to accommodate multiple capital types and TTB (Wildasin, 1984; Altug, 1989). But empirical estimates of models designed to accommodate both features of the data – especially TTB – are surprisingly scant.[2] Allowing *both* features simultaneously is useful because it sharpens identification. In particular, if TTB is important, the magnitude of its effects ought to be larger and statistically easier to recognize for structures than for equipment. Since equipment and structures are treated symmetrically in the model, there is no reason to expect spurious findings for one over the other. Hence, if the predicted contrast in the magnitude of TTB is supported by the data, then it is harder to attribute the results to spurious factors.

Our paper uses panel data on Italian firms to estimate a model that allows for two capital types (equipment and structure), each with its own time to plan and build. These data are well-suited to our purposes because they report stocks and expenditures for equipment and structure separately. We investigate the multi-factor TTB model derived in Altug (1993). Our empirical implementation follows the vector autoregressive approach of Abel and Blanchard (1986), as modified for panel data and

[2] Papers that directly or indirectly estimate investment models with TTB include Altug (1989), Oliner, Rudebush, and Sichel (1995), Peeters (1998), Christiano and Vigfusson (1999), and Koeva (2001).

multiple capital inputs by Gilchrist and Himmelberg (1995, 1998) and Bontempi, Del Boca, Franzosi, Galeotti, and Rota (2004), respectively.

We find strong evidence of time to build effects for structures. Our estimates of the structural parameters for time to build indicate that investment projects for structures require 2-3 years from their initial planning to their final completion. For equipment, by contrast, we cannot reject a model in which all investment becomes productive within a period of one year. These findings are broadly consistent with evidence obtained from data at the project level (Montgomery, 1995b; Koeva, 2000), firm level (Koeva, 2001), and aggregate macroeconomic data (Altug, 1993; Zhou, 1997).

The estimates for structures also indicate that expenditures are low initially, and increase as projects near completion. These results provide empirical support for including "time to plan" effects for the structures component of investment, and thus provide firm-level evidence complementary to the macroeconomic evidence documented in Christiano and Todd (1996), Bernanke, Gertler, and Gilchrist (1999), and Christiano and Vigfusson (2001).

Our findings are interesting for the following reasons. First, our results shed light on well-known evidence of specification error in existing estimates of investment models. For one, investment is characteristically persistent, and existing research shows this persistence is not easily explained. Empirical investigations of the Q model, for example, typically report residual correlation in the error term. This finding is consistent with (unmodeled) multiple capital types or TTB. Second, time to plan and build also has important implications for models of production-based asset pricing (of which Tobin's Q model is a special case).[3] In particular, it can explain why investment appears "insufficiently" sensitive to asset prices (e.g., interest rates or equity prices, including Q ratios). The relative insensitivity to current price changes arises because the current flow of investment reflects not only expenditures for new projects, but

[3]Cochrane (1991) and Gomes, Yaron, and Zhang (2003).

also the completion of existing projects, the decisions for which were based on the expectations of costs and benefits formed in earlier periods.

Finally, modern business cycle models have difficulty accounting for the persistence of output. Our evidence should be of value to research on business cycles because TTB is one commonly cited source of persistence and cycles. Recent work by Christiano and Todd (1996), Bernanke, Gertler and Gilchrist (1999), and Christiano and Vigfusson (2001) finds that allowing for "time to plan" (where initial periods are characterized by low expenditures) is important for explaining the "hump-shaped" response of investment expenditures to shocks. In related work, however, Rouwenhorst (1991) argues that TTB plays only a secondary role in the propagation of shocks in the calibration experiments in Kydland and Prescott (1982) (which assumed capital takes four quarters to install, one fourth in each quarter). Further evidence is reported by Cogley and Nason (1995), who argue that the quantitative role of TTB for shock propagation is small. The results in the current paper suggest that these results may be reconciled by the choice of calibration values. The above studies tend to assume the time to plan and build is 3 to 4 quarters. By contrast, empirical work increasingly suggests longer construction periods. Altug (1989) and Koeva (2000), for example, suggest TTB on the order of 7 to 12 quarters. This is consistent with our findings. Our evidence suggests that TTB is on the order of 12 quarters for structures (at least in Italy), versus less than a year for equipment expenditures. It remains an open question whether these larger values would be enough to produce interesting shock propagation in business cycles models like those calibrated, for example, by Cogley and Nason (1995).

The paper is organized as follows. Section 2 provides a brief overview of the research on time to build. In Section 2 we lay out the model of optimal investment decisions in heterogeneous capital under time to build. Section 3 describes the data set. In Section 4 we discuss the estimation methodology and present the empirical results. In Section 5 we interpret the structural parameters. Section 6 concludes.

2 The Investment Model with Heterogenous Capital Under Time-to-Build

When relating flows to stocks of capital goods, the standard assumption in the investment literature is that one unit of investment at time t yields an additional unit of capital stock in the same period. An alternative that is sometimes considered assumes that a unit of investment adds to the stock only in period $t+1$. This case, which implies that investment becomes productive with a lag, is usually referred to as one-period delivery lag. Of course, longer lags are possible, but with annual data that is the case most often entertained.

The time-to-build model postulates that it takes a number of periods (greater than one) for an investment project to be completed. Following Altug (1993), let P_t denote the real size of a capital project initiated in period t. Each project takes τ periods to complete; additions to time t capital stock equal projects started in period $t-\tau$. Thus: $K_{it} = (1-\delta) K_{it-1} + P_{it-\tau}$ (δ is the i-th firm's capital depreciation rate). Let ϕ_h denote the proportion of the value of a project that is put in place h periods after the start, with $\phi_h \geq 0$ ($h = 0, 1, \ldots, \tau$) and $\sum_h \phi_h = 1$. Finally, letting I_t be the value put in place during period t from all projects under way at that time, we have: $I_t = \sum_{h=0}^{\tau} \phi_h P_{t-h}$. Because different capital goods are likely to be characterized by different completion patterns, it is important to consider optimal investment decisions with many capital inputs.

We embed the TTB hypothesis in a model of optimal investment decisions in individual capital goods. Consider a firm which, at time $t = 0$, decides the optimal size of projects in the various capital inputs in order to maximize the expected present value of the future stream of profits:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \Pi \left(K_{1,it}, ...K_{J,it}, \theta_{it} \right) - \sum_{j=1}^{J} \left[c^j \left(I_{j,it}, K_{j,it}, \xi_{j,it} \right) - p_{j,t} I_{j,it} \right] \right\} \quad (1)$$

subject to the constraints $(j = 1, \ldots, J)$:

$$K_{j,it} = (1 - \delta_j) K_{j,it-1} + P_{j,it-\tau} \tag{2}$$

and:

$$I_{j,it} = \sum_{h=0}^{\tau} \phi_{j,h} P_{j,it-h}, \tag{3}$$

where i indexes the firm and j the capital input whose stock is denoted by K_j, θ is a shock to profits, β is the real discount rate, $\Pi(.)$ indicates current short run profits, $c^j(.)$ represent the adjustment cost functions, p_j the acquisition price of capital goods, and ξ_j are shocks to individual adjustment costs. E_t is the expectations operator conditional on information available at t. This set may or may not include time t variables. The price of each capital good is normalized by the output price. We assume that variable inputs are always at their optimal level; in order to simplify the notation we omit the explicit dependence of the profit function on variable input prices.

Substituting the two constraints into the objective function and optimizing with respect to P_j and K_j, the time t j-th first order conditions are:

$$-E_t \sum_{h=0}^{\tau} \phi_{j,h} \beta^{t+h} \left[p_{j,it+h} + \frac{\partial c^j_{it+h}}{\partial I_{j,it+h}} \right] + E_t \beta^{t+\tau} \mu_{j,it+\tau} = 0 \tag{4}$$

and:

$$E_t \beta^t \left[\frac{\partial \Pi_{it}}{\partial K_{j,it}} - \frac{\partial c^j_{it}}{\partial K_{j,it}} \right] - \beta^t \mu_{j,it} + E_t (1 - \delta_j) \beta^{t+1} \mu_{j,it+1} = 0 \tag{5}$$

At the optimal level of starts, condition 4 states that the expected cost of acquiring and installing one unit of capital over the next τ periods equals the expected shadow value of the marginal addition to the capital stock when the project comes on line, μ_j. Both the cost and the shadow value are discounted back to period t. To obtain an expression for this shadow value we first divide by β^t and then lead condition 5 τ

periods. Solving repeatedly forward the result yields:

$$E_t \beta^\tau \mu_{j,it+\tau} = E_t \beta^\tau \sum_{s=0}^{\infty} \beta^s (1-\delta_j)^s \left[\frac{\partial \Pi_{it+s+\tau}}{\partial K_{j,it+s+\tau}} - \frac{\partial c^j_{it+s+\tau}}{\partial K_{j,it+s+\tau}} \right] \tag{6}$$

This expression states that the time $t+\tau$ shadow value of a unit of j-th capital, expected and discounted at time t, equals the present value of profits generated by a unit of undepreciated capital from $t+\tau$ onward. Expression 6 can be combined with 4, divided by β^t, which we rewrite more extensively as follows:

$$E_t \beta^\tau \mu_{j,it+\tau} = E_t \left[\begin{array}{c} \phi_{j,0} \left(\frac{\partial c^j_{it}}{\partial I_{j,it}} + p_{j,it} + \xi_{j,it} \right) + \phi_{j,1} \beta \left(\frac{\partial c^j_{it+1}}{\partial I_{j,it+1}} + p_{j,it+1} + \xi_{j,it+1} \right) \\ ... + (1 - \phi_{j,0} - \phi_{j,1} - ... - \phi_{j,\tau}) \beta^\tau \left(\frac{\partial c^j_{it+\tau}}{\partial I_{j,it+\tau}} + p_{j,it+\tau} + \xi_{j,it+\tau} \right) \end{array} \right] \tag{7}$$

After having exogenously set the maximum time period of TTB, τ, expression 7 is amenable to econometric estimation once we parametrize adjustment costs and relate the expected shadow value of capital on the left hand side to observed variables. Taking up this last aspect first, we follow Abel and Blanchard (1986) and Gilchrist and Himmelberg (1995) by constructing the shadow value of capital from fundamentals, which is hence named "Fundamental Q." This is obtained by specifying a linear forcing process for a vector of variables observable to the econometrician and useful to forecast the expected marginal profitability of capital. The important feature of this approach is that it does not require knowledge of the stock market valuation of the firm and is therefore applicable to unlisted companies as in our case.

Next we generalize this approach to the case of heterogeneous capital, as in Bontempi, Del Boca, Franzosi, Galeotti, and Rota (2004). To construct the expectations of the future marginal profitability of capital appearing in 6, we assume that the firm's technology is Cobb-Douglas. Under perfect competition in the output market, we may relate marginal profits of capital to the observed variables as follows:

$$\frac{\partial \Pi_{it}}{\partial K_{j,it}} = \rho_{j,i} \left(\frac{\Pi_{it}}{K_{j,it}} \right) \tag{8}$$

where $\rho_{j,i}$ is the output elasticity of capital. In equation 8, the marginal profitability of each capital input is proportional to the corresponding average profitability. If, alternatively, imperfect competition is assumed, then we have:

$$\frac{\partial \Pi_{it}}{\partial K_{j,it}} = \sigma_{j,i} \left(\frac{S_{it}}{K_{j,it}} \right) \tag{9}$$

where S indicates sales and $\sigma_{j,i} = \left(1 + \eta_i^{-1}\right) \rho_{j,i}$ with η_i representing the firm level price elasticity of demand. In this case the marginal profitability of each capital input is proportional to the corresponding sales to capital ratio.

Consider now a vector $x_{j,it}$ comprised of capital-specific operating income to capital and sales to capital ratios and any other variables containing information which is useful for forecasting the future marginal profitability of capital. More precisely, the vector $x_{j,it}$ contains the right hand side of 8 and 9, i.e. the operating income based and the sales based marginal profitability of each capital good. Following Gilchrist and Himmelberg (1995) we allow for unobserved cross-sectional heterogeneity in the forcing process for $x_{j,it}$ by introducing firm-specific means (fixed effects) to allow the conditional mean to vary arbitrarily across firms. We also introduce a time specific component to the conditional mean to capture common movements in fundamentals caused by the business cycle (aggregate shocks). We assume that $x_{j,it}$ follows a stationary stochastic process with a finite-order autoregressive representation that we write in its AR(1) companion form:

$$x_{j,it} = A_j x_{j,it-1} + f_{j,i} + d_{j,t} + u_{j,it} \tag{10}$$

where A_j is the matrix of capital specific coefficients. Cross sectional heterogeneity is captured by a vector $f_{j,i}$ of firm unobservable fixed effects, while $d_{j,t}$ is a vector of shocks common to all firms for which we assume a finite-order autoregressive representation. Finally, $u_{j,it}$ is a vector of disturbance terms that are orthogonal to $x_{j,it-1}$.

Assume that variables dated t are part of the information set used to forecast future variables. Since we are assuming a stationary process and a finite-order autoregressive representation for both $x_{j,it}$ and $d_{j,t}$, then the expectation of $x_{j,it+s+\tau}$ given $x_{j,it}$ may be written as:

$$E\left[x_{j,it+s+\tau}|x_{j,it}\right] = A_j^{s+\tau} x_{j,it} \tag{11}$$

where we have omitted the terms involving $f_{j,i}$ and $d_{j,t}$ which result to be nuisance parameters in the subsequent analysis. The expected shadow value of capital on the left hand side of 6 may then be approximated by a variable which we call Fundamental Q given by the following expression:

$$\begin{aligned} FQ_{j,it+\tau} &= \beta^{\tau} \sum_{s=0}^{\infty} \lambda_j^s E[c' x_{j,it+s+\tau}|x_{j,it}] \\ &= \beta_j^{\tau} A_j^{\tau} \sum_{s=0}^{\infty} c' \lambda_j^s A_j^s x_{j,it} \\ &= c' \left(I - \lambda_j A_j\right)^{-1} \beta_j^{\tau} A_j^{\tau} x_{j,it} \end{aligned} \tag{12}$$

where $\lambda = (1-\delta)\beta$. Letting operating income be the first element of $x_{j,it}$, c is a vector with the first element equal to one and zeros elsewhere, under perfect competition.[4] We equate Fundamental Q as given above to the right hand side of 7 and parametrize

[4]If we assume that variables dated t are not part of the information set, the formula of Fundamental Q in 11 is slightly different. In particular, the expectation of $x_{j,it+s+\tau}$ given $x_{j,it-1}$ may be written as $E\left[x_{j,it+s+\tau}|x_{j,it-1}\right] = A_j^{s+\tau+1} x_{j,it-1}$, so that Fundamental Q becomes: $FQ_{j,it+\tau} = c' \left(I - \lambda_j A_j\right)^{-1} \beta_j^{\tau} A_j^{\tau+1} x_{j,it-1}$. If we compute Fundamental Q in this way, the empirical results of the regressions reported in the next sections are somewhat inferior but the main conclusions hold true.

adjustment costs by means of standard quadratic, linear homogenous functions of investment and capital stock. In addition, we replace expected values with realizations thereby introducing forecast errors up to period $t+\tau$. Because we do not have firm-specific observations on the prices of new capital goods, we neglect the $p_{j,it+\tau}$'s and let the firm and time fixed effects capture also their evolution. Letting a_j be the parameter summarizing the marginal adjustment cost associated to the j-th capital type, we obtain the final equation we estimate for each capital input:

$$\begin{aligned} FQ_{j,it+\tau} &= a_j\phi_{j,0}\left(\frac{I_{j,it}}{K_{j,it}}\right)+a_j\phi_{j,1}\beta\left(\frac{I_{j,it+1}}{K_{j,it+1}}\right)+... \\ &\quad +a_j(1-\phi_{j,0}-\phi_{j,1}-...-\phi_{j,\tau-1})\beta^{\tau}\left(\frac{I_{j,it+\tau}}{K_{j,it+\tau}}\right)+\upsilon_{j,i}+\nu_{j,t}+\epsilon_{j,it}. \end{aligned} \tag{13}$$

In 13 the terms $\upsilon_{j,i}$ and $\nu_{j,t}$ represent the composite firm fixed effects and time effects resulting from the substitution of equation 12 into 7; the error $\epsilon_{j,it}$ includes both the shock to adjustment costs, $\xi_{j,it}$, and the error introduced by replacing the present value of future marginal profits of each type of capital goods with its proxy obtained through the VAR auxiliary forecasting model.

One assumption that is sometimes considered is that of delivery lags, which posits that time has to pass before new capital is delivered. This implies that it gets added to productive capital with a lag. Although some confusion in the terminology is present in the literature, we concur with Peeters (1996, 1998) who defines "gestation lags" both the case in which time passes before capital goods are "constructed" (Time-to-build) and/or delivered (Delivery Lags). Aside from this, a standard assumption is that of one-period delivery lag, which results in the following relationship between investment and capital stock: $K_{it+1}=(1-\delta)K_{it}+I_{it}$. If we embed this assumption in our TTB approach, we obtain that the optimal firm's program is now subject to the constraint $K_{it+1}=(1-\delta)K_{it}+P_{it-\tau}$. In this case the relevant Fundamental Q expression is slightly different. More precisely, we have:

$$FQ_{j,it+\tau} = c' \left(I - \lambda_j A_j\right)^{-1} \beta_j^{\tau+1} A_j^{\tau+1} x_{j,it} \tag{14}$$

We will estimate the investment relationship 13 also under the above specification of Fundamental Q.[5]

3 Data Description

We use data from Italy's Company Accounts Data Service (CADS), a large database with information on the balance sheets and income statements of more than 52,000 Italian firms covering all industries from 1982 to 1995. In addition to company accounts the database contains information on firm demographics, location, sector, type of organization, ownership status, the composition of the board of management and the board of auditors. CADS is well representative of the population of Italian companies, covering over 50% of the value added produced by the firms included in the Census of the Italian Central Statistical Office. In Appendix A.1 we report variable definition and construction.

The original data set comprised 5,086 manufacturing firms over 1982-1995; after omitting firms with incomplete or problematic records we were left with a balanced panel of 1,539 companies for the 1985-1995 period.[6] This subsample remains representative of the original data set.[7] Consistently with the Italian industrial structure, our data mostly cover non-listed companies: in the final sample out of 1,539 units only 0.32% is listed on the stock exchange. According to the national figures, only

[5] Of course, if only dated $t-1$ variables are in the information set, then Fundamental Q becomes: $FQ_{j,it+\tau} = c' \left(I - \lambda_j A_j\right)^{-1} \beta_j^{\tau+1} A_j^{\tau+2} x_{j,it-1}$.

[6] The main reason why we are left with 1539 firms is the need to have companies with continuous records on equipment and structure and, separately, on purchases and sales of those assets.

[7] Only firms which have been in receipt of a bank loan at the initial date are tracked. This introduces a possible specification bias through the exclusion of new and/or financially weak firms. Firm mortality is very low and is unlikely to be problematic.

0.13% of Italian manufacturing companies were listed on the Stock Exchange in 1995. This is the main justification for adopting the Fundamental Q approach to model investment in Italy. Another aspect of our data set is the inclusion of a high number of small and medium firms. These are predominant in Italy: on average the Italian manufacturing limited liability companies have 44 employees. The average number of employees in our final sample is 166 employees with 30.2% of the companies have less than 50 employees.[8]

We define net investment as purchases minus sales of fixed capital, and gross investment as purchases only; unlike gross investment, net investment may take negative values, when capital sales are larger than purchases. Table A.2.1 in Appendix A.2 presents the summary statistics for the variables we use: net investment $(I/K_T, I/K_E, I/K_S)$, gross investment or purchases $(I/K_T^+, I/K_E^+, I/K_S^+)$ and disinvestment or sales $(I/K_T^-, I/K_E^-, I/K_S^-)$, real sales $(S/K_T, S/K_E, S/K_S)$, and operating income $(\Pi/K_T, \Pi/K_E, \Pi/K_S)$. All these variables are divided by the stock of total capital (T), equipment (E), and structures (S).[9] The positive skewness suggests that investment is temporally concentrated; in particular, this is true for structures which exhibit a zero net investment rate in the first quartile. Purchases follow a similar pattern. Most of the disinvestment is small and have a markedly skewed distribution, with the highest degree in the case of structures. The mean annual rates of disinvestment are as low as 0.037, 0.040 and 0.035 respectively, with an even lower median, strongly affected by the high number of zero episodes. Given the high frequency of positive outliers due to the skewness of our data, we use pseudo-standard deviation which is a more robust as a measure of variability.[10]

[8] In Table A.2.2 in Appendix A.2 we report the distribution of firms by industry and size.

[9] We measure the stocks of equipment and structures as they are reported on the firm's balance sheet. Strictly speaking, the time-to-build model would not include "work in progress" as part of the capital stock since those capital expenditures are not yet productive. Incorporating the true measure would require a complex, nonlinear estimation techniques. Since work in progress is a relatively small fraction of the total stock, and because it appears in the denominator of a relatively small ratio, the effect on measured investment rates is likely small. It is therefore unlikely that is has much effect on our results, although we do not produce evidence for this conjecture.

[10] The pseudo-standard deviation is defined as the ratio of the interquartile range (*q3*-*q1*) and

4 Estimation and Empirical Results

We estimate our investment model using a two-stage procedure. In the first stage we estimate a VAR model for each type of capital good and calculate the corresponding Fundamental Q. In the second stage we estimate the individual investment equations as functions of the Fundamental Q's previously obtained.

We adopt a bivariate VAR of order two specification and estimate the coefficient matrices A_j's in equation 10 for aggregated capital, equipment, and structures. The vector $x_{j,it}$ comprises the two measures of the marginal profitability of capital, based on operating income and sales, as in the right hand side of equations 8 and 9. Following Gilchrist and Himmelberg (1998), the technology and demand parameters, $\rho_{j,it}$ and $\sigma_{j,it}$, are calculated as industry-level averages as follows:

$$\widetilde{\rho}_{j,h} = \left(\frac{1}{N_h T} \sum_{i \in N_h} \sum_{t \in Tj,it} \frac{\Pi_{it}}{K_{j,it}} \right)^{-1} \frac{1}{N_h T} \sum_{i \in N_h} \sum_{t \in Tj,it} (r_{it} + \delta_{j,ht}) \tag{15}$$

and:

$$\widetilde{\sigma}_{j,h} = \left(\frac{1}{N_h T} \sum_{i \in N_h} \sum_{t \in Tj,it} \frac{S_{it}}{K_{j,it}} \right)^{-1} \frac{1}{N_h T} \sum_{i \in N_h} \sum_{t \in Tj,it} (r_{it} + \delta_{j,ht}) \tag{16}$$

where j indicates the type of capital good, h denotes industry, $N_h T$ is the number of observations by firm and year in industry h, $\delta_{j,ht}$ is the rate of physical depreciation which varies by industry and time, and r_{it} is the rate of interest on financial debt. Table A.3 in the appendix reports the computed values of $\widetilde{\rho}_{j,h}$ and $\widetilde{\sigma}_{j,h}$by industry.

The VAR model is estimated using DPD for Ox following Doornik, Arellano, and Bond (2002), which essentially applies an efficient GMM estimator to the equation transformed by first differences to eliminate fixed firm effects. Common time shocks are eliminated by including time dummies, and the estimates of the standard errors are consistent under heteroskedasticity.

1.349 where 1.349=2*0.674 is the interval containing 50% of the cases in a normal distribution.

The parameter estimates of the VAR and associated diagnostics are reported in Table A.4 of the appendix. This table is divided into three parts. The headings refer to the capital stock used in the denominator of the variable ratios included in the VAR. For example, in the first panel, $(\Pi/K)_t$ and $(S/K)_t$ indicate operating income and sales scaled by the aggregate capital stock. In the second and third panels, K consistently refers to equipment and structures, respectively. Sargan's test of over-identifying restrictions is reported for each equation. Values statistically different from zero at the five and one percent levels (two-tailed) are denoted by two and one asterisks, respectively. Table A.4 also reports AR(1) and AR(2) tests for serial correlation in the residuals. The differencing transformation used by DPD to remove the fixed-firm effects induces first-order serial correlation in the errors. Longer lags ought to be zero if the underlying model errors are mutually orthogonal. This predicted pattern in the diagnostics is strongly confirmed by the results, suggesting an adequate VAR specification for the time series process of the vector $\{(\Pi/K)_t, (S/K)_t\}$.

The second stage of this approach uses the estimated elements of the VAR matrices $\widehat{A}_j$'s to construct the Fundamental Q's. The term λ_j varies according to the type of capital, and it is equal to 0.8614 for total investment, 0.8394 for equipment and 0.8944 in the case of structures.[11] Armed with these ingredients, we set the maximum TTB period equal to three and present estimates for this and the lower order cases. We consider four alternative specifications of the unrestricted Fundamental Q model, the cases corresponding to $\tau = 0, 1, 2$, and 3. For the case $\tau = 3$, for example, the model

[11] These values correspond to the sample average of firm and time specific discount factors: $\widetilde{\lambda}_j = \frac{1}{H}\sum_{h\in H}\frac{1}{N_h T}\sum_{i\in N_h}\sum_{t\in T}\beta_{it}(1-\delta_{j,ht})$, where H is the total number of industries. The discount rate β_{it} is calculated as $[1+(1-\tau_t)r_{it}-z_{ht}]^{-1}$ where τ_t is the statutory tax rate on firm profits, and z_{ht} is the inflation rate (see Appendix A.1 for variable definitions). We follow Abel and Blanchard (1986) and Gilchrist and Himmelberg (1995) who consider the average across firms and over time of the discount factor and assume that firm-specific and year-specific effects in the λ's are captured by the individual and temporal effects in the VAR equations.

is:

$$FQ_{j,it+3} = b_0 \frac{I_{j,it}}{K_{j,it}} + b_1 \frac{I_{j,it+1}}{K_{j,it+1}} + b_2 \frac{I_{j,it+2}}{K_{j,it+2}} + b_3 \frac{I_{j,it+3}}{K_{j,it+3}} + f_{j,i} + \nu_{j,t} + \xi_{it}. \quad (17)$$

where $b_0=a_j\phi_0$, $b_1=a_j\phi_1\beta$, $b_2=a_j\phi_2\beta^2$ and $b_3=a_j(1-\phi_0-\phi_1-\phi_2)\beta^3$. We estimate the investment equation 17 for aggregated capital, equipment, and structures distinguishing between net investment (purchases minus sales) and gross investment (purchases only). As in the VAR, we use GMM in first differences to take into account the possible correlation of the fixed effects. We include a vector of time dummies in order to control for common aggregate shocks, for changes in tax code and for price variations in each capital good.[12] The instruments used are lagged values of the ratios of operating income, sales and investment to capital and time dummies. The effective estimation period is 1987-1995.

The estimation results of the unrestricted models are reported, along with diagnostic statistics, in appendix Tables A.6-A.8. These tables report only the reduced-form parameters, which are not of direct interest, so we do not discuss them here; instead we will discuss the values of the structural parameters reported in Tables 1-3 below. Before proceeding to that discussion, however, it is interesting to note the pattern of specification tests across the four columns of Table A. 6. First, Sargan's test rejects all eight specifications. However, the pattern is interesting. In the first column, the specification assumes $\tau = 0$. Sargan's test is 170.6, which rejects the model at the one percent level. Moreover, the t-test for autocorrelation at the second lag has a value of 2.968, which rejects zero. Whatever the source of specification error, this test suggests that it results in (unmodeled) correlation in the residuals.

The second column relaxes the specification to allow for $\tau = 1$, that is, the time

[12] The estimated coefficients, not reported, capture in all the equations the significant effect on marginal profitability and investment of the recession which occurred in 1991-1993 and of the boost in investment generated by the "Tremonti law" (firms which in 1994-1995 were investing an amount greater than the average over the previous five years were entitled to a 50% tax reduction on the excess).

to plan and build is allowed to take up to one year. The data reject this model, too: both Sargan's test and AR(2) are statistically significant at the one percent levels. In columns three and four, however, the evidence against the model drops somewhat as the time to build is extended to two and three periods, respectively. Sargan's statistic still rejects, but has fallen to levels of 112.2 and 97.89. The AR(2) t-statistic has is somewhat lower, too, at values of 1.607 and 2.438. In all, these tests reveal an ill-fitting model.

For the sake of completeness, the second half of the table (in columns 5-8) report results using net rather than gross investment. The usual stories for adjustment costs and time to plan and build are more consistent with gross investment than net, so we prefer the specification in columns 1-4, but for the record, these estimates tell a similar story. Sargan's test rejects in all cases, and for two of the four specifications, the AR(2) statistic rejects. For the remainder of the discussion in this section, we discuss only the results for gross investment, but for the reader's convenience we report results for both gross and net investment.

Tables A.7 and A.8 report estimates for the disaggregated investment model. Table A.7 reports equipment investment, and Table A.8 reports structures investment. These models fare better by the specification tests. Sargan's test rejects in all cases, but in the models that do not allow for TTB, there is more evidence against the models for structures than equipment. In column 1 of Table A.7, for example, Sargan's statistic is 129.1 for equipment, whereas in Table A.8 for structures it is 183.1. As we relax the model specification, the fit improves considerably, and the model for structures benefits more than the model for equipment. For structures, the AR(2) statistic does not reject zero for specification involving $\tau > 0$. The results for equipment are less stable. For $\tau = 1$ or $\tau = 2$, this test rejects with values of 4.402 and 4.027, but for $\tau = 0$ or $\tau = 3$, it fails to reject (values of 0.911 and 0.108, respectively).

For more clues on the fit of these models, we can also inspect the statistical significance of the parameter coefficients reported in the upper half of each of the tables. For equipment (Table A.7), as we move from column 1 to columns 2-4, there is very little evidence to support alternatives to a null hypothesis $\tau = 0$. For structures (Table A.8), however, the additional parameters introduced by models with $\tau > 0$ are almost always different from zero at statistically significant levels. In the model assuming $\tau = 1$ in column 2, for example, the reduced form coefficient on $(I/K)_{t+1}$ is 0.661 (0.105), where the standard error is reported in the parentheses. When the model is further relaxes to allow $\tau = 2$, the coefficient on $(I/K)_{t+1}$ drops to 0.498 (0.101), while the now unrestricted coefficient on the $(I/K)_{t+2}$ rises to 0.651 (0.119). The best fit for structures, however, appears to be the case $\tau = 3$ reported in column 4. All for coefficients on the current and three forward lags of I/K are positive and precisely estimated. As usual, the Sargan test rejects, but the AR(2) and AR(3) easily fail to reject zero, while the AR(4) value indicates weak evidence against the model.

In summary, we find that when TTB is increased up to a period of three years, model fit improves substantially for structures investment. For equipment investment, however, the improvement in model fit is modest to none. These results are consistent with our prior beliefs about the time required to plan, build and install new structures as opposed to new equipment.

5 Interpretation of the Structural Parameters

Conditional on model performance, discussed in the preceding section, we can now examine the structural parameters implied by the estimated models. Adjustment cost and TTB coefficients are presented for the cases in which the maximum number of years for TTB goes from zero to three. Table 1 reports the evidence for the case of aggregate investment, while tables 2 and 3 disaggregate total capital into equipment and structures respectively. For each case both gross investment (asset purchases) and net investment (purchases net of sales) are considered.

As seen in the previous section, a long TTB - up to the maximum length of three years - seems to describe well the case of structures, whereas equipment has either a zero or a one period TTB. The case of aggregate investment is less clear, though the findings just mentioned make clear that looking at aggregate investment makes little sense. One reason for considering nonetheless the aggregate case is because most, or nearly all business cycle models making use of the TTB concept only consider total capital stock.

A first consideration concerns estimated adjustment costs. The model considered here retained the assumption of quadratic, convex cost structures. We can see the coefficient a is always positive and statistically significant. Hence convexity of adjustment costs cannot be rejected. In terms of magnitude of the parameter, we note that for aggregate and equipment investment it declines as we increase the maximum length of TTB, while the opposite occurs for structures. For instance, in the TTB(3) case for structures the adjustment cost parameter is equal to 1.537 (case of purchases). This is markedly lower than the value of 5.26 reported by Bontempi et al. (2003), which is the study more directly comparable to the present one.[13] In the light of the very high coefficients of the literature using stock-marked based measures of (average) Q, our finding is very reasonable as it implies that the cost of adding

[13] See Bontempi et al. (2003) for a brief discussion of the evidence in the literature concerning the size of estimated adjustment costs in Q-investment equations.

to the existing stock a dollar of structures entails an extra cost of 27 cents.[14] As for equipment, adjustment costs are found to be smaller than those characterizing structures, as expected. However, the decreasing magnitudes of this coefficient as we move toward higher order TTB technologies makes them less and less reasonable, something that goes along with the worsening overall performance of the estimated model. Thus, a reasonable value of adjustment costs for equipment is 0.743 in the TTB(1) case (for purchases), corresponding to 22 cents of adjustment costs per dollar of additional equipment.

We now turn to examine the ϕ_i parameters, which are those we are mostly concerned with in this paper. Kydland and Prescott (1982) first showed that allowing for TTB proved important for business cycle analysis. Short of empirical evidence, or for the sake of simplicity, they assumed that completing new investment projects takes a maximum of four quarters and that payments are equally distributed over this period of time, so that $\phi_i = 0.25$. Moreover, they considered a single aggregate capital asset. In fact, even before those authors' contribution, some evidence based on surveys was available. Analyzing the nonresidential structures of 110 U.S. companies in 1954, Mayer (1960) found the average period from start to completion of a typical project to be five quarters. In addition, between decisions to build and completion seven quarters elapsed. Using Census data, Taylor (1982) considered nonresidential buildings in U.S. manufacturing industries requiring up to three years to complete. He found that a major fraction of the value put in place occurs in the initial periods, i.e. for two (three) year projects 81% (85%) of resources are expended in the first (first two) year(s). Montogomery (1995) finds that the average completion period is 16,7 months in a survey of U.S. Department of Commerce data for a long period of time (1961-1991). Peeters (1996) studies new plants in the Dutch industry during the

[14]This calculation is made at the mean value of the investment ratio for structures. Note also that traditional Q investment equations produce estimates of the reciprocal of the adjustment cost parameter a. Because our model has instead Fundamental Q on the left hand side we obtain a direct estimate of that parameter.

period 1990:2-1991:4 and finds the TTB is more than two years in this case. Finally, Koeva (2000) analyzes structures in a sample of 106 U.S. companies. The average length for completion is two years in most industries with 86 months in utilities and just 13 months in the rubber industry.

The alternative route to characterize TTB technologies rests on the estimation of the parameters of a structural model, a strategy also followed here. Most studies in this area, however, use aggregate data, thus casting doubts on the realism of the evidence so obtained. Altug (1989) assumes a TTB process for structures of maximum four quarters, while equipment is treated in the standard way. On aggregate quarterly U.S. data for 1948-1985 he estimates increasing values for the ϕ_i, suggesting that a declining proportion of resources are allocated to investment projects close to completion. More specifically, 70% of the resources needed to complete a given project are expended in the first two quarters. Same assumptions are made by Palm, Peeters, and Pfann (1993) who use quarterly total manufacturing data for the U.S. over the period 1960-1988. The authors find that the TTB parameters are all positive and significant and display a hump-shaped distribution. The U.S. private business sector forms the basis of the investigation by Oliner, Rudebusch, and Sichel (1995), which assumes a four-quarter TTB both for equipment and for structures. The data cover the years 1952-1992. Both types of capital assets have all the coefficients significant and both cases are characterized by declining weights. Peeters (1998) carries out an international studies, based on quarterly manufacturing data for the U.S., Canada, U.K., West Germany, France, the Netherlands for the periods 1960-1990 or 1970-1990. A TTB(1) (a one-period "delivery lag") is assumed for equipment and a TTB(3) for structures. The author finds all parameters significant, with declining magnitudes for Canada, U.K., West Germany, and France. A U-shape instead characterizes the U.S., while a hump shape applies to the Netherlands. Finally, using quarterly data over 1949-1991 for the U.S., Zhou (2000) rejects the zero TTB hypothesis. He then assumes either a four or a six quarters maximum TTB. These two cases provides a distribution which is declining as we approach completion in the former case, and U-shaped in the latter.[15]

Koeva (2001) is the only econometric study of investment under TTB conducted at the firm level. The author uses U.S. Compustat data for the years 1974-1996 and assumes a maximum two year TTB. Based on this assumption, only the manufacturing companies belonging to industries which, from previous analysis, have at most a TTB(2), are selected for the final sample, which consists of 528 firms. The study considers only aggregate investment and estimates a TTB-augmented Euler equation with quadratic adjustment costs. The TTB parameters are statistically significant and equal to $\phi_1 = 0.05$, and $\phi_2 = 0.90$, leading the author to conclude that the design phase involves no large expenditures. Finally, the adjustment cost parameters, while decreasing with the introduction of TTB relative to TTB(0), remains too large.

As we have just seen, with one exception, the available evidence is always based on aggregate data. This is clearly unrealistic, and makes it difficult to interpret the TTB coefficients. The second remark is that quarterly data are typically used. Finally, we note that, with just an exception, the evidence is available only for the Unites States.

How do our findings compare with those of the papers surveyed above? The first notable result is that, in the case of Italian data, completion of projects takes up to four years in the case of structures. One year seems instead to be sufficient for equipment. The finding for structures may be unexpected when compared with other studies. One likely explanation is the different institutional setup of the country relative to the U.S. (different working practices, bureaucratic regimes, tax structure, and so on). On the other hand, the above studies seem to have retained the original Kydland and Prescott (1982) four quarter assumption, while being more interested in assessing the uniform distribution of expenditures across periods. In this respect our findings as far as structures are concerned interestingly suggest that the uniform distribution may be a reasonable way of describing the TTB pattern. Indeed, if we

[15] The author states that results similar are obtained for an eight quarters TTB.

look at columns (4) and (8) of Table 3 we see that the $\phi' s$ are all between 0.2 and 0.3, with the highest proportion (about 30%) of expenditures in the second year. In the case of equipment, looking at columns (2) and (6) of Table 2, we see that in the first period about 15% of the expenditures are made, the rest being done in the following and final year.

Table 1
Estimated of Time-to-Build Parameters for Aggregate Investment
(Equipment plus Structures)

Structural Parameter	Gross Expenditures (1)	(2)	(3)	(4)	Net Expenditures (5)	(6)	(7)	(8)
a	1.144**	1.206**	1.235**	0.814**	1.476**	1.270**	1.095**	0.743**
	(0.190)	(0.213)	(0.258)	(0.199)	(0.178)	(0.229)	(0.262)	(0.316)
ϕ_0		0.367**	0.016	0.002		0.280**	0.206*	0.232*
		(0.083)	(0.079)	(0.072)		(0.104)	(0.112)	(0.139)
ϕ_1			0.280**	0.266**			-0.219	-0.350
			(0.092)	(0.112)			(0.249)	(0.288)
ϕ_2				0.614**				0.777**
				(0.814)				(0.281)

Notes: Robust standard errors appear in parentheses.

Table 2
Estimated of Time-to-Build Parameters for Equipment

Structural Parameter	Gross Expenditures (1)	(2)	(3)	(4)	Net Expenditures (5)	(6)	(7)	(8)
a	1.259**	0.743**	0.270**	0.191*	1.606**	0.753**	0.326	0.253*
	(0.215)	(0.115)	(0.125)	(0.104)	(0.222)	(0.146)	(0.262)	(0.151)
ϕ_0		0.839**	1.891**	1.145**		0.894**	1.422	0.931**
		(0.150)	(0.774)	(0.486)		(0.131)	(1.224)	(0.414)
ϕ_1			-1.070	-0.290			-0.571	-0.218
			(0.704)	(0.364)			(1.023)	(0.269)
ϕ_2				-0.003				0.077
				(0.167)				(0.173)

Notes: Robust standard errors appear in parentheses.

Table 3
Estimated of Time-to-Build Parameters for Structures

	Structures							
Structural Parameter	Gross Expenditures (1)	(2)	(3)	(4)	Net Expenditures (5)	(6)	(7)	(8)
a	0.415**	0.877**	1.349**	1.537**	0.585**	1.051**	1.507**	1.698**
	(0.110)	(0.165)	(0.220)	(0.218)	(0.109)	(0.198)	(0.258)	(0.230)
ϕ_0		0.246**	0.148**	0.213**		0.328**	0.149**	0.211**
		(0.093)	(0.062)	(0.054)		(0.071)	(0.077)	(0.052)
ϕ_1			0.369**	0.213**			0.361**	0.202**
			(0.043)	(0.031)			(0.070)	(0.032)
ϕ_2				0.301**				0.319**
				(0.034)				(0.038)

Notes: Robust standard errors appear in parentheses.

6 Conclusions

When looking at the structural parameters, this paper allows us to draw the following interesting conclusions. First of all, it is important to distinguish between different capital assets. This study has confirmed that equipment and structures are different in many respects, including the time it takes to build a new investment project. We find that equipment can be reasonably characterized by a one-period TTB: this case we can alternatively referred to as one-period gestation lag. On the other hand, it takes up to four years to build structures, at least in the Italian institutional context. This finding is clearly very different from the evidence of the bulk of the literature, which has typically looked at the U.S. case and made use of aggregate data, albeit with quarterly frequency. The only firm level study assumes a maximum of two years for the TTB in structures, while survey evidence suggests long periods required for completing building projects. The average period is two years, with 86 months required in the case of utilities. In the case of the pattern of expenditure installments, we find that the hypothesis of a uniform distribution across periods is a reasonable, albeit approximate, description of reality. This finding is clearly in line with the original assumption maintained by Kydland and Prescott (1982), but is at variance with the patterns estimated by previous structural models.

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A Appendix

A.1 Variable Construction

δ_T, δ_E, δ_S: depreciation rates of total fixed assets, equipment and structures by year and 2-digit manufacturing industry (ISTAT, Italian Statistical Office).
p_T, p_E, p_S, pp, z: price indexes for investment in total assets, equipment and structures, output price and rate of inflation, by year and 2-digit manufacturing industry (ISTAT).
r: actual interest rate on financial debt (interest on bank loans, factoring and leasing divided by the stock of debt).
I_T^+, I_E^+, I_S^+: capital expenditures of total capital, equipment and structures (direct purchases of new fixed capital).
I_T^-, I_E^-, I_S^-: sales of total capital, equipment and structures at the sale value.

We use the method proposed by Bond and Meghir (1994) in order to distinguish between equipment and structures. We use the change in gross capital (end of period book values) to estimate purchases (sales) of equipment and structures:

$$I_{E,it}^+ = I_{T,it}^+ \frac{\widetilde{K}_{E,it} - \widetilde{K}_{E,it-1}}{\widetilde{K}_{T,it} - \widetilde{K}_{T,it-1}}$$

I_T, I_E, I_S: net investment in total capital, equipment and structures. Net investment is computed as the difference between direct purchases and sales.
K_T, K_E, K_S: replacement cost values of total capital, equipment and structures. These values are estimated from historic cost accounts by using an iterative perpetual inventory formula (modified in order to take into account the " *Visentini Law*", which allowed firms to revalue the book values of their capital stock in 1982 and 1983):

$$K_{j,it+1} = K_{j,it}\left(1 - \delta_{j,ht+1}\right)\left(p_{j,ht+1}/p_{j,ht}\right) + I_{j,it+1}$$

where $j = T, E, S$; h indicate industry, and the initial K_j is equal to the net book value in 1982 or 1983.
S_T, S_E, S_S: real sales as a proxy for the nominal value of output deflated by the output price index, *pp*.
Π_T, Π_E, Π_S: operating income as a proxy for marginal product of capital, deflated by the output price index, *pp*.

Table A.1
Descriptive Statistics

	q_1	$Median$	q_3	$Mean$	$Pseudo - s.dev.$	$Skewness$
I/K_T	0.066	0.129	0.228	0.178	0.120	3.632
I/K_E	0.065	0.157	0.289	0.221	0.166	4.199
I/K_S	0	0.037	0.181	0.177	0.134	4.258
I/K_T^+	0.083	0.155	0.274	0.215	0.141	7.724
I/K_E^+	0.076	0.168	0.304	0.261	0.169	6.723
I/K_S^+	0.003	0.044	0.194	0.212	0.142	7.727
I/K_T^-	0	0.002	0.014	0.037	0.010	22.601
I/K_E^-	0	0.002	0.011	0.040	0.008	21.202
I/K_S^-	0	0.0001	0.004	0.035	0.003	32.118
S/K_T	2.282	3.432	5.347	4.344	2.272	2.770
S/K_E	3.472	5.565	9.451	7.910	4.432	4.223
S/K_S	5.939	9.651	16.017	13.278	7.471	3.305
Π/K_T	0.235	0.365	0.563	0.459	0.243	3.863
Π/K_E	0.365	0.588	0.968	0.832	0.448	6.767
Π/K_S	0.591	1.015	1.741	1.449	0.852	5.156

Table A.2
Distribution of Firms by Industry and Size

Industry	**No. of firms**	**Frequency**
Food, drinks and tobacco	167	10.85
Textile and clothing	177	11.5
Leather and footwear	31	2.01
Timber and wooden furniture	34	2.21
Paper and printing	82	5.33
Oil, chemicals and fibres	128	8.32
Rubber and plastic	101	6.56
Minerals	116	7.54
Metal and metal goods	108	7.02
Mechanical engineering	384	24.95
Electric mat. and prec. instruments	93	6.04
Motor vehicles and oth. trans. equip.	36	2.34
Other manufacturing	82	5.33
Size		
0-49	454	29.71
50-259	875	57.26
$\geq$250	199	13.02

Table A.3
Estimates of σ_j and ρ_j by industry

	σ_j			ρ_j		
Industry	**Agg.**	**Equip.**	**Struct.**	**Agg.**	**Equip.**	**Struct.**
Food, drinks & tobacco	0.046	0.028	0.013	0.617	0.380	0.166
Textile & clothing	0.069	0.038	0.020	0.660	0.372	0.184
Leather & footwear	0.051	0.034	0.14	0.647	0.440	0.170
Timber & wooden furniture	0.095	0.055	0.027	0.844	0.495	0.231
Paper & printing	0.088	0.063	0.021	0.753	0.541	0.174
Oil, chemicals & fibres	0.051	0.032	0.018	0.478	0.300	0.156
Rubber & plastic	0.082	0.049	0.022	0.712	0.425	0.190
Minerals	0.101	0.066	0.024	0.754	0.499	0.179
Metal & metal goods	0.072	0.047	0.020	0.701	0.468	0.193
Mechanical engineering	0.064	0.036	0.019	0.578	0.325	0.167
Electric materials & precision instruments	0.065	0.039	0.018	0.479	0.286	0.131
Motor vehicles & other transport equip.	0.064	0.038	0.015	0.587	0.333	0.137
Other manufacturing	0.072	0.040	0.024	0.763	0.422	0.260

Table A.4
Bivariate VAR Estimates

	Aggregate		Equipment		Structures	
Variables	$(\Pi/K)_t$	$(S/K)_t$	$(\Pi/K)_t$	$(S/K)_t$	$(\Pi/K)_t$	$(S/K)_t$
$(\Pi/K)_{t-1}$	0.691**	0.016	0.588**	-0.008	0.654**	-0.013
	(0.040)	(0.022)	(0.057)	(0.037)	(0.064)	(0.033)
$(\Pi/K)_{t-2}$	-0.029	-0.001	-0.055	-0.021	-0.020	0.009
	(0.023)	(0.015)	(0.041)	(0.034)	(0.0387	(0.025)
$(S/K)_{t-1}$	0.018	0.816**	-0.071	0.636**	0.101	0.824**
	(0.048)	(0.043)	(0.076)	(0.081)	(0.079)	(0.058)
$(S/K)_{t-2}$	-0.104*	-0.133**	0.006	-0.064	-0.081	-0.059
	(0.038)	(0.032)	(0.055)	(0.057)	(0.069)	(0.047)
no. of obs.	12312	12312	12132	12312	12312	12312
Sargan χ^2	31.32	50.89	48.35**	60.66**	40.51	46.38*
AR(1)	-12.87**	-8.46**	-5.51**	-6.48**	-7.39**	-7.35**
AR(2)	0.40	-0.24	0.18	0.86	1.03	0.98

Table A.5:
Guide to the Four Model Specifications Estimated in Table A.6-A.8

Model Specification	Equation
TTB=0	$FQ_{j,it} = b_0 \frac{I_{j,it}}{K_{j,it}} + f_{j,i} + \nu_{j,t} + \xi_{it}$
TTB=1	$FQ_{j,it+1} = b_0 \frac{I_{j,it}}{K_{j,it}} + b_1 \frac{I_{j,it+1}}{K_{j,it+1}} + f_{j,i} + \nu_{j,t} + \xi_{it}$
TTB=2	$FQ_{j,it+2} = b_0 \frac{I_{j,it}}{K_{j,it}} + b_1 \frac{I_{j,it+1}}{K_{j,it+1}} + b_2 \frac{I_{j,it+2}}{K_{j,it+2}} + f_{j,i} + \nu_{j,t} + \xi_{it}$
TTB=3	$FQ_{j,it+3} = b_0 \frac{I_{j,it}}{K_{j,it}} + b_1 \frac{I_{j,it+1}}{K_{j,it+1}} + b_2 \frac{I_{j,it+2}}{K_{j,it+2}} + b_3 \frac{I_{j,it+3}}{K_{j,it+3}} + f_{j,i} + \nu_{j,t} + \xi_{it}$

Table A.6
Reduced-Form Model Estimates

	Aggregate Investment							
	Gross Expenditure Specifications				Net Expenditures Specifications			
Parameter	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I_t/K_t	1.144**	0.443**	0.020	0.001	1.476**	0.355**	0.225**	0.172**
	(0.190)	(0.118)	(0.093)	(0.061)	(0.178)	(0.103)	(0.096)	(0.067)
I_{t+1}/K_{t+1}		0.763**	0.346**	0.217**		0.914**	-0.240	-0.259
		(0.207)	(0.164)	(0.099)		(0.229)	(0.222)	(0.146)
I_{t+2}/K_{t+2}			0.869**	0.499**			1.109**	0.577**
			(0.166)	(0.104)			(0.208)	(1.333)
I_{t+3}/K_{t+3}				0.096				0.254
				(0158)				(0.143)
no. of obs.	13842	12304	10766	9288	13842	12304	10766	9288
Sargan χ^2_{29}	170.6**	165.6**	112.2**	97.89**	180.9**	166.1**	104.6**	90.45**
AR(1)	-5.084**	-1.165	-1.436	–0.373	-7.152**	-1.992*	-2.625**	-2.490*
AR(2)	-2.968**	-3.133**	-1.607	-2.438*	-6.013**	-3.035**	1.285	0.4365
AR(3)			0.183	-1.177			-1.163	0.8499
AR(4)				-2.143*				-1.194

Table A.7
Reduced-Form Model Estimates

	Equipment Investment							
	Gross Expenditures Specifications				Net Expenditures Specifications			
Parameter	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I_t/K_t	1.259**	0.624**	0.510**	0.218**	1.606**	0.674**	0.464**	0.235**
	(0.215)	(0.111)	(0.095)	(0.047)	(0.222)	(0.102)	(0.082)	(0.045)
I_{t+1}/K_{t+1}		0.119	-0.288**	-0.055		0.080	-0.186**	-0.055
		(0.115)	(0.117)	(0.054)		(0.103)	(0.090)	(0.055)
I_{t+2}/K_{t+2}			0.048	0.0006			0.048	0.019
			(0.078)	(0.032)			(0.071)	(0.036)
I_{t+3}/K_{t+3}				0.028				0.053
				(0.032)				(0.036)
no. of obs.	13842	12304	10766	9288	13842	12304	10766	9288
Sargan χ^2_{29}	129.1**	113.6**	74.13**	74.57**	122.0**	115.0**	82.99**	70.39**
AR(1)	-5.785**	-5.447**	-4.507**	-4.279**	-5.965**	-5.198**	-4.849**	-4.443**
AR(2)	-0.911	-4.402**	4.027**	-0.108	-1.611	-4.802**	4.040**	-0.125
AR(3)			1.058	2.892**			0.344	3.713**
AR(4)				-2.765**				-3.471**

Table A.8
Reduced-Form Model Estimates

	Structures Investment							
	Gross Expenditures Specifications				Net Expenditures Specifications			
Parameter	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I_t/K_t	0.415**	0.216**	0.199**	0.328**	0.585**	0.344**	0.225**	0.357**
	(0.110)	(0.083)	(0.097)	(0.106)	(0.109)	(0.103)	(0.111)	(0.111)
I_{t+1}/K_{t+1}		0.661**	0.498**	0.328**		0.706**	0.544**	0.344**
		(0.105)	(0.101)	(0.083)		(0.101)	(0.112)	(0.096)
I_{t+2}/K_{t+2}			0.651**	0.463**			0.738**	0.542**
			(0.119)	(0.090)			(0.136)	(0.107)
I_{t+3}/K_{t+3}				0.419**				0.455**
				(0.099)				(0.105)
no. of obs.	13842	12304	10766	9288	13842	12304	10766	9288
Sargan χ^2_{29}	183.1**	122.2**	67.94**	64.56**	171.7**	125.8**	64.89**	57.63**
AR(1)	-2.929**	-3.555**	-1.336	-0.363	-3.055**	-2.881**	-1.472	-0.201
AR(2)	-3.438**	-0.286	-2.535*	-1.582	-4.014**	-0.838	-2.506*	-1.648
AR(3)			-0.523	-0.363			-0.415	-0.297
AR(4)				-2.431*				-2.407*

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