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ABSTRACT

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What role does labor play in firms' market value? We explore this question using a production-based asset pricing model with frictions in the adjustment of both capital and labor. We posit that hiring of labor is akin to investment in capital and that the two interact, with the interaction being a crucial determinant of market value behavior.
We use aggregate U.S. corporate sector data to estimate firms' optimal hiring and investment decisions and the consequences for firms' value. We then decompose this value, thereby quantifying the link between firms' market value and gross hiring flows, employment, gross investment and physical capital. We find that a conventional specification – quadratic adjustment costs for capital and no hiring costs – performs poorly. Rather hiring and investment flows, unlike employment and capital stocks, are volatile and both are essential to account for market volatility. A key result is that firms' value embodies the value of hiring and investment over and above the capital stock.

JEL Classification: E22, E23, E24, G12

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Labor and the Market Value of the Firm[1]

1. Introduction

What role does labor play in the market value of firms? According to the frictionless neoclassical model - a benchmark for our exploration - labor is not a part of this value, because it is costlessly adjusted and hence receives its share in output. In this frictionless environment the firm's market value equals its stock of physical capital. When combining this setup with adjustment costs of physical capital as in Tobin (1969) or Tobin and Brainard (1977), the well-known Tobin's Q-model results. Adjustment costs of capital involve implementation costs, the learning of new technologies, or the fact that production is temporarily interrupted. The standard Q-model still assigns no explicit role for labor, as determination of the firm's value only requires correction for the value of the capital adjustment technology. Labor explicitly enters the picture whenever there are frictions in the labor market [see the discussion in Danthine and Donaldson (2002a)]. With frictional labor markets, labor is a quasi-fixed factor from which a firm extracts rents. These rents compensate it for the costs associated with adjusting the work force. The firm's value needs to take these rents into account.

In this paper we build on the production-based model for firms' market value proposed by Cochrane (1991, 1996) and insert frictional labor markets and capital adjustment costs as crucial

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ingredients. We represent labor market frictions by trade frictions between searching firms and workers, and by advertising, screening, and training costs [Mortensen and Pissarides (1999) survey the relevant search and matching literature]. We let the adjustment costs for labor interact with those for capital, with all adjustment costs relating to gross rather than to net changes. This specification allows us to simultaneously study the dynamic behavior of variables which hitherto have been explored separately. In particular, we qualitatively illustrate how firms' market value is linked to the flows of gross hiring and gross investment and to the stocks of employment and physical capital. This link results from the following economic mechanism. Firms decide on the number of vacancies to post in order to hire workers and on the size of the investment in physical capital to undertake in their effort to maximize their market value. Doing so they face labor market frictions interacting with adjustment costs for capital. Optimal hiring and investing determines firms' profits – including rents from employment – and consequently their value, as well as the time path of employment and capital.

We quantify this link by structurally estimating the model using aggregate time-series data for the U.S. corporate sector. Our data set has a number of distinctive features. It makes use of gross rather than net hiring flow series, the former exhibiting considerable volatility; data on output, gross investment and the capital stock, as well as market value data, pertain to the non-financial corporate business sector rather than to broader, but inappropriate measures of the U.S. economy; alternative, time-varying discount rates are examined; and key elements of the corporate tax structure are explicitly taken into account. We use alternative convex adjustment costs specifications and a non-linear, structural estimation procedure in order to allow for a more general framework than the traditional quadratic cost formulation that dominates most of the related literature.

The main goal of our empirical work is to explain firms' joint hiring and investment behavior and its implications for market values. Towards this end we estimate the firms' adjustment costs function. Our results suggest that this exploration is worthwhile. With a reasonable magnitude for adjustment costs, we can characterize optimal hiring and investment. The implied value of hiring and that of investment account fairly well for the predicted component of firms' value, over and above the size of the physical capital stock. We decompose firms' value in terms of both mean and volatility. We find that factor adjustment costs play a role in explaining the mean of market values, and that volatility cannot be explained without both capital and labor adjustment costs.

Our paper makes several contributions. First, the model qualitatively derives the link between firms' market value and gross hires, employment, gross investment and physical capital, thereby showing that, in addition to capital, labor should matter. The empirical results lend quantitative support to this link. The reason for the relative success here – comparing to previous formulations which have failed – lies in the examination of investment and hiring costs jointly and in terms of gross flows. Note that much of the literature either focused on one and ignored the other, or dealt with net changes rather than with gross flows. Second, the paper puts the Q-model on a much more solid empirical footing, thereby explaining the weakness of previous results and demonstrates the role of labor market frictions for the behavior of investment and firms' market value. Finally, the paper generates a structural specification of a production-based asset pricing model, linking financial variables to macroeconomic ones.

The paper proceeds as follows. Section 2 presents the model. Section 3 discusses the data and the empirical methodology. Section 4 presents the results. Section 5 derives the implications with respect to the adjustment costs function and to hiring and investment behavior. Section 6 discusses the implications for market values. Section 7 concludes. Technical derivations and data definitions are elaborated in appendices.

2. The Model

We delineate the partial equilibrium model which serves as the basis for estimation.[2]

[2] The parts concerned with the labor market follow the prototypical search and matching model within a stochastic framework. See Pissarides (2000) and Yashiv (2000).

2.1. The Economic Environment

The economy is populated by identical workers and identical firms. All agents live forever and have rational expectations. Workers and firms interact in the markets for goods, labor, capital, and financial assets. This setup deviates from the standard neoclassical framework. That is, it takes time and resources for firms to adjust their capital stock, or to hire new workers. All variables are expressed in terms of the output price level.

2.2. Hiring and Investment

Firms make investment and hiring decisions. They own the physical capital stock k and decide each period how much to invest in capital, i. In order to attract new workers, a firm needs to post a job-vacancy v. For each vacancy posted, the firm takes as given the rate q at which this vacancy is filled with a non-employed worker. Hence, in every period, a firm's gross hires are given by qv.[3] Once a new worker is hired, the firm pays her a per-period gross compensation rate w. Firms use physical capital and labor as inputs in order to produce output goods y according to a constant-returns-to-scale production function f with productivity shock z:

$$y_t = f(z_t, n_t, k_t), \tag{2.1}$$

Gross hiring and gross investment are costly activities. Hiring costs include advertising, screening, and training. In addition to the purchase costs, investment involves capital installation costs, learning the use of new equipment, etc. Adjusting labor or capital involves disruptions to production, and potentially also the implementation of new organizational structure within the firm and new production practices. All of these costs reduce the firm's profits. We represent these costs by an adjustment costs function $g[i_t, k_t, q_t v_t, n_t]$ which is convex in the firm's decision variables and exhibits constant returns-to-scale. We allow hiring costs and capital adjustment costs to interact. We specify the functional form of g in the empirical work below.

[3] In the standard matching model, those gross hires are labeled new job-matches, and the transition rate q for a vacancy equals the ratio of job-matches to vacancies posted.

In every period t, the capital stock depreciates at the rate δ_t and is augmented by new investment i_t. The capital stock's law of motion equals:

$$k_{t+1} = (1-\delta_t)k_t + i_t, \quad 0 \leq \delta_t \leq 1. \tag{2.2}$$

Similarly, the number of a firm's employees decreases at the rate ψ_t. It is augmented by new hires $q_t v_t$:

$$n_{t+1} = (1-\psi_t)n_t + q_t v_t, \quad 0 \leq \psi_t \leq 1. \tag{2.3}$$

Firms' profits before tax, π, equal the difference between revenues net of adjustment costs and total labor compensation, wn:

$$\pi_t = [f(z_t, n_t, k_t) - g(i_t, k_t, q_t v_t, n_t)] - w_t n_t\,. \tag{2.4}$$

Every period, firms make after-tax cash flow payments cf to the stock owners and bond holders of the firm. These cash flow payments equal profits after tax minus purchases of investment goods plus investment tax credits and depreciation allowances for new investment goods:

$$cf_t = (1-\tau_t)\pi_t - (1-\chi_t - \tau_t D_t)\,\widetilde{p}_t^I\, i_t \tag{2.5}$$

where τ_t is the corporate income tax rate, χ_t the investment tax credit, D_t the present discounted value of capital depreciation allowances, $\tilde{p}_t^I$ the real pre-tax price of investment goods.

The representative firm's *ex dividend* market value in period t, s_t, is defined as follows:

$$s_t = E_t\left[\beta_{t+1}\left(s_{t+1} + cf_{t+1}\right)\right]. \tag{2.6}$$

Solving equation (2.6) forward, we can alternatively define the firm's market value in period t as the present discounted value of future cash flows:

$$s_t = E_t\left\{\sum_{j=1}^{\infty}\left(\prod_{i=1}^{j}\beta_{t+i}\right) cf_{t+j}\right\}, \tag{2.7}$$

where E_t denotes the expectational operator conditional on information available in period t. The discount factor between periods $t+j-1$ and $t+j$ for $j \in \{1, 2, ...\}$ is given by:

$$\beta_{t+j} = \frac{1}{1 + r_{t+j-1,t+j}}$$

where $r_{t+j-1,t+j}$ denotes the time-varying discount rate between periods $t+j-1$ and $t+j$. Appendix B contains a detailed description of how alternative values of the discount rate r are computed in the empirical work.

The representative firm chooses sequences of i_t and v_t in order to maximize its *cum dividend* market value $cf_t + s_t$:

$$\max_{\{i_{t+j}, v_{t+j}\}} E_t \left\{ \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} \beta_{t+i} \right) cf_{t+j} \right\} \tag{2.8}$$

subject to the definition of cf_{t+j} in equation (2.5) and the constraints (2.2) and (2.3). The firm takes the variables q, w, p^I, δ, ψ, and β as given. The Lagrange multipliers associated with these two constraints are Q^K_{t+j} and Q^N_{t+j}, respectively. These Lagrange multipliers can be interpreted as marginal Q for physical capital, and marginal Q for employment, respectively.

The accompanying first-order necessary conditions for dynamic optimality are the same for any two consecutive periods $t+j$ and $t+j+1$, $j \in \{0, 1, 2, ...\}$. For the sake of notational simplicity, we drop the subscript j from the respective equations to follow:

$$Q^K_t = E_t \left\{ \beta_{t+1} \left[(1-\tau_{t+1}) \left(f_{k_{t+1}} - g_{k_{t+1}} \right) + (1-\delta_{t+1}) Q^K_{t+1} \right] \right\} \tag{2.9}$$

$$Q^K_t = (1-\tau_t) \left(g_{i_t} + p^I_t \right) \tag{2.10}$$

$$Q^N_t = E_t \left\{ \beta_{t+1} \left[(1-\tau_{t+1}) \left(f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1} \right) + \left(1-\psi_{t+1} \right) Q^N_{t+1} \right] \right\} \tag{2.11}$$

$$Q^N_t = (1-\tau_t) \frac{g_{v_t}}{q_t} \tag{2.12}$$

where we use the real after-tax price of investment goods, given by:

$$p^I_{t+j} = \frac{1 - \chi_{t+j} - \tau_{t+j} D_{t+j}}{1 - \tau_{t+j}} \widetilde{p}^I_{t+j}. \tag{2.13}$$

Dynamic optimality requires the following two transversality conditions to be fulfilled

$$\begin{aligned} \lim_{T \to \infty} E_T \left(\beta_T \, Q_T^K \, k_{T+1} \right) &= 0 \\ \lim_{T \to \infty} E_T \left(\beta_T \, Q_T^N \, n_{T+1} \right) &= 0. \end{aligned} \tag{2.14}$$

We can summarize the firm's first-order necessary conditions from equations (2.9)-(2.12) by the following two expressions:

$$\begin{aligned} F1 &: (1-\tau_t) \left(g_{i_t} + p_t^I \right) = E_t \left\{ \beta_{t+1} \left(1-\tau_{t+1}\right) \left[f_{k_{t+1}} - g_{k_{t+1}} + (1-\delta_{t+1})(g_{i_{t+1}} + p_{t+1}^I) \right] \right\} \\ F2 &: (1-\tau_t) \frac{g_{v_t}}{q_t} = E_t \left\{ \beta_{t+1} \left(1-\tau_{t+1}\right) \left[f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1} + (1-\psi_{t+1}) \frac{g_{v_{t+1}}}{q_{t+1}} \right] \right\}. \end{aligned}$$

Solving equation (2.9) forward and using the law of iterated expectations expresses Q_t^K as the expected present value of future marginal products of physical capital net of marginal capital adjustment costs:

$$Q_t^K = E_t \left\{ \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} \beta_{t+1+i} \right) \left(\prod_{i=0}^{j} (1-\delta_{t+1+i}) \right) (1-\tau_{t+1+j}) \left(f_{k_{t+1+j}} - g_{k_{t+1+j}} \right) \right\}. \tag{2.15}$$

It is straightforward to show that in the special case of time-invariant discount factors, no adjustment costs, no taxes, and a perfectly competitive market for capital, Q_t^K equals one. Similarly, solving equation (2.11) forward and using the law of iterated expectations expresses Q_t^N as the expected present value of the future stream of surpluses arising to the firm from an additional hire of a new worker:

$$Q_t^N = E_t \left\{ \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} \beta_{t+1+i} \right) \left(\prod_{i=0}^{j} (1-\psi_{t+1+i}) \right) (1-\tau_{t+1+j}) \left(f_{n_{t+1+j}} - g_{n_{t+1+j}} - w_{t+1+j} \right) \right\}. \tag{2.16}$$

In the special case of a perfectly competitive labor market and no hiring costs, Q_t^N equals zero.

2.3. Implications For Asset Values

We use standard asset-pricing theory to derive the implications of the model for the links between the market value of the firm and the asset value of a new hire. As stated in equation (2.6), the firm's period t market value is defined as the expected discounted pre-dividend market value of the following period:

$$s_t = E_t\left[\beta_{t+1}\left(s_{t+1} + cf_{t+1}\right)\right]. \tag{2.17}$$

The firm's market value can be decomposed into the sum of the value due to physical capital, ϑ_t^k, and the value due to the stock of employment, ϑ_t^n. We label the latter fraction of the firm's market value the asset value of a new hire and express s_t as

$$s_t = \vartheta_t^k + \vartheta_t^n = E_t\left[\beta_{t+1}\left(\vartheta_{t+1}^k + cf_{t+1}^k\right)\right] + E_t\left[\beta_{t+1}\left(\vartheta_{t+1}^n + cf_{t+1}^n\right)\right], \tag{2.18}$$

Using the constant returns-to-scale properties of the production function f and of the adjustment cost function, g, we rely on equation (2.5) when decomposing the stream of maximized cash flow payments as follows:

$$\begin{aligned} cf_t &= (1-\tau_t)\left(f_{k_t}k_t + f_{n_t}n_t - w_t n_t - p_t^I i_t - g_{k_t}k_t - g_{i_t}i_t - g_{n_t}n_t - g_{v_t}v_t\right) \\ &= (1-\tau_t)\left[\left(f_{k_t}k_t - p_t^I i_t - g_{k_t}k_t - g_{i_t}i_t\right) + \left(f_{n_t}n_t - w_t n_t - g_{n_t}n_t - g_{v_t}v_t\right)\right] \\ &\equiv cf_t^k + cf_t^n. \end{aligned}$$

In order to establish a link between the firm's market value and its stock of capital and employment using the first-order necessary condition (FONC) we manipulate the latter equation to obtain (see Appendix A for the full derivation) the central asset pricing equation relying on the afore-cited CRS properties of f and g :

$$s_t = \vartheta_t^k + \vartheta_t^n = k_{t+1}Q_t^K + n_{t+1}Q_t^N, \tag{2.19}$$

where Q_t^K and Q_t^N are defined in equations (2.15) and (2.16), respectively.

Equation (2.19) summarizes an important qualitative result. With frictional labor markets, the shadow value of employment typically is non-zero. Hence in such settings, the level of employment, multiplied by the respective shadow value, enters the firm's market value. Put differently, equation (2.19) illustrates the fact that the current model generalizes the neoclassical formulation, whereby the firm's market value equals its physical capital stock, to an environment with capital adjustment costs and labor market frictions. Note that, using the expressions (2.9)-(2.12) we can alternatively express the firm's market value in period t as follows:

$$\begin{aligned} s_t &= k_{t+1}E_t \left\{\beta_{t+1}(1-\tau_{t+1})\left[f_{k_{t+1}} - g_{k_{t+1}} + (1-\delta_{t+1})(p^I_{t+1} + g_{i_{t+1}})\right]\right\} \\ &\quad + n_{t+1}E_t\left\{\beta_{t+1}(1-\tau_{t+1})\left(f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1} + (1-\psi_{t+1})\frac{g_{v_{t+1}}}{q_{t+1}}\right)\right\} \end{aligned} \tag{2.20}$$

Next we turn to explore the empirical implications of the model.

3. Data and Methodology

The adjustment cost function g is the main object of structural estimation. We present the parameterization of this function as well as of the production function, the data, and the econometric methodology. This presentation includes a discussion of data and econometric issues and the resulting alternative specifications.

3.1. Parameterization

To quantify the model we need to parameterize the relevant functions. For the production function we use a standard Cobb-Douglas:

$$f(z_t, n_t, k_t) = e^{z_t} {n_t}^{\alpha} k_t^{1-\alpha},\ 0 < \alpha < 1. \tag{3.1}$$

For the adjustment costs function g, some experimentation led us to adopt the following generalized convex function:

$$g(\cdot) = \left[\frac{e_1}{\eta_1}(\frac{i_t}{k_t})^{\eta_1} + \frac{e_2}{\eta_2}(\frac{q_t v_t}{n_t})^{\eta_2} + \frac{e_3}{\eta_3}(\frac{i_t}{k_t}\frac{q_t v_t}{n_t})^{\eta_3}\right] f(z_z, n_t, k_t). \tag{3.2}$$

This function is linearly homogenous in its four arguments i, v, k and $n.$ The function postulates that costs are proportional to output, and that they increase in investment and hiring rates. Recent work by Cooper and Haltiwanger (2000) and Cooper and Willis (2003) gives empirical support to the use of a convex adjustment costs function. They showed that while non-convexities may matter at the micro level, a convex formulation is appropriate at the aggregate, macroeconomic level. The above specification captures the idea that the disruption in the production process increases with the extent of the factor adjustment relative to the size of the firm, where a firm's size is measured by its physical capital stock, or its level of employment. The last term in square brackets expresses the interaction of capital and labor adjustment costs. The parameters e_l, $l = 1, 2, 3$ express scale, and η_l express the elasticity of adjustment costs with respect to the different arguments. The function encompasses the widely used quadratic case for which $\eta_1 = \eta_2 = 2$. The estimates of these parameters will allow the quantification of the derivatives g_{i_t} and g_{v_t} that appear in the firms' FONC.[4]

3.2. The Data

Our data sample is quarterly, corporate sector data for the U.S. economy from 1976:1 to 1997:4. The beginning of the sample period is constrained by the availability of consistent gross worker flow data. We end the sample in 1997 so as not to contaminate the data with the possible build up and bursting of a bubble in the market value series s in 1998-2002. In what follows we briefly describe the data set and emphasize its distinctive features; for full definitions and sources see Appendix B. Table 1 presents summary statistics of the series used.

Table 1

For output f, capital k, investment i and depreciation δ we use a new data set on the non-financial corporate business (NFCB) sector recently published by the Bureau of Economic Analysis

[4] This generalized functional form proved useful in structural estimation of the search and matching model presented in Yashiv (2000). We also tried the more general formulation:

$$g(\cdot) = \left[\frac{e_1}{\eta_1} (\frac{i_t}{k_t})^{\eta_1} + \frac{e_2}{\eta_2} (\frac{q_t v_t}{n_t})^{\eta_2} + e_3 \left(\frac{i_t}{k_t} \right)^{\eta_3} \left(\frac{q_t v_t}{n_t} \right)^{\eta_4} \right] f(z_t, n_t, k_t).$$

as discussed below.

(BEA) of the U.S. Department of Commerce.[5] This data set leaves out variables that are often used in the literature but that are not consistent with the above model, such as residential or government investment.

For gross hiring flows qv and for the separation rate ψ we use series based on adjusted Current Population Survey (CPS) data as computed by Bleakely et al. (1999). Two aspects of the data merit attention: (i) We use gross flows between employment and both unemployment and out of the labor force; the latter flows are sizeable,[6]and in terms of the model are not different from unemployment – employment flows. (ii) The gross worker flows are adjusted to cater for misclassification and measurement error.[7] For the labor share of income $\frac{wn}{f}$ we use the compensation of employees, i.e., the sum of wage and salary accruals and supplements to wages and salaries as a fraction of the gross product of the non-financial corporate sector. We take the latter variable from the National Income and Product Accounts (NIPA).

We measure firms' market value s using the market value of all non-farm, non-financial corporate businesses. This value equals the sum of financial liabilities and equity less financial assets. The data are taken from Hall (2001) based on the Fed Flow of Funds accounts. This series in a detrended version is highly correlated with stock market measures such as the total market value reported by the Center for Research in Security Prices (CRSP) at the University of Chicago, and the SP500 index. For the discount rate r we use a weighted average of the returns to debt (using a commercial paper rate) and to equity (using CRSP returns), with changing weights reflecting actual debt and equity finance shares. We also test two alternatives for r, the SP500 rate

[5] See www.bea.doc.gov/bea/ARTICLES/NATIONAL/NIPAREL/2000/0400fxacdg.pdf The investment rate series $\frac{i_t}{k_t}$ for this sector is very similar to the private sector non-residential series with roughly the same mean, a slightly higher variance and a correlation of 0.94; the average output series $\frac{f}{k}$ is also very similar, with slightly lower mean and variance and a correlation of 0.92 with the private sector non-residential series.

[6] The difference in size between gross and net worker flows is noteable. Gross flows per quarter amount to 9 percent, whereas net flows equal 0.5 percent only.

[7] See Bleakely et al. (1999) for a discussion of the adjustment methodology. The construction of the series used here is explained in Appendix B.

of change, and the rate of non-durable consumption growth, which serves as the discount rate in many dynamic stochastic general equilibrium models featuring log utility.

3.3. Methodology

We structurally estimate the firms' first-order necessary conditions ($F1$) and ($F2$), and the asset pricing equation (2.20) using Hansen's (1982) generalized method of moments (GMM). The moment conditions estimated are those obtained under rational expectations. That is, the firms' expectational errors are orthogonal to any variable in their information set at the time of the investment and hiring decisions. The moment conditions are derived by replacing expected values with actual values plus expectational errors j and specifying that the errors are orthogonal to the instruments Z, i.e., $E(j_t \otimes Z_t) = 0$. We formulate the equations in stationary terms by dividing the FONC for capital by $\frac{f_t}{k_t}$, the FONC for labor by $\frac{f_t}{n_t}$, and the asset pricing equation throughout by the level of output, f_t.

We explore a number of alternative specifications:

1) *The degree of convexity of the g function.* A major issue proves to be the degree of convexity of the g function. The literature has for the most part assumed quadratic adjustment costs. We examine more general convex functions, either by estimating the power parameters (η_1, η_2, η_3) or by constraining them to take different values. We also allow for an asymmetric formulation of the interaction term, i.e., $e_3(\frac{i_t}{k_t})^{\eta_3}(\frac{q_t v_t}{n_t})^{\eta_4}$ rather than $\frac{e_3}{\eta_3}(\frac{i_t}{k_t}\frac{q_t v_t}{n_t})^{\eta_3}$.

2) *Instrument sets.* We use alternative instrument sets in terms of variables and number of lags. The instrument sets differ across the three equations and include lags of variables that appear in the corresponding equation.

3) *Variables' formulation.* We check the effect of using alternative time series for some of the variables, which have multiple representations. These include $\frac{qv}{n}, \psi, \delta$ and β.

After verifying that the estimates of the g function satisfy the conditions for convexity with respect to the decision variables i and v in sample means, we apply two major GMM test statistics [see the discussion in Ogaki and Jang (2002), in particular chapters 3.2.3, 9 and 10], the J-statistic test of the overidentifying restrictions proposed by Hansen (1982) and the Noise Ratio statistic proposed by Durlauf and Hall (1990). The latter is based on the following rationale. Under the null hypothesis, the error described above is a white noise forecast error. Under any alternative, the error is the sum of white noise and a variable (Γ_t) that represents the deviation of the error from white noise, and is called "the model noise" i.e. $j_{t+1} = \varepsilon_{t+1} + \Gamma_t$ where ε_{t+1} is the white noise "new information." An estimate of Γ_t - to be denoted $\widehat{\Gamma}_t$ - may be obtained by projecting j_{t+1} on the information set at time t. We compute it by running an OLS regression of j_{t+1} on the variables included in the instrument set. Durlauf and Hall show that $var(\widehat{\Gamma}_t) < var(\Gamma_t)$. The Noise Ratio statistic is then defined as $N.R. = \frac{var(\widehat{\Gamma}_t)}{var(j_{t+1})}$ which is a lower bound on the percentage of var (j_{t+1}) attributable to model noise.

We also check whether the estimated g function is 'reasonable' in that it fulfills the convexity requirement and implies total and marginal adjustment costs that lie within a plausible range. We discuss what such a range might be below.

4. Estimation Results

The focal point of the empirical work is estimation of the parameters of the adjustment costs function g. These estimates allow us to generate time series for the costs of hiring and investing, and for firms' market values, thereby quantifying the links between these three series. The literature has typically used the quadratic specification of the adjustment costs function and ignored possible interactions between hiring and investment costs.[8] Our results suggest that modifying

[8] Nadiri and Rosen (1969) examined both capital and labor adjustment costs, and since then a number of papers have done so. The most notable contribution in the current context is Shapiro (1986), who used structural estimation. Our paper differs along several dimensions:(i) labor adjustment costs here pertain to gross costs and therefore are a function of gross worker flows into employment; in Shapiro (and other work) they pertain to net costs and relate to changes in the employment stock, which are considerably smaller; (ii) the current paper uses the market values of firms in estimation while no such information is used in Shapiro; (iii) the latter paper uses linear-quadratic adjustment

this specification is essential. We report alternative specifications, including unconstrained powers and alternative forms of constrained parameters.[9]

Table 2 reports the results of the joint GMM estimation of the firms' first-order conditions ($F1$) and ($F2$), and the asset pricing equation (2.20). We present the point estimates of the power parameters η_1, η_2, and η_3, the scale parameters e_1, e_2, and e_3, and the employment elasticity of output, α, the standard errors of the estimates (except where constrained), and the test statistics discussed above.

Table 2

We start off in panel (a) with alternative specifications of the power parameters (η_1, η_2 and η_3). Column 1 is the most general, with all parameters freely estimated. Thus the degree of convexity is allowed to vary across the different arguments of the function. The results point to a cubic specification for both investment and hiring and to an interaction term of lower convexity. The estimates of the scale parameters, however, exhibit large standard errors. The other columns impose some more structure, though they are still more general than the prevalent formulations in the literature. Following the point estimates of column 1 and some experimentation, η_2 is freely estimated, and η_1 is constrained to equal η_2; for the interaction term the generalized formulation discussed above, i.e., $e_3(\frac{i_t}{k_t})^{\eta_3}(\frac{q_t v_t}{n_t})^{\eta_4}$, is used whereby η_3 and η_4 are constrained to equal $\eta_2 - K$, with $K \in (1.5, 1.6)$. The estimates point to $\eta_2 = 3$ with a low standard error, and there does not seem to be much importance for the differentiation of η_3 and η_4. The point estimates of the scale parameters are similar across columns 2 and 3 (constraining the power parameters significantly reduces their standard errors), and the test statistics are relatively good. The employment elasticity

costs, a formulation found to be too restrictive here; (iv) Shapiro's uses data on manufacturing while here non-financial corporate business data are used; (v) the discount rate in Shapiro is a T-bill rate plus a risk premium, while here alternative time-varying rates are used.

[9] The reason for doing so is that unconstrained estimation of three power parameters and three scale parameters proves too formidable for the GMM estimation procedure; see elaboration below.

of output, α, is estimated at values around 0.67, which is reasonable in that it coincides with evidence from the literature on estimation of the production function for the U.S. economy. Thus, panel (a) points to a cubic formulation for gross investment costs ($\eta_1 = 3$) and for gross hiring costs ($\eta_2 = 3$), and a convex interaction term ($\eta_3 = \eta_4 \simeq 1.5$).

Panel (b) reports variations on this basic specification with respect to the instrument set. We go back to the symmetric specification of the interaction term, i.e., $\frac{e_3}{\eta_3}(\frac{i_t}{k_t}\frac{q_t v_t}{n_t})^{\eta_3}$. The variations are the instruments used and their lags. All variations are outlined in the table's notes. The point estimates, and thus the implied cost function, are very similar across specifications. The major difference across columns pertains to the standard errors and the test statistics. For a given instrument set increasing the number of lags improves the p-value of the J-statistic. Increasing the instrument sets by adding variables lowers the standard errors and improves the p-values, but the noise ratios tend to worsen.

Panel (c) looks at alternative formulations of certain variables, using the instrument set of column 3 of panel (b). Column 1 in this panel uses the sample averages for the depreciation rate δ and for the separation rate ψ. Columns 2 to 5 examine variations in β. Column 2 uses a discount factor based on the rate of growth of non-durable consumption, column 3 uses a discount factor based on the SP500 rate of change, column 4 uses a fixed discount factor $\beta = 0.98$, and column 5 uses an alternative method of computing the basic specification (see Appendix B for exact formulations). Columns 6 and 7 use alternative formulations of $\frac{qv}{n}$ and ψ as explained in Appendix B. The estimates are robust to the use of these alternative formulations.

Table 3 attempts to gauge the value added of different components of the afore-going specifications.

Table 3

Column 1 reports the traditional equation estimated in the Q-literature, i.e., quadratic adjustment costs of capital only. The results imply extremely low adjustment costs – a sample average of 0.08 percent of output for total costs and a sample mean of 0.06 of average capital productivity, f/k, for marginal costs. The results include large standard errors of the e_1 estimates, and the test statistics indicate rejection. Column 2 merits special attention. It takes the same power specification for η_1 and η_2 as used in the preceding panels ($\eta_1 = \eta_2 = 3$) but does not allow for interaction between capital adjustment costs and hiring costs, i.e., $e_3 = 0$ is imposed. This restriction yields a negative e_2 estimate, i.e., negative costs of hiring, as well as an implausible value for α, the production function parameter. In column 3 we replicate the basic specification of panels (a) and (b) but estimate only $(F1)$ and the asset pricing equation, i.e., we drop the $(F2)$ equation. We get large standard errors and rejection according to the p-value of the J-statistic. We thus conclude that specifications that fail to take into account hiring costs, the interaction between capital adjustment costs and hiring costs, or the hiring optimality equation perform poorly.

We turn now to examine the implications of these estimates for the adjustment costs function and for the time series behavior of hiring, investment and asset values. While the results of Table 2 are fairly robust across specifications, we shall report a number of them when discussing their implications below.

5. The Value of Hiring and Investing

In this section we look at the implications of the results using the point estimates reported in Table 2. We begin by looking at the implied adjustment costs function (section 5.1) and then study the joint behavior of hiring and investment (section 5.2).

5.1. Adjustment Costs

The results of Table 2 allow us to construct time series for total and marginal adjustment costs by using the point estimates of the parameters of the g function. Equations $(F1)$ and $(F2)$ embody the role of adjustment costs in determining firms' hiring and investment behavior. In Table 4, we report the two first sample moments for marginal and total adjustment costs using the eight specifications that had good p-values in Table 2. In Figure 1 we plot the estimated function using the point estimates of Table 2b column 1.

Table 4 and Figure 1

Panels (a) and (b) of Table 4 report the LHS of each Euler equation (without taxes) and its decomposition. This represents the costs for the firm of hiring or investing at the margin. Note that we report marginal costs of investing in terms of average output per unit of capital, f/k in order to generate marginal costs as a function of the investment rate, i/k and the hiring rate, qv/n. These measures are comparable to what is typically reported in the literature. For similar reasons, we report marginal costs of hiring in terms of average output per worker, f/n so as to also express them in terms of i/k and qv/n. We report total costs in panel (c).

Consider gross hiring as reported in panel (a). The first row reports net costs on the marginal gross hire. This expression equals Q^N before taxes, set in terms of average output per worker, f/n. The specifications yield estimates varying between 0.20 and 0.44. This is roughly equivalent to one to two months of wage payments, as wages are 0.658 of output per worker on average (see Table 1). Hamermesh (1993) reports results from micro studies that are in line with these magnitudes, and it seems plausible that marginal costs associated with a new hire are in the order of one to two thirds of a quarter's worth of work. Note that gross marginal costs which we report in the second row are much higher than net marginal costs. That is because gross costs are reduced by the interaction between hiring and investment costs, with the interaction term, which we report in the third row, having a negative sign.

Consider now the adjustment costs on the marginal unit of new capital, as reported in panel (b). The firm pays a purchase price p^I and incurs adjustment costs. The first row reports the total capital expenditure on the marginal unit. Looking at its decomposition in the second, third and fourth rows it is clear that this expenditure is dominated by the purchase price – comparing the first and second rows we see that the purchase price is 95%-98% of the total marginal expenditure.

This is so because gross marginal adjustment costs are greatly reduced by the interaction term, leaving much smaller net marginal adjustment costs which we report in the next to last row. The net adjustment costs terms exhibit higher volatility than the purchase price. The table also reports Tobin's Q^K before-tax. The estimates are around 1.4-1.5.

How reasonable are these magnitudes of capital adjustment costs? There exists a vast literature on the quantitative importance of adjustment costs for investment in physical capital. This literature builds upon the traditional Q-theory of investment discussed above and encompasses time series as well as panel data analyses. Chirinko (1993) provides a comprehensive survey. In what follows, we briefly review the main findings in order to compare to the results of panel (b) in Table 4. Table 5 offers a summary of some key studies, using the same units as those reported in Table 4 (panel b) for marginal costs of investment.[10]

Table 5

The studies surveyed, relating to different data sets and time periods, indicate that the average investment rate ($\frac{i}{k}$) per annum differs for aggregate data, where it is typically around 0.10, and the widely-used Compustat firm panel data, where it is around 0.20. The estimates of g_i exhibit large variation within and across studies. This variation may be described as follows. The early studies [Summers (1981) and Hayashi (1982)] tended to show large values of adjustment costs, implying very slow adjustment of capital. This finding led researchers to refine the data used and the econometric specification, and, so, most later studies yield estimates of g_i in a lower range, typically between 0.1 and 1.1. This variation is found both across and within studies and reflects differences in the sample of firms, in the specification (variables included, measurement issues) and econometric methodology. Even for the five papers dealing with Compustat data the estimates vary widely in the cited range.

[10] The studies surveyed assume a quadratic formulation, i.e., $g\left(\frac{i_t}{k_t}\right) = \frac{e_1}{2}\left(\frac{i_t}{k_t}\right)^2 k_t$. This implies that marginal costs of adjusting capital, g_i are $g_i = e_1\left(\frac{i_t}{k_t}\right)$.

How do these results compare to those reported in panel (b) of Table 4? First, note that the estimates reported in Table 5 do not refer to purchase costs and that the cited studies do not consider an interaction between capital adjustment costs and hiring costs. Next, note that our specification has $\eta_1 = 3$ based on estimation, while the reported literature assumes $\eta_1 = 2$. These differences notwithstanding, the net estimates reported in the next to last row of panel (b) in Table 4 are consistent with the cited range. They vary between 0.15 and 0.42, i.e., they are at the lower part of the cited range. More importantly, the results of Table 4 shed light on two issues with respect to this literature. First, judging marginal costs as high or low requires consideration of the purchase price, which is clearly dominant in our results, and the interaction with hiring costs, that greatly reduces gross costs. Second, it is clear from Table 4 that omitting the hiring-investment interaction, one obtains very high estimates – around 18. This finding can explain the tendency of studies with such omission to yield high estimates.

The last panel of Table 4 shows total adjustment costs, with estimates ranging between 1.2% and 2% of output. These appear to be reasonable. Their decomposition into components shows that gross costs of hiring are somewhat higher than gross costs of investment and, once more, the importance of the interaction term is straightforward.

5.2. Hiring and Investment

Across all specifications, the estimate of the coefficient of the interaction term, e_3, is negative. This negative point estimate implies a negative value for g_{vi} and, therefore, a positive sign for $\partial \frac{q_t v_t}{n_t} / \partial Q^k$. (For the full derivation see Appendix C.) Hence, when the marginal value of investment Q^K rises, both the investment rate $\frac{i}{k}$ and the hiring rate $\frac{qv}{n}$ rise. A similar argument shows that when the marginal value of hiring Q^N rises, both $\frac{i}{k}$ and $\frac{qv}{n}$ rise. Put differently, this result states that for given levels of investment rates, total and marginal costs of investment decline as hiring increases. Similarly, for given levels of hiring rates, total and marginal costs of hiring decline as investment increases. This finding is to be expected as it implies simultaneous hiring and investment. One interpretation of this result is that simultaneous hiring and investment is less costly than sequential hiring and investment of the same magnitude. This may be due to the fact that simultaneous action by the firm is less disruptive to production than sequential action.

The following distinction, however, is important. The afore-going argument favors simultaneous hiring and investment, i.e., positive levels of both, but does not necessarily imply a positive correlation between hiring and investment. Using (C.1) below, one can see that if Q^K rises and Q^N declines at the same time then the former will lead to higher investment and higher hiring, while the latter will lead to lower investment and lower hiring. If the effect of Q^K on investment and the effect of Q^N on hiring are dominant (respectively), then investment would rise and hiring would fall. Thus hiring may fall when investment rises even when e_3 is negative. In the data sample, hiring and investment have been generally negatively correlated – weakly (-0.11) for the entire sample or moderately for the sub-samples 1976-1985 (around -0.26) and 1991-1997 (around -0.20) – but have also been positively correlated (0.23) in the sub-sample 1985-1990.

6. Asset Values Decomposed

In this section we examine the behavior of different components of the firm's value, which we label asset values. The estimates allow us to generate time series of asset values using the RHS of equation (2.20), i.e., the RHS of:

$$\frac{s_t}{f_t} = \beta_{t+1}(1-\tau_{t+1})\frac{f_{t+1}}{f_t}\left[\begin{array}{c} (1-\alpha) + \left[e_1(\frac{i_{t+1}}{k_{t+1}})^{\eta_1} + e_3(\frac{i_{t+1}}{k_{t+1}}\frac{q_{t+1}v_{t+1}}{n_{t+1}})^{\eta_3}\right] \\ -(1-\alpha)\left[\frac{e_1}{\eta_1}\left(\frac{i_{t+1}}{k_{t+1}}\right)^{\eta_1} + \frac{e_2}{\eta_2}\left(\frac{q_{t+1}v_{t+1}}{n_{t+1}}\right)^{\eta_2} + \frac{e_3}{\eta_3}\left(\frac{i_{t+1}}{k_{t+1}}\frac{q_{t+1}v_{t+1}}{n_{t+1}}\right)^{\eta_3}\right] \\ +(1-\delta_{t+1})(\frac{p^I_{t+1}}{\frac{f_{t+1}}{k_{t+1}}} + \left[e_1(\frac{i_{t+1}}{k_{t+1}})^{\eta_1-1} + e_3(\frac{i_{t+1}}{k_{t+1}}\frac{q_{t+1}v_{t+1}}{n_{t+1}})^{\eta_3-1}\frac{q_{t+1}v_{t+1}}{n_{t+1}}\right]) \\ +\alpha - \frac{w_{t+1}n_{t+1}}{f_{t+1}} + \left[e_2(\frac{q_{t+1}v_{t+1}}{n_{t+1}})^{\eta_2} + g_3(\frac{i_{t+1}}{k_{t+1}}\frac{q_{t+1}v_{t+1}}{n_{t+1}})^{\eta_3}\right] \\ -\alpha\left[\frac{e_1}{\eta_1}\left(\frac{i_{t+1}}{k_{t+1}}\right)^{\eta_1} + \frac{e_2}{\eta_2}\left(\frac{q_{t+1}v_{t+1}}{n_{t+1}}\right)^{\eta_2} + \frac{e_3}{\eta_3}\left(\frac{i_{t+1}}{k_{t+1}}\frac{q_{t+1}v_{t+1}}{n_{t+1}}\right)^{\eta_3}\right] \\ +(1-\psi_{t+1})\left[e_2(\frac{q_{t+1}v_{t+1}}{n_{t+1}})^{\eta_2-1} + e_3(\frac{i_{t+1}}{k_{t+1}}\frac{q_{t+1}v_{t+1}}{n_{t+1}})^{\eta_3-1}\frac{i_{t+1}}{k_{t+1}}\right] \end{array}\right] + j_3$$

Denote the entire expression on the RHS save for the expectational error by $\widetilde{\left(\frac{s_t}{f_t}\right)}$ [i.e. $\frac{s_t}{f_t} = \widetilde{\left(\frac{s_t}{f_t}\right)} + j_3$]. It can be decomposed, in order to examine the relative role played by capital and by labor, as follows:

$$
\begin{aligned}
\widetilde{\left(\frac{s_t}{f_t}\right)} &= \left(\frac{s_t}{f_t}\right)^1 + \left(\frac{s_t}{f_t}\right)^2 + \left(\frac{s_t}{f_t}\right)^3 \\
\left(\frac{s_t}{f_t}\right)^1 &= \beta_{t+1}(1-\tau_{t+1})\frac{f_{t+1}}{f_t}\left[(1-\alpha) + (1-\delta_{t+1})\frac{p^I_{t+1}}{\frac{f_{t+1}}{k_{t+1}}}\right] \\
\left(\frac{s_t}{f_t}\right)^2 &= \beta_{t+1}(1-\tau_{t+1})\frac{f_{t+1}}{f_t}\left[\begin{array}{c} \left[e_1(\frac{i_{t+1}}{k_{t+1}})^{\eta_1} + e_3(\frac{i_{t+1}}{k_{t+1}}\frac{q_{t+1}v_{t+1}}{n_{t+1}})^{\eta_3}\right] \\ -(1-\alpha)\left[\frac{e_1}{\eta_1}\left(\frac{i_{t+1}}{k_{t+1}}\right)^{\eta_1} + \frac{e_2}{\eta_2}\left(\frac{q_{t+1}v_{t+1}}{n_{t+1}}\right)^{\eta_2} + \frac{e_3}{\eta_3}\left(\frac{i_{t+1}}{k_{t+1}}\frac{q_{t+1}v_{t+1}}{n_{t+1}}\right)^{\eta_3}\right] \\ +(1-\delta_{t+1})\left[e_1(\frac{i_{t+1}}{k_{t+1}})^{\eta_1-1} + e_3(\frac{i_{t+1}}{k_{t+1}}\frac{q_{t+1}v_{t+1}}{n_{t+1}})^{\eta_3-1}\frac{q_{t+1}v_{t+1}}{n_{t+1}}\right] \end{array}\right] \\
\left(\frac{s_t}{f_t}\right)^3 &= \beta_{t+1}(1-\tau_{t+1})\frac{f_{t+1}}{f_t}\left[\begin{array}{c} \left[\alpha - \frac{w_{t+1}n_{t+1}}{f_{t+1}}\right] + \left[e_2(\frac{q_{t+1}v_{t+1}}{n_{t+1}})^{\eta_2} + e_3(\frac{i_{t+1}}{k_{t+1}}\frac{q_{t+1}v_{t+1}}{n_{t+1}})^{\eta_3}\right] \\ -\alpha\left[\frac{e_1}{\eta_1}\left(\frac{i_{t+1}}{k_{t+1}}\right)^{\eta_1} + \frac{e_2}{\eta_2}\left(\frac{q_{t+1}v_{t+1}}{n_{t+1}}\right)^{\eta_2} + \frac{e_3}{\eta_3}\left(\frac{i_{t+1}}{k_{t+1}}\frac{q_{t+1}v_{t+1}}{n_{t+1}}\right)^{\eta_3}\right] \\ +(1-\psi_{t+1})\left[e_2(\frac{q_{t+1}v_{t+1}}{n_{t+1}})^{\eta_2-1} + e_3(\frac{i_{t+1}}{k_{t+1}}\frac{q_{t+1}v_{t+1}}{n_{t+1}})^{\eta_3-1}\frac{i_{t+1}}{k_{t+1}}\right] \end{array}\right]
\end{aligned}
$$

The first part $\left(\frac{s_t}{f_t}\right)^1$ reflects value without any adjustment costs. The other two parts represent the present value of investing $\left(\frac{s_t}{f_t}\right)^2$ and of hiring $\left(\frac{s_t}{f_t}\right)^3$.

We present the decomposition in Table 6, using the point estimates of the eight specifications selected from Table 2. Before the decompositions we present a preliminary panel with diagnostic statistics.

Table 6

Panel (a) shows the correlations of $\widetilde{\left(\frac{s_t}{f_t}\right)}$ and its components with actual $\frac{s_t}{f_t}$ as well as the ratio between the variances. Note that these correlations do not indicate goodness of fit, as this is not linear regression analysis. For example, in a 'noisy' economy with high variance of the expectational error j, this correlation could be very small even when $\widetilde{\left(\frac{s_t}{f_t}\right)}$ is correctly and precisely estimated. What we do learn from them is how much the decomposition of $\widetilde{\left(\frac{s_t}{f_t}\right)}$ matters when our real interest is in the behavior of actual $\frac{s_t}{f_t}$. It turns out that the correlation of $\widetilde{\left(\frac{s_t}{f_t}\right)}$ and actual $\frac{s_t}{f_t}$ is above 0.4 with $\left(\frac{s_t}{f_t}\right)^2$ having a correlation of almost 0.6.

Panel (b) presents the sample average value of the different terms in the above decomposition. The "neoclassical" part, $\left(\frac{s_t}{f_t}\right)^1$, is but 89%-93% – and not 100% – of total firm value. The value due to adjustment costs is 7%-11% of the total value. Out of the latter, the larger part is due to value of investment in capital $\left(\frac{s_t}{f_t}\right)^2$ at 5.2% to 7.7% of total asset value. The value of hiring $\left(\frac{s_t}{f_t}\right)^3$ accounts for 1.6%-3.8% of total asset value.

Panel (c) shows the sample variance decomposition of $\widetilde{\left(\frac{s_t}{f_t}\right)}$. Each term is divided by the total variance so the elements of the matrix sum to 1. By far the biggest role in explaining the variance is played by value of investment in capital $\left(\frac{s_t}{f_t}\right)^2$. The traditional part $\left(\frac{s_t}{f_t}\right)^1$ plays a very small role (5%-9%). This is consistent with two facts. One, noted by Christiano and Fisher (2003), is that p^I was negatively correlated with s in the sample period, and the second is that p^I has lower volatility than capital adjustment costs (as estimated in Table 4b above). In fact, the value of investment in capital $\left(\frac{s_t}{f_t}\right)^2$ "over-explains" asset volatility, and so an important contribution is the negative co-variation of the investment and hiring values terms. Note two other features of the results. First, the term capturing the value of investment in capital $\left(\frac{s_t}{f_t}\right)^2$ takes into account hiring rates via the interaction term; second, the hiring value term $\left(\frac{s_t}{f_t}\right)^3$ has twice as much volatility as the traditional term $\left(\frac{s_t}{f_t}\right)^1$. Thus both adjustment costs are essential in accounting for market value volatility. The role played by hiring rates here is threefold: via the interaction term in $\left(\frac{s_t}{f_t}\right)^2$, via the hiring value term $\left(\frac{s_t}{f_t}\right)^3$, and via the covariance between $\left(\frac{s_t}{f_t}\right)^2$ and $\left(\frac{s_t}{f_t}\right)^3$.

To gain some intuition with respect to these results in relation to standard formulations, consider again the asset pricing equation:

$$s_t = k_{t+1}Q_t^K + n_{t+1}Q_t^N.$$

In stationary form this can be re-written:

$$\frac{s_t}{f_t} = \frac{f_{t+1}}{f_t}\left[\frac{Q_t^K}{\frac{f_{t+1}}{k_{t+1}}} + \frac{Q_t^N}{\frac{f_{t+1}}{n_{t+1}}}\right].$$

In the neoclassical model $Q^K = 1, Q^N = 0$. It is clear from examining the data that $\frac{k_{t+1}}{f_t}$ cannot explain $\frac{s_t}{f_t}$. In the standard quadratic formulation of Tobin's Q, the expression on the RHS becomes $\frac{f_{t+1}}{f_t}\left[\frac{Q_t^K}{\frac{f_{t+1}}{k_{t+1}}}\right]$, where Q_t^K is linear in $\frac{i_t}{k_t}$. This, too, is insufficient to explain the volatility of $\frac{s_t}{f_t}$. The current formulation has Q_t^K and Q_t^N be convex functions of $\frac{i_t}{k_t}$ and $\frac{q_t v_t}{n_t}$ with a sufficiently high degree of convexity and with interaction between the two arguments. These features generate the required volatility.

7. Conclusions

The paper embeds frictional labor markets and capital adjustment costs in a production-based asset pricing model, focusing on the relationship between labor and the market value of the firm. The model is corroborated using structural estimation with aggregate time-series data for the U.S. non-financial corporate business sector. Estimation, focusing on frictions and adjustment costs parameters, yields reasonable values for these costs. We find that the conventional specification – quadratic adjustment costs for capital and no hiring costs – performs poorly. Rather, the interaction between capital and labor adjustment costs is important and non-linearities matter.

The key implication of the results is that firms' market value embodies the value of hiring and investment over and above the capital stock. These costs play a role in explaining both the mean and the volatility of firms' market values. Investment flows and hiring flows define the asset value of capital and of labor, respectively. These values are forward-looking, expected present value expressions. Consequently they exhibit relatively high volatility, similar to the behavior of financial variables with an asset value nature. The paper's key theme is to link a major financial variable – the market value of firms – to these asset values. The standard neoclassical model links this market value with a stock – namely capital – that does not have such properties. This difference explains the fact that the current model is able to account for the high volatility of firms' market value and to provide an empirically credible link between financial markets and the markets for physical capital and labor.

This paper does not attempt to characterize the driving impulses affecting hiring, investment and firms' market values. Further exploration of these forces, such as changes in productivity, is a natural next step. Such an investigation will require a general equilibrium setup.[11] As shown in previous studies this involves dealing with the consumption side and all the associated empirical difficulties. Another potential exploration is a micro study using firm-level data. Such a study could allow for firm or worker heterogeneity and the examination of issues such as fixed costs. However, a serious empirical difficulty lies in the (non) existence of appropriate data on gross worker flows in conjunction with consistent data on investment flows and firms' market value. Given that the interaction of hiring and investment rates has been shown to be important, this data problem needs to be resolved before any empirical exploration at the firm-level can be accomplished.

[11] The standard set-up will need to be changed to account for investment and hiring decisions of the type examined here; see, for example the discussion in Danthine and Donaldson (2002b).

References

[1] Bleakley, Hoyt, Ann E. Ferris, and Jeffrey C. Fuhrer 1999. "New Data on Worker Flows During Business Cycles," *New England Economic Review* July-August, 49-76.

[2] Chirinko, Robert S. 1993. "Business Fixed Investment Spending: Modeling Strategies, Empirical Results, and Policy Implications," *Journal of Economic Literature* XXXI:1875-1911.

[3] Christiano, Lawrence J. and Jonas D.M. Fisher, 2003. "Stock Market and Investment Good Prices: Implications for Macroeconomics," NBER Working Paper no. 10031.

[4] Cochrane, John H. 1991. "Production-Based Asset Pricing and the Link Between Stock Returns and Economic Fluctuations," *Journal of Finance* 146:207-234.

[5] _________ 1996. "A Cross-Sectional Test of an Investment-Based Asset Pricing Model," *Journal of Political Economy* 104:572-621.

[6] Cooper, Russell and John Haltiwanger, 2000." On the Nature of Capital Adjustment Costs," NBER Working Paper no. 7925.

[7] Cooper, Russell and Jonathan Willis, 2003. "The Cost of Labor Adjustment: Inferences from the Gap," NBER Working Paper no. 10006.

[8] Danthine, Jean-Pierre and John B. Donaldson 2002a."Labour Relations and Asset Returns," *Review of Economic Studies* 69:41-64.

[9] _________ 2002b. "Decentralizing the Stochastic Growth Model," working paper.

[10] Durlauf, Steven N. and Robert E. Hall 1990. "Bounds on the Variances of Specification Errors in Models with Expectations," University of Wisconsin Working Paper.

[11] Fama, Eugene F. and Kenneth R. French 1999."The Corporate Cost of Capital and the Return on Corporate Investment," *Journal of Finance* LIV:1939-1967.

[12] Hall, Robert E. 2001."The Stock Market and Capital Accumulation," *American Economic Review* 91:1185-1202.

[13] Hamermesh, Daniel S., 1993. *Labor Demand*, Princeton (Princeton University Press).

[14] Hansen, Lars P. 1982. "Large Sample Properties of Generalized Method of Moments Estimators," *Econometrica* 50:1029-1054.

[15] Hayashi, Fumio 1982. "Tobin's Marginal q and Average q: A Neoclassical Interpretation," Econometrica 50:213-224.

[16] Herman, Shelby 2000. "Fixed Assets and Consumer Durable Goods," Survey of Current Business, Bureau of Economic Analysis, Department of Commerce, April, 17-30.

[17] Jorgenson, Dale W. 1996. *Capital Theory and Investment Behavior*, Cambridge (MIT Press) vol.1.

[18] Mortensen, Dale. T. and Christopher A. Pissarides 1999. "Job Reallocation, Employment Fluctuations, and Unemployment Differences," Ch. 18 in John B. Taylor and Michael Woodford (eds.), *Handbook of Macroeconomics*, Vol. 1B, Amsterdam (North-Holland).

[19] Nadiri, M. Ishaq and Sherwin Rosen 1969. "Interrelated Factor Demand Functions," *American Economic Review* 59:457-471.

[20] Ogaki, Masao and Kyungho Jang 2002. Structural Macroeconometrics, manuscript, in preparation. Available online at http://economics.sbs.ohio-state.edu/ogaki/econ811/lecture.htm.

[21] Pissarides, Christopher A. 2000. *Equilibrium Unemployment Theory*, 2nd edition, Cambridge (MIT Press).

[22] Shapiro, Matthew D. 1986. "The Dynamic Demand for Capital and Labor," *The Quarterly Journal of Economics* 101:513-542.

[23] Tobin, James 1969. "A General Equilibrium Approach to Monetary Theory," *Journal of Money, Credit, and Banking* 1:15-29.

[24] Tobin, James and William Brainard 1977. "Assets Markets and the Cost of Capital," in B. Belassa and R.Nelson (eds.) *Economic Progress, Private Values and Public Policies: Essays in Honor of William Fellner*, Amsterdam (North-Holland), 235-262.

[25] Yashiv, Eran 2000. "The Determinants of Equilibrium Unemployment," *American Economic Review* 90:1297-1322.

A. Derivation of the Firms' Market Value Equation

The following derivations are based on Hayashi (1982). First we multiply throughout the FONC with respect to investment (2.10) by i_t, the FONC with respect to capital (2.9) by k_{t+1}, the FONC with respect to vacancies (2.12) by v_t, and the one with respect to employment (2.11) by n_{t+1} to get

$$\begin{aligned} 0 &= -\left(1-\tau_t\right)\left(p_t^I + g_{i_t}\right) i_t + i_t Q_t^K && \text{(A.1)} \\ 0 &= -\left(1-\tau_t\right) g_{v_t} v_t + v_t q_t Q_t^N && \text{(A.2)} \\ k_{t+1} Q_t^K &= k_{t+1} E_t\left\{\beta_{t+1}\left[\left(1-\tau_{t+1}\right)\left(f_{k_{t+1}} - g_{k_{t+1}}\right) + (1-\delta_{t+1}) Q_{t+1}^K\right]\right\} && \text{(A.3)} \\ n_{t+1} Q_t^N &= n_{t+1} E_t\left\{\beta_{t+1}\left[\left(1-\tau_{t+1}\right)\left(f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1}\right) + (1-\psi_{t+1}) Q_{t+1}^N\right]\right\} && \text{(A.4)} \end{aligned}$$

We then insert the law of motion for capital (2.2) into equation (A.1), roll forward all expressions one period, multiply both sides by β_{t+1} and take conditional expectations on both sides:

$$E_t\left[\beta_{t+1}\left(1-\tau_{t+1}\right)\left(p_{t+1}^I + g_{i_{t+1}}\right) i_{t+1}\right] = E_t\left\{\beta_{t+1}\left[k_{t+2} - (1-\delta_{t+1}) k_{t+1}\right] Q_{t+1}^K\right\}. \quad \text{(A.5)}$$

and so:

$$E_t\left[\beta_{t+1}(1-\delta_{t+1})\left(k_{t+1} Q_{t+1}^K\right)\right] = E_t\left\{\beta_{t+1}\left[\left(k_{t+2} Q_{t+1}^K - \left(1-\tau_{t+1}\right)\left(p_{t+1}^I + g_{i_{t+1}}\right) i_{t+1}\right)\right]\right\}$$

Combining the last expression with equation (A.3) we get

$$k_{t+1} Q_t^K = E_t\left(\beta_{t+1}\left(c f_{t+1}^k + k_{t+2} Q_{t+1}^K\right)\right) \quad \text{(A.6)}$$

or

$$E_t\left(\beta_{t+1} c f_{t+1}^k\right) = k_{t+1} Q_t^K - E_t\left(\beta_{t+1} k_{t+2} Q_{t+1}^K\right). \quad \text{(A.7)}$$

It follows from the definition of the firm's market value in equation (2.18) that

$$\vartheta_t^k - E_t\left(\beta_{t+1} \vartheta_{t+1}^k\right) = E_t\left(\beta_{t+1} c f_{t+1}^k\right). \quad \text{(A.8)}$$

Thus,

$$\vartheta_t^k - E_t\left(\beta_{t+1}\vartheta_{t+1}^k\right) = k_{t+1}Q_t^K - E_t\left(\beta_{t+1}k_{t+2}Q_{t+1}^K\right), \tag{A.9}$$

which implies

$$\vartheta_t^k = k_{t+1}Q_t^K.$$

We derive a similar expression for the case of labor. Inserting the law of motion for labor from equation (2.3) into equation (A.2), multiplying both sides by β_t, rolling forward all expressions by one period, taking conditional expectations, and combining with equation (A.4) we get

$$E_t\left(\beta_{t+1}cf_{t+1}^n\right) = n_{t+1}Q_t^N - E_t\left(\beta_{t+1}n_{t+2}Q_{t+1}^N\right). \tag{A.10}$$

The definition of the firm's value in equation (2.6) implies that

$$\vartheta_t^n - E_t\left(\beta_{t+1}\vartheta_{t+1}^n\right) = E_t\left(\beta_{t+1}cf_{t+1}^n\right). \tag{A.11}$$

Thus,

$$\vartheta_t^n - E_t\left(\beta_{t+1}\vartheta_{t+1}^n\right) = n_{t+1}Q_t^N - E_t\left(\beta_{t+1}n_{t+2}Q_{t+1}^N\right). \tag{A.12}$$

This implies the following expression for the asset value of employment:

$$\vartheta_t^n = n_{t+1}Q_t^N.$$

Hence, the total market value of a firm, s_t, equals:

$$s_t = \vartheta_t^k + \vartheta_t^n = k_{t+1}Q_t^K + n_{t+1}Q_t^N. \tag{A.13}$$

where Q_t^K and Q_t^N are defined in equations (2.15) and (2.16), respectively.

B. Data

The data are quarterly and cover the period from 1976:1 to 1997:4. They pertain to the U.S. non-financial corporate business (NFCB) sector unless noted otherwise.

B.1. Output and Price Deflator

Output, f and its price deflator p^f pertain to the NFCB sector. They originate from the NIPA accounts published by the BEA of the Department of Commerce.[12]

B.2. Investment, Capital, Depreciation and the Price of Investment

These are new data series on the non-financial corporate sector made available in the first quarter of 2001 by the BEA of the Department of Commerce. See Herman (2000)[13] for definitions.

The capital stock k series is measured as the sum of non-residential equipment, software and structures of the non-financial corporate sector. In 1997, for example, total private k was 17,653 billion dollars; total private non-residential k totalled 9,006 billion dollars; 6,125 billion dollars were non-financial corporate. Thus the latter was 35% of private k and 68% of the non-residential part.

Both k and i are reported at an annual frequency. We construct the quarterly capital stock data by interpolating the annual series according to the following formula:

$$\ln(k_{t+1,l}) = \ln(k_t) + \frac{l}{4}[\ln(k_{t+1}) - \ln(k_t)]$$

$l = 1, 2, 3, 4$, k_t denotes the capital stock at the end of year t and $k_{t+1,l}$ denotes the capital stock in the l-th quarter of year $t + 1$.

We construct the quarterly investment series using the following three alternative interpolation schemes:

[12] See www.bea.doc.gov/bea/dn/st-tabs.htm

[13] See www.bea.doc.gov/bea/ARTICLES/NATIONAL/NIPAREL/2000/0400fxacdg.pdf

(i) distributing i according to the weights of the private sector investment series which is available quarterly.

b) dividing i evenly to 4 quarters.

c) taking the annual growth rate in logs, denoting it by g^a, defining $g = (1 + g^a)^{0.25} - 1$ and then computing

$i^1 = \frac{i}{1+(1+g)+(1+g)^2+(1+g)^3}$; $i^2 = i^1(1 + g)$; $i^3 = i^2(1 + g)$; $i^4 = i^3(1 + g)$.

It turns out that there is little difference between these series. Thus in the empirical work reported in the tables we rely on the last measure.

For the rate of depreciation we use the depreciation series computed by the BEA; this is available in annual frequency[14] and we convert it to quarterly using $\delta_t = (1 + \delta_t^a)^{0.25} - 1$.

In order to compute the real price of new capital, p^I, we determine the price indices for output and for investment goods. The price index for output, p^f, equals the ratio of nominal to real GDP. Similarly, the price index for a particular type of investment good, PSE equals the ratio of nominal to real investment. The parameter τ denotes the statutory corporate income tax rate as reported by the U.S. Tax Foundation. ITC denotes the investment tax credit on equipment and public utility structures, $ZPDE$ the present discounted value of capital depreciation allowances, and χ the percentage of the cost of equipment that cannot be depreciated if the firm takes the investment tax credit.[15]Furthermore, S denotes structures, Eq denotes equipment, and s_{Eq} denotes the fraction of equipment in business fixed investment.

The real price of business fixed capital, p^I, then equals

$$p^I = p^I_{Eq}\frac{(1 - \tau\ ZPDE)}{1 - \tau}s_{Eq} + p^I_S\frac{1 - ITC - \tau ZPDE\,(1 - \chi ITC)}{1 - \tau}\,(1 - s_{Eq})\,, \qquad \text{(B.1)}$$

[14] See line 28 in Tables 4.1 (Current-Cost Net Stock of Nonresidential, Nonfinancial Fixed Assets) and 4.4 (Current-Cost Depreciation of Nonresidential, Nonfinancial Fixed Assets) at http://www.bea.gov/bea/dn/faweb/AllFATables.asp#S4

[15] The last three series are the ones compiled for the macro model of the Board of Governors of the U.S. Federal Reserve System. Flint Brayton kindly provided us with these series.

where $p^I_{Eq} = PSE_{Eq}/p^f$, and $p^I_S = PSE_S/p^f$.

We transform annual values into quarterly values by interpolating the annual i into quarterly using the growth method (method c above) and computing the quarterly PSE by dividing the nominal by the real.

B.3. Employment, Matches and Separations

Employment n is defined as wage and salary workers in non-agricultural industries less government workers less workers in private households less self-employed workers less unpaid family workers. All series originate from the BLS.

For matches (qv) and separation (ψ) we use data on gross worker flows as computed by Bleakely et al. (1999). These data are adjusted, including seasonal adjustment, in ways explained in the latter reference. They pertain to flows between the employment pool on the one hand and the unemployment and out of the labor force pools on the other hand.

This data set pertains to the entire economy. In most specifications we wish to consider flows pertaining to the non-financial corporate sector. We thus proceed as follows:

a. Denoting variables for the entire economy by TOT we solve for ψ^{TOT} period by period from the labor force dynamics equation:

$$n^{TOT}_{t+1} = n^{TOT}_t (1 - \psi^{TOT}_t) + (qv)^{TOT}_t$$

b. We then use the dynamic equation to solve for $(qv)^{NFCB}$ (where $NFCB =$ non financial corporate business) period by period as follows:

$$n^{NFCB}_{t+1} = n^{NFCB}_t (1 - \psi^{TOT}_t) + (qv)^{NFCB}_t$$

In estimation we use $\frac{(qv)^{NFCB}_t}{n^{NFCB}_t}$ and ψ^{TOT}_t. Thus we are implicitly assuming – for lack of data – that $\psi^{TOT}_t = \psi^{NFCB}_t$ but we are not imposing such restrictions on $(qv)^{NFCB}_t$ on which we do not have data directly.

In Table 2c we use two alternatives. Column 6 solves $(qv)_t^{NFCB}$ from the following equation:

$$n_{t+1}^{NFCB} = n_t^{NFCB}(1 - \psi_t^{TOT,actual}) + (qv)_t^{NFCB}$$

Here we use the actual separation rate for the entire economy $\psi_t^{TOT,actual}$.

In column 7 of that table we use $\frac{(qv)_t^{TOT}}{n_t^{TOT}}$ and ψ_t^{TOT} i.e. values for the entire economy rather than just the corporate sector.

B.4. The Labor Share

For the labor share of income $\frac{wn}{f}$ we use compensation of employees (the sum of wage and salary accruals and supplements to wages and salaries) as a fraction of the gross product of the non-financial corporate business sector.[16]

B.5. Market Value Data

We use the market value of non-farm, non-financial business. The data originate from Hall (2001).[17] They are based on the Fed Flow of Funds accounts and are defined as follows.

Source: Flow of Funds data and interest rate data from www.federalreserve.gov/releases. The data are for non-farm, non-financial business. Stock data were taken from ltabs.zip.[18]

Definition: The value of all securities is the sum of financial liabilities and equity less financial assets, adjusted for the difference between market and book values for bonds.[19]

B.6. Discount Rate and Discount Factor

We use four alternatives for the firms' discount rate r_t, which generates the discount factor given by $\beta_t = [1/(1 + r_t)]$:

[16] The data are taken from NIPA Table 1.16, lines 19 and 24.

[17] See www.stanford.edu/~rehall/Procedure.htm for a full description and www.stanford.edu/~rehall/page3.html.

[18] Downloaded at www.federalreserve.gov/releases/z1/Current/data.htm.

[19] The subcategories unidentified miscellaneous assets and liabilities were omitted from all of the calculations. These are residual values that do not correspond to any financial assets or liabilities.

a. The main series used, following the weighted average cost of capital approach in corporate finance, is a weighted average of the returns to debt, r_t^b, and equity, r_t^e:

$$r_t = \omega_t r_t^b + (1 - \omega_t)\, r_t^e,$$

with

$$\begin{aligned} r_t^b &= (1 - \tau_t)\, r_t^{CP} - \theta_t \\ r_t^e &= \frac{\widetilde{cf}_t}{\widetilde{s}_t} + \widetilde{\widehat{s}}_t - \theta_t \end{aligned}$$

where:

(i) ω_t is the share of debt finance as reported in Fama and French (1999).

(ii) The definition of r_t^b reflects the fact that nominal interest payments on debt are tax deductible. r_t^{CP} is Moody's seasoned Aaa commercial paper rate. The commercial paper rate for the first month of each quarter represents the entire quarter. The tax rate is τ as discussed above.

(iii) θ denotes inflation and is measured by the GDP-deflator of p^f discussed above.

(iv) For equity return we use the CRSP Value Weighted NYSE, Nasdaq and Amex nominal returns ($\frac{\widetilde{cf}_t}{\widetilde{s}_t} + \widetilde{\widehat{s}}_t$ in terms of the model, using tildes to indicate nominal variables) deflated by the inflation rate θ.

The above is computed quarterly using monthly returns of a given quarter. As an alternative we compute the quarterly returns using the monthly returns of months 2 and 3 within the same quarter and month 1 in the following quarter.

We experiment with two other series to see their effect on the results:

b. The rate of change of the SP500 index computed as follows:

$$r_t^Q = \frac{\left[\frac{S_3}{S_0}\frac{S_4}{S_1}\frac{S_5}{S_2}\right]^{\frac{1}{3}}}{1 + \vartheta} - 1$$

where S_j is the level of the stock index at the end of month l, the current quarter has months 4 and 5, the preceding quarter has months $1, 2, 3$ and the quarter preceding that has month 0.

c. Non-durable consumption growth, which corresponds to the discount rate in a DSGE model with logarithmic utility. If utility is given by:

$$U(c_t) = \ln c_t$$

Then in general equilibrium:

$$U'(c_t) = U'(c_{t+1})\,(1 + r_{t,t+1})$$

Hence:

$$r_{t,t+1} = \frac{c_{t+1}}{c_t} - 1$$

C. The Interaction between Investment and Hiring

In order to understand the significance of the e_3-estimates, it is useful to see how hiring depends on the value of investment and how investment depends on the value of hiring. First, consider the former case (hiring). The FONC may be re-written as follows:

$$\begin{aligned} F1 &: \left(\widetilde{g}_{i_t}(\frac{i_t}{k_t}, \frac{q_t v_t}{n_t}) + p_t^I\right) = Q_t^k \\ F2 &: \frac{1}{q_t}\widetilde{g}_{v_t}(\frac{i_t}{k_t}, \frac{q_t v_t}{n_t}) = Q_t^N. \end{aligned}$$

Differentiate both equations with respect to Q^K yields:

$$\begin{aligned} \frac{\partial \widetilde{g}_{i_t}}{\partial \frac{i_t}{k_t}} \frac{\partial \frac{i_t}{k_t}}{\partial Q^k} + \frac{\partial \widetilde{g}_{i_t}}{\partial \frac{q_t v_t}{n_t}} \frac{\partial \frac{q_t v_t}{n_t}}{\partial Q^k} &= 1 \\ \frac{1}{q_t}\left[\frac{\partial \widetilde{g}_{v_t}}{\partial \frac{i_t}{k_t}} \frac{\partial \frac{i_t}{k_t}}{\partial Q^k} + \frac{\partial \widetilde{g}_{v_t}}{\partial \frac{q_t v_t}{n_t}} \frac{\partial \frac{q_t v_t}{n_t}}{\partial Q^k}\right] &= 0 \end{aligned}$$

where we use the following notation:

$$g_{ii} = \frac{\partial \widetilde{g}_{i_t}}{\partial \frac{i_t}{k_t}} \; g_{iv} = \frac{\partial \widetilde{g}_{i_t}}{\partial \frac{q_t v_t}{n_t}} \; g_{vi} = \frac{1}{q}\frac{\partial \widetilde{g}_{v_t}}{\partial \frac{i_t}{k_t}} \; g_{vv} = \frac{1}{q}\frac{\partial \widetilde{g}_{v_t}}{\partial \frac{q_t v_t}{n_t}}$$

Then:

$$g_{ii}\frac{\partial \frac{i_t}{k_t}}{\partial Q^k} + g_{iv}\frac{\partial \frac{q_t v_t}{n_t}}{\partial Q^k} = 1 \tag{C.1}$$
$$g_{vi}\frac{\partial \frac{i_t}{k_t}}{\partial Q^k} + g_{vv}\frac{\partial \frac{q_t v_t}{n_t}}{\partial Q^k} = 0$$

Solving for the marginal effect of Q^K on investment and on hiring yields:

$$\frac{\partial \frac{i_t}{k_t}}{\partial Q^k} = \frac{g_{vv}}{g_{ii}g_{vv} - g_{iv}g_{vi}} > 0$$
$$\frac{\partial \frac{q_t v_t}{n_t}}{\partial Q^k} = -\frac{g_{vi}}{g_{ii}g_{vv} - g_{iv}g_{vi}}.$$

With a convex adjustment costs function g, the denominator is positive. Evidently investment rates rise with Q^K; its effect on hiring $(\frac{\partial \frac{q_t v_t}{n_t}}{\partial Q^k})$ depends on the sign of g_{vi}. A negative point estimate of e_3 implies a negative value for g_{vi} and, therefore, a positive sign for $\partial \frac{q_t v_t}{n_t}/\partial Q^k$. Hence, when Q^K rises both $\frac{i}{k}$ and $\frac{qv}{n}$ rise.

Using a similar argument we can show that $\frac{i}{k}$ and $\frac{qv}{n}$ rise with an increase in Q^N.

Table 1

Descriptive Statistics

Variable	Mean	Standard Deviation
$\frac{i}{k}$	0.025	0.002
$\frac{f}{k}$	0.17	0.01
p^I	1.39	0.14
τ	0.40	0.06
δ	0.018	0.002
$\frac{wn}{f}$	0.658	0.010
$\frac{qv}{n}$	0.090	0.009
ψ	0.085	0.008
$\frac{s}{f}$	5.2	1.3
β	0.980	0.005

Note: The sample size is 88 quarterly observations from 1976:1 to 1997:4. For data definitions see Appendix B.

Table 2

GMM Estimates of F1, F2 and asset pricing equation s/f, 1976:1-1997:4

a. Alternative Power Specifications

	1	2	3
$\{\eta_1, \eta_2, \eta_3, \eta_4\}$	free $\eta' s$	free η_2	free η_2
η_1	3.02	η_2	η_2
	(0.89)		
η_2	3.02	3.02	3.00
	(1.10)	(0.08)	(0.09)
η_3	1.51	$\eta_2 - 1.5$	$\eta_2 - 1.6$
	(0.23)		
η_4	–	$\eta_2 - 1.6$	$\eta_2 - 1.5$
e_1	30,500	29,250	27,300
	(128,967)	(7,455)	(7,681)
e_2	707	623	670
	(1,381)	(157)	(173)
e_3	-4,416	-2,360	-2,000
	(7,924)	(1,262)	(1,128)
α	0.67	0.66	0.68
	(0.09)	(0.05)	(0.06)
J-Statistic	39.8	43.8	41.6
p-Value	0.04	0.03	0.05
$N.R.\ F1$	0.18	0.17	0.18
$N.R.\ F2$	0.14	0.14	0.14
$N.R.\ s/f$	0.22	0.26	0.24

b. Alternative Instrument Sets

	1	2	3	4	5	6	7	8	9
η_1					η_2				
η_2	3.00	3.00	3.00	3.00	3.00	3.01	3.01	3.01	3.00
	(0.18)	(0.11)	(0.06)	(0.05)	(0.04)	(0.03)	(0.04)	(0.02)	(0.01)
η_3					$\eta_2 - 1.5$				
e_1	27,942	27,624	28,529	27,938	27,624	28,051	28,897	28,304	27,229
	(13,109)	(8,372)	(5,490)	(5,946)	(4,531)	(4,000)	(4,467)	(2,275)	(1,027)
e_2	660	659	680	660	659	656	654	657	664
	(368)	(217)	(145)	(256)	(130)	(108)	(121)	(58)	(25)
e_3	-4,170	-4,126	-4,306	-4,167	-4,126	-4,281	-4,398	-4,311	-3,999
	(6,071)	(3,643)	(2,280)	(2,046)	(1,523)	(1,389)	(1,594)	(743)	(295)
α	0.68	0.68	0.67	0.68	0.68	0.68	0.68	0.72	0.67
	(0.16)	(0.09)	(0.05)	(0.07)	(0.03)	(0.03)	(0.04)	(0.02)	(0.01)
J-Statistic	22.5	35.8	41.3	32.4	38.4	45.1	43.3	56.9	71.0
p-Value	0.004	0.01	0.05	0.001	0.06	0.27	0.004	0.13	0.44
$N.R.\ F1$	0.11	0.15	0.17	0.11	0.15	0.17	0.20	0.42	0.51
$N.R.$ s$F2$	0.04	0.11	0.14	0.04	0.11	0.14	0.10	0.21	0.31
$N.R.\ s/f$	0.14	0.22	0.23	0.53	0.57	0.58	0.58	0.64	0.73

c. Variations in the Measurement of $\psi, \delta, \beta, qv/n$

	1	2	3	4	5	6	7
η_1				η_2			
η_2	3.00	3.00	3.00	3.00	3.00	3.00	3.01
	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.05)
η_3				$\eta_2 - 1.5$			
e_1	28,413	28,600	28,400	28,444	28,458	28,400	28,003
	(5,479)	(5,026)	(5,158)	(5,114)	(5,675)	(5,447)	(4,412)
e_2	677	670	680	676	681	680	679
	(143)	(127)	(139)	(130)	(159)	(167)	(155)
e_3	-4,258	-4,342	-4,250	-4,271	-4,277	-4,250	-4,328
	(2,241)	(2,155)	(2,001)	(2,130)	(2,436)	(2,408)	(1,813)
α	0.67	0.67	0.67	0.67	0.67	0.67	0.67
	(0.05)	(0.04)	(0.05)	(0.05)	(0.06)	(0.07)	(0.05)
J-Statistic	40.8	49.2	42.9	40.1	40.8	41.9	42.6
p-Value	0.06	0.01	0.04	0.07	0.06	0.04	0.04
$N.R.\ F1$	0.18	0.20	0.12	0.19	0.21	0.19	0.23
$N.R.\ F2$	0.14	0.15	0.16	0.15	0.16	0.22	0.10
$N.R.\ s/f$	0.23	0.24	0.24	0.24	0.24	0.22	0.28

Notes:

1. The specification used is:

$$g(\cdot) = \left[\frac{e_1}{\eta_1}(\frac{i_t}{k_t})^{\eta_1} + \frac{e_2}{\eta_2}(\frac{q_t v_t}{n_t})^{\eta_2} + \frac{e_3}{\eta_3}(\frac{i_t}{k_t}\frac{q_t v_t}{n_t})^{\eta_3}\right] f(z_t, n_t, k_t).$$

except for columns 2 and 3 in panel (a) where we use:

$$g(\cdot) = \left[\frac{e_1}{\eta_1}(\frac{i_t}{k_t})^{\eta_1} + \frac{e_2}{\eta_2}(\frac{q_t v_t}{n_t})^{\eta_2} + e_3\left(\frac{i_t}{k_t}\right)^{\eta_3}\left(\frac{q_t v_t}{n_t}\right)^{\eta_4}\right] f(z_t, n_t, k_t).$$

2. Standard errors are given in parentheses.

3. Instruments used are a constant and:

In panels (a) and (c) – six lags of $\{\frac{i}{k}, \frac{f}{k}\}$ in $F1, \{\frac{qv}{n}, \frac{wn}{f}\}$ in $F2$ and $\frac{s}{f}$ in the asset pricing equation.

In panel (b) – In column 1 two lags, in column 2 four lags, and in column 3 six lags of $\{\frac{i}{k}, \frac{f}{k}\}$ in $F1, \{\frac{qv}{n}, \frac{wn}{f}\}$ in $F2$ and $\frac{s}{f}$ in the asset pricing equation.

In column 4 two lags, in column 5 four lags, and in column 6 six lags of $\{\frac{i}{k}, \frac{f}{k}\}$ in $F1, \{\frac{qv}{n}, \frac{wn}{f}\}$ in $F2$ and $\{\frac{s}{f}, \frac{i}{k}, \frac{qv}{n}\}$ in the asset pricing equation.

In column 7 two lags, in column 8 four lags, and in column 9 six lags of $\{\frac{i}{k}, \frac{f}{k}, p^I, \frac{s}{f}\}$ in $F1, \{\frac{qv}{n}, \frac{wn}{f}, \frac{s}{f}\}$ in $F2$ and $\{\frac{s}{f}, \frac{i}{k}, \frac{f}{k}, \frac{qv}{n}, \frac{wn}{f}\}$ in the asset pricing equation.

4. In panel (c) – column 1 has $\delta = 0.22$ and $\psi = 0.08$. In column 2, β is based on non-durable consumption rate of growth , in column 3 on the SP500 rate of change , in column 4 $\beta = 0.98$ and in column 5, β is based on an alternative computation of the benchmark β. In columns 6 and 7 alternative definitions of ψ and $\frac{qv}{n}$ are used. See Appendix B.

Table 3

GMM Estimates of F1, F2 and asset pricing equation s/f, 1976:1-1997:4

Conventional Specifications of g

	1	2	3
$\{\eta_1, \eta_2, \eta_3\}$	fixed	fixed	free η_2
η_1	2	3	η_2
η_2	–	3	3.00
			(0.14)
η_3	–	–	$\eta_2 - 1.5$
e_1	2.4	17,985	28,419
	(6.4)	(1,536)	(9,508)
e_2	-	-1,422	681
		(133)	(514)
e_3	-	-	-4,257
			(4,215)
α	0.66	0.45	0.67
	(0.001)	(0.06)	(0.18)
J-Statistic	54.7	41.4	35.9
p-value	0.005	0.08	0.002
N.R. $F1$	0.15	0.22	0.17
N.R. $F2$	0.76	0.16	–
N.R. s/f	0.87	0.21	0.23

Notes: 1. In column 1 we set $e_2 = e_3 = 0$ and in column 2 we set $e_3 = 0$.

2. In column 3 only $F1$ and the asset pricing equation are estimated.

3. Instruments are a constant and six lags of $\{\frac{i}{k}, \frac{f}{k}\}$ in $F1$, $\{\frac{qv}{n}, \frac{wn}{f}\}$ in $F2$, and $\frac{s}{f}$ in the asset pricing equation.

Table 4

Sample Moments of Marginal and Total Adjustment Costs

a. Gross Hiring

Table 2, panel and column	b3	b5	b6	b8	b9	c1	c4	c5
Net Marginal Costs $\frac{g_v}{f/n}$	0.30	0.35	0.20	0.23	0.44	0.31	0.30	0.33
	(1.07)	(1.04)	(1.03)	(1.04)	(1.05)	(1.07)	(1.07)	(1.08)
Gross Marginal Costs	5.47	5.35	5.23	5.26	5.42	5.46	5.44	5.48
	(1.00)	(0.99)	(0.96)	(0.98)	(0.99)	(1.00)	(1.00)	(1.00)
Interaction Labor-Capital	-5.16	-5.0	-5.03	-5.03	-4.99	-5.15	-5.15	-5.16
	(0.68)	(0.65)	(0.67)	(0.66)	(0.65)	(0.68)	(0.68)	(0.68)

b. Gross Investment

Table 2, panel and column	b3	b5	b6	b8	b9	c1	c4	c5
Net Marginal Costs +	8.33	8.38	8.27	8.30	8.53	8.41	8.39	8.37
Purchase Price $\frac{g_i}{f/k} + \frac{p^I}{f/k}$	(3.25)	(3.14)	(3.15)	(3.15)	(3.15)	(3.24)	(3.24)	(3.25)
Purchase Price	8.11	8.11	8.11	8.11	8.11	8.11	8.11	8.11
	(1.23)	(1.23)	(1.23)	(1.23)	(1.23)	(1.23)	(1.23)	(1.23)
Gross Marginal Costs	18.42	17.93	17.89	17.96	18.00	18.43	18.42	18.43
	(3.19)	(3.06)	(3.10)	(3.08)	(3.11)	(3.19)	(3.19)	(3.19)
Interaction Capital-Labor	-18.20	-17.69	-17.73	-17.81	-17.58	-18.14	-18.14	-18.18
	(2.53)	(2.49)	(2.47)	(2.52)	(2.43)	(2.52)	(2.52)	(2.53)
Net Marginal Costs	0.22	0.24	0.16	0.15	0.42	0.29	0.28	0.26
	(3.69)	(3.60)	(3.60)	(3.62)	(3.59)	(3.69)	(3.69)	(3.69)
Before Tax Q^K	1.44	1.44	1.43	1.43	1.47	1.45	1.45	1.44
	(0.59)	(0.57)	(0.58)	(0.58)	(0.58)	(0.59)	(0.59)	(0.59)

c. Total Adjustment Costs

Table 2, panel and column	b3	b5	b6	b8	c1	c4	c5
Total Costs $\frac{g}{f}$	0.015	0.017	0.012	0.013	0.016	0.016	0.016
	(0.010)	(0.009)	(0.009)	(0.009)	(0.010)	(0.010)	(0.010)
Investment Costs $\frac{e_1}{\eta_1}(\frac{i_t}{k_t})^{\eta_1}$	0.158	0.154	0.153	0.154	0.158	0.158	0.158
	(0.041)	(0.040)	(0.040)	(0.040)	(0.041)	(0.041)	(0.041)
Hiring Costs $\frac{e_2}{\eta_2}(\frac{q_t v_t}{n_t})^{\eta_2}$	0.166	0.163	0.158	0.160	0.165	0.165	0.167
	(0.045)	(0.045)	(0.043)	(0.044)	(0.045)	(0.045)	(0.045)
Interaction $\frac{e_3}{\eta_3}(\frac{i_t}{k_t}\frac{q_t v_t}{n_t})^{\eta_3}$	-0.309	-0.300	-0.300	-0.301	-0.308	-0.307	-0.308
	(0.055)	(0.053)	(0.053)	(0.054)	(0.054)	(0.055)	(0.055)

Note: Sample means are reported with standard deviations in parentheses.

Table 5

Estimates of Marginal Adjustment Costs for Capital

Summary of Studies for the U.S. Economy

Study	Sample	Mean $\frac{i}{k}$	Mean g_i
[1]	BEA, 1932-1978	0.13	$2.5 - 60.5$
[2]	Corporate Sector, 1953-1976	0.14	3.2
[3]	Manufacturing, 1955-1980	0.08	1.33
[4]	Compustat, 1976-1987	$0.20 - 0.23$	$0.15 - 0.45$
[5]	Compustat, 1985-1989	$0.17 - 0.18$	$0.50 - 0.98$
[6]	Compustat, 1980-1993	0.23	$0.15 - 0.21$
	Split Sample		$0.13 - 1.1$
[7]	Compustat, 1960-1987	0.20	0.27
[8]	LRD panel, 1972-1988	0.12	$0.04, 0.26$
[9]	35 industry panel, 1958-1999	0.10	0.10
[10]	Compustat 1974-1993	0.15	$1.2 - 22.9$

Note: Investment rates $\frac{i}{k}$ are expressed in annual terms. All studies pertain to annual data except Shapiro (1986) who uses quarterly data. The entries in the last column are expressed in terms of f/k,so, they are comparable to net marginal costs in Table 4b.

References

[1] Summers, L.H. 1981. "Taxation and Corporate Investment: A q-Theory Approach," *Brookings Papers on Economic Activity* 1:67-127.

[2] Hayashi, F. 1982. "Tobin's marginal q and Average q: A Neoclassical Interpretation," *Econometrica* 50:213-224.

[3] Shapiro, M.D. 1986. "The Dynamic Demand for Capital and Labor," *The Quarterly Journal of Economics* 101:513-542.

[4] Hubbard, R.G., A.K Kashyap, T.M. Whited 1995. "Internal Finance and Firm Investment," *Journal of Money, Credit and Banking* 27:683-701.

[5] Gilchrist, S., C.P. Himmelberg 1995. "Evidence on the Role of Cash Flow for Investment," *Journal of Monetary Economics* 36:541-572.

[6] _______ 1998. "Investment: Fundamentals and Finance," *NBER Macroeconomic Annual* 223-262.

[7] Barnett, S.A., P. Sakellaris 1999. "A New Look at Firm Market Value, Investment, and Adjustment Costs," *The Review of Economics and Statistics* 81:250-260.

[8] Cooper, R., J. Haltiwanger 2002. "On the Nature of Capital Adjustment Costs," Working Paper available online at www.bu.edu/econ/faculty/cooper/.

[9] Hall, R.E. 2002. "Industry Dynamics with Adjustment Costs," NBER Working Paper 8849, March.

[10] Abel, A., J.C. Eberly 2002. "Investment and q With Fixed Costs: An Empirical Analysis," Working Paper available online at www.kellogg.edu/faculty/eberly/htm/research/research.html.

Table 6

Implications of Estimates for Firm Market Values $\frac{s}{f}$

a. Diagnostic Statistics

Table 2, panel and column	b3	b5	b6	b8	b9	c1	c4	c5
$\rho(\widetilde{\frac{s_t}{f_t}}, \frac{s_t}{f_t})$	0.44	0.43	0.43	0.43	0.43	0.44	0.50	0.43
$\rho(\widetilde{\left(\frac{s_t}{f_t}\right)^1}, \frac{s_t}{f_t})$	-0.69	-0.69	-0.69	-0.70	-0.69	-0.69	-0.72	-0.69
$\rho(\widetilde{\left(\frac{s_t}{f_t}\right)^2}, \frac{s_t}{f_t})$	0.57	0.56	0.57	0.57	0.57	0.57	0.57	0.56
$\rho(\widetilde{\left(\frac{s_t}{f_t}\right)^3}, \frac{s_t}{f_t})$	-0.53	-0.52	-0.53	-0.53	-0.53	-0.53	-0.53	-0.52
$\frac{var \widetilde{\frac{s_t}{f_t}}}{var \frac{s_t}{f_t}}$	1.28	1.19	1.22	1.21	1.21	1.29	1.30	1.27

b. Decomposition of the Mean Predicted Market Values $\widetilde{\left(\frac{s_t}{f_t}\right)}$

Table 2, panel and column	b3	b5	b6	b8	b9	c1	c4	c5
Share of $\widetilde{\left(\frac{s_t}{f_t}\right)^1}$	0.917	0.907	0.933	0.923	0.885	0.907	0.911	0.912
Share of $\widetilde{\left(\frac{s_t}{f_t}\right)^2}$	0.058	0.062	0.052	0.055	0.077	0.066	0.064	0.059
Share of $\widetilde{\left(\frac{s_t}{f_t}\right)^3}$	0.026	0.031	0.016	0.022	0.038	0.027	0.025	0.029

c. Variance Decomposition of the Predicted Market Values $\widetilde{\left(\frac{s_t}{f_t}\right)}$

Table 2b

Col. 3

	$\widetilde{\left(\frac{s_t}{f_t}\right)^1}$	$\widetilde{\left(\frac{s_t}{f_t}\right)^2}$	$\widetilde{\left(\frac{s_t}{f_t}\right)^3}$
$\widetilde{\left(\frac{s_t}{f_t}\right)^1}$	0.09	-0.20	0.05
$\widetilde{\left(\frac{s_t}{f_t}\right)^2}$	-0.20	2.32	-0.65
$\widetilde{\left(\frac{s_t}{f_t}\right)^3}$	0.05	-0.65	0.18

Col. 5

	$\widetilde{\left(\frac{s_t}{f_t}\right)^1}$	$\widetilde{\left(\frac{s_t}{f_t}\right)^2}$	$\widetilde{\left(\frac{s_t}{f_t}\right)^3}$
$\widetilde{\left(\frac{s_t}{f_t}\right)^1}$	0.09	-0.22	0.06
$\widetilde{\left(\frac{s_t}{f_t}\right)^2}$	-0.22	2.34	-0.65
$\widetilde{\left(\frac{s_t}{f_t}\right)^3}$	0.06	-0.65	0.18

Col. 6

	$\left(\frac{s_t}{f_t}\right)^1$	$\left(\frac{s_t}{f_t}\right)^2$	$\left(\frac{s_t}{f_t}\right)^3$
$\left(\frac{s_t}{f_t}\right)^1$	0.09	-0.21	0.05
$\left(\frac{s_t}{f_t}\right)^2$	-0.21	2.32	-0.64
$\left(\frac{s_t}{f_t}\right)^3$	0.05	-0.64	0.18

Col. 8

	$\left(\frac{s_t}{f_t}\right)^1$	$\left(\frac{s_t}{f_t}\right)^2$	$\left(\frac{s_t}{f_t}\right)^3$
$\left(\frac{s_t}{f_t}\right)^1$	0.09	-0.22	0.06
$\left(\frac{s_t}{f_t}\right)^2$	-0.21	2.31	-0.64
$\left(\frac{s_t}{f_t}\right)^3$	0.06	-0.64	0.18

Col. 9

	$\left(\frac{s_t}{f_t}\right)^1$	$\left(\frac{s_t}{f_t}\right)^2$	$\left(\frac{s_t}{f_t}\right)^3$
$\left(\frac{s_t}{f_t}\right)^1$	0.09	-0.22	0.06
$\left(\frac{s_t}{f_t}\right)^2$	-0.21	2.33	-0.65
$\left(\frac{s_t}{f_t}\right)^3$	0.06	-0.65	0.18

Table 2c

Col. 1

	$\left(\frac{s_t}{f_t}\right)^1$	$\left(\frac{s_t}{f_t}\right)^2$	$\left(\frac{s_t}{f_t}\right)^3$
$\left(\frac{s_t}{f_t}\right)^1$	0.09	-0.20	0.05
$\left(\frac{s_t}{f_t}\right)^2$	-0.20	2.31	-0.64
$\left(\frac{s_t}{f_t}\right)^3$	0.05	-0.64	0.18

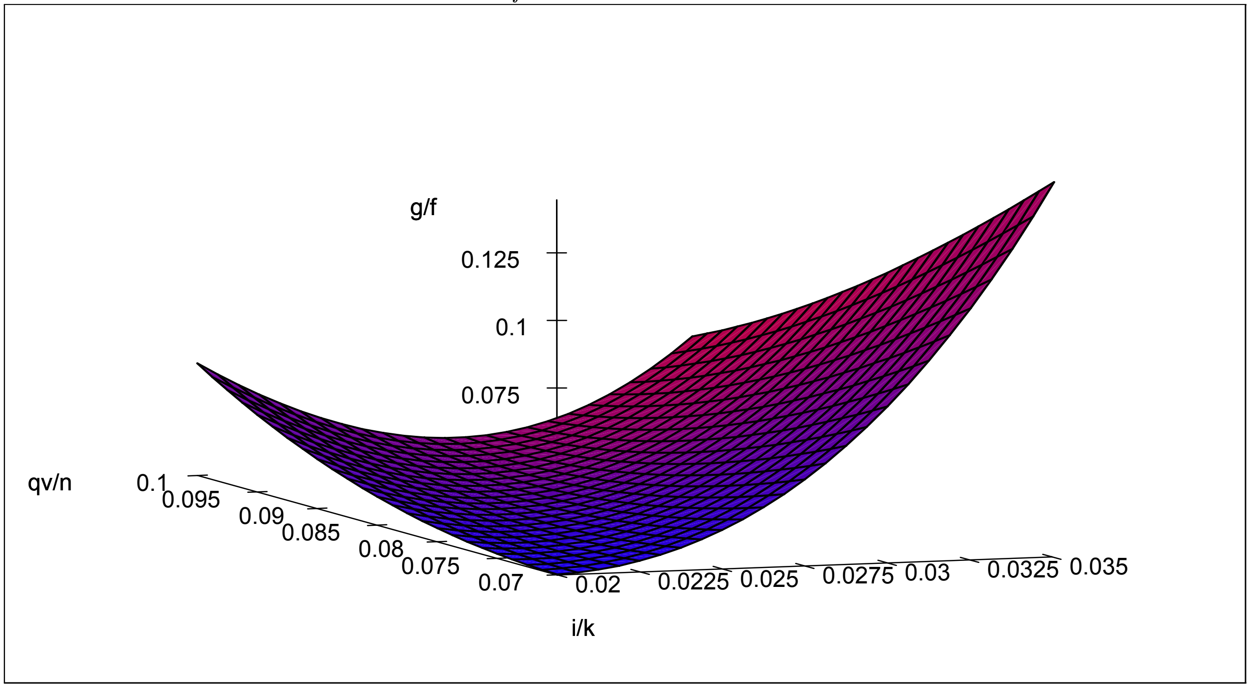
Col. 4

	$\left(\frac{s_t}{f_t}\right)^1$	$\left(\frac{s_t}{f_t}\right)^2$	$\left(\frac{s_t}{f_t}\right)^3$
$\left(\frac{s_t}{f_t}\right)^1$	0.05	-0.22	0.06
$\left(\frac{s_t}{f_t}\right)^2$	-0.22	2.43	-0.67
$\left(\frac{s_t}{f_t}\right)^3$	0.06	-0.67	0.19

Col. 5

	$\left(\frac{s_t}{f_t}\right)^1$	$\left(\frac{s_t}{f_t}\right)^2$	$\left(\frac{s_t}{f_t}\right)^3$
$\left(\frac{s_t}{f_t}\right)^1$	0.08	-0.25	0.07
$\left(\frac{s_t}{f_t}\right)^2$	-0.25	2.45	-0.69
$\left(\frac{s_t}{f_t}\right)^3$	0.07	-0.69	0.19

Figure 1: $\frac{g}{f}$



Note:

Values of $\frac{i}{k}$ and $\frac{qv}{n}$ in the figure lie within the actual range of the obervations in the data.

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