Labor and the Market Value of the Firm

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What role does labor play in the market value of firms? According to the standard 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 James Tobin (1969) or Tobin and William 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 assigns no explicit role for labor, as determination of the firm's value requires only 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 Jean-Pierre Danthine and John B. 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 captures these rents.

In this paper we investigate links between the financial market and the labor market. Toward this end, we build on the production-based model for firms' market value proposed by John H. Cochrane (1991, 1996) and insert labor and capital adjustment costs as crucial ingredients. 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 that 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 workers to hire and on the size of the investment in physical capital to undertake in their effort to maximize their market value. Doing so, they face adjustment costs for capital and labor, which interact. Optimal hiring and investing determine firms' profits—including rents from employment—and consequently their market value, as well as the time path of employment and capital.

We quantify the link between financial markets and labor markets by structurally estimating the model using aggregate time-series data for the US corporate sector. Our dataset 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 nonfinancial corporate business sector rather than to broader, but inappropriate, measures of the US 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 nonlinear, 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 value. Toward 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

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for the predicted component of firms' value, over and above the size of the physical capital stock.

The paper contributes to two key models in macroeconomics and finance and establishes a connection between them: the Q-model and the production-based asset pricing model. First, it adds the important dimension of labor to the Q-model, and shows that it is crucially important for the model's empirical relevance. Second, for the production-based asset pricing model, it gives much greater empirical relevance with the inclusion of labor. It has the ability to match the first two moments of stock price data.

The paper proceeds as follows. Section I presents the model. Section II discusses the data and the empirical methodology. Section III presents the results. Section IV derives the implications with respect to the adjustment costs function and to the joint behavior of hiring and investment. Section V discusses the implications for market values, and Section VI concludes. Technical derivations, data definitions, and robustness checks are elaborated in Merz and Yashiv (2005).

I. The Model

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

A. *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 good.

B. *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, and how many workers to hire. A firm's gross hires per period are given by h. 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:

$$(1) \qquad y_t = f(z_t, n_y, k_t).$$

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 a 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 $g(i_t, k_t, h_t, n_t)$ 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.

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

$$(2) \qquad k_{t+1} = (1 - \delta_t)k_t + i_t, \ 0 \le \delta_t \le 1.$$

Similarly, the number of a firm's employees decreases at the rate ψ_t and is augmented by new hires h_t:

$$(3) \qquad n_{t+1} = (1 - \psi_t)n_t + h_t, \ 0 \le \psi_t \le 1.$$

Firms' profits before tax, π_t, equal the difference between revenues net of adjustment costs and total labor compensation, $w_t n_t$:

$$(4) \qquad \pi_t = [f(z_t, n_t, k_t) - g(i_t, k_t, h_t n_t)] - w_t n_t.$$

Every period, firms make after-tax cash flow payments cf_t 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:

$$(5) \qquad cf_t = (1 - \tau_t)\pi_t - (1 - \chi_t - \tau_t D_t)\,\tilde{p}_t^I i_t,$$

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, and $\tilde{p}_t^I$ 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:

$$(6) \qquad s_t = E_t[m_{t+1}(s_{t+1} + cf_{t+1})],$$

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

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

where $r_{t+j-1,t+j}$ denotes the time-varying discount rate between periods $t + j - 1$ and $t + j$.

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

$$(7) \qquad \max_{\{i_{t+j}, nh_{t+j}\}} E_t \left\{ \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} m_{t+i} \right) cf_{t+j} \right\},$$

subject to the definition of cf_{t+j} in equation (5) and the constraints (2) and (3). The firm takes the variables $w, p^I, \delta, \psi,$ and m as given. The Lagrange multipliers associated with these two constraints are Q_{t+j}^K and Q_{t+j}^N, respectively. These 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 $t + j + 1, j \in \{0, 1, 2,...\}$. We denote by f_x the marginal product of factor x, and by g_x the marginal cost of raising variable x. For the sake of notational simplicity, we drop the subscript j from the respective equations to follow:

$$F1 : (1 - \tau_t)(g_{i_t} + p_t^I)$$

$$= E_t\{m_{t+1}(1 - \tau_{t+1})$$

$$\times [f_{k_{t+1}} - g_{k_{t+1}} + (1 - \delta_{t+1})(g_{i_{t+1}} + p_{t+1}^I)]\};$$

$$F2 : (1 - \tau_t)g_{h_t}$$

$$= E_t\{m_{t+1}(1 - \tau_{t+1})$$

$$\times [f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1} + (1 - \psi_{t+1})g_{h_{t+1}}]\},$$

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

$$(8) \qquad p_{t+j}^I = \frac{1 - \chi_{t+j} - \tau_{t+j}D_{t+j}}{1 - \tau_{t+j}} \tilde{p}_{t+j}^I.$$

We can define Q_t^K to be the expected present value of future marginal products of physical capital net of marginal capital adjustment costs:

$$(9) \quad Q_t^K = E_t \left\{ \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} m_{t+1+i} \right) \left(\prod_{i=0}^{j} (1 - \delta_{t+1+i}) \right) \right.$$

$$\left. \times (1 - \tau_{t+1+j}) [f_{k_{t+1+j}} - g_{k_{t+1+j}}] \right\}.$$

It is straightforward to show that in the special case of a time-invariant discount factor, depreciation rate and price of investment goods, no adjustment costs, no taxes, and a perfectly competitive market for capital, Q_t^K equals the price of investment goods p^I.

Similarly, Q_t^N is the expected present value of the future stream of surpluses accruing to the firm from an additional hire of a new worker:

$$(10) \quad Q_t^N = E_t \left\{ \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} m_{t+1+i} \right) \left(\prod_{i=0}^{j} (1 - \psi_{t+1+i}) \right) \right.$$

$$\times (1 - \tau_{t+1+j})$$

$$\left. \times (f_{n_{t+1+j}} - g_{n_{t+1+j}} - w_{t+1+j}) \right\}.$$

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

C. *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 (6), the firm's period t market value is defined as the expected discounted pre-dividend market value of the following period:

$$(11) \qquad s_t = E_t[m_{t+1}(s_{t+1} + cf_{t+1})].$$

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

$$(12) \quad s_t = \vartheta_t^k + \vartheta_t^n$$

$$= E_t[m_{t+1}(\vartheta_{t+1}^k + cf_{t+1}^k)]$$

$$+ E_t[m_{t+1}(\vartheta_{t+1}^n + cf_{t+1}^n)].$$

Using the constant returns-to-scale properties of the production function f and of the adjustment cost function g, we rely on equation (5) when decomposing the stream of maximized cash flow payments as follows:

$$cf_t = (1 - \tau_t)\ (f_{k_t}k_t + f_{n_t}n_t - w_t n_t - p_t^I i_t - g_{k_t}k_t$$

$$- g_{i_t}i_t - g_{n_t}n_t - g_{h_t}h_t)$$

$$= (1 - \tau_t)\ [(f_{k_t}k_t - p_t^I i_t - g_{k_t}k_t - g_{i_t}i_t)$$

$$+ (f_{n_t}n_t - w_t n_t - g_{n_t}n_t - g_{h_t}h_t)]$$

$$\equiv cf_t^k + cf_t^n.$$

In order to establish a link between the firm's market value and its stock of capital and employment using the first-order necessary conditions (FONC), we manipulate the latter equations to obtain the central asset pricing equation (Merz and Yashiv 2005, Appendix A, delineates the full derivation):

$$(13) \quad s_t = \vartheta_t^k + \vartheta_t^n = k_{t+1}Q_t^K + n_{t+1}Q_t^N,$$

where Q_t^K and Q_t^N are defined in equations (9) and (10), respectively.

Equation (13) summarizes an important qualitative result. With labor adjustment costs, the shadow value of employment typically is nonzero. Hence, in such settings, the level of employment, multiplied by the respective shadow value, enters the firm's market value. Put differently, equation (13) illustrates the fact that the current model generalizes the neoclassical formulation to an environment with capital and labor

adjustment costs. We can alternatively express the firm's market value in period t as

$$(14) \quad s_t = k_{t+1}E_t\{m_{t+1}(1 - \tau_{t+1})\ [f_{k_{t+1}} - g_{k_{t+1}}$$

$$+ (1 - \delta_{t+1})\ (p_{t+1}^I + g_{i_{t+1}})]\}$$

$$+ n_{t+1}E_t\{m_{t+1}(1 - \tau_{t+1})(f_{n_{t+1}} - g_{n_{t+1}}$$

$$- w_{t+1} + (1 - \psi_{t+1})g_{h_{t+1}})\}.$$

Next, we turn to explore the empirical implications of the model. One of them shall be the estimation of the asset value of investment, Q^K, and that of hiring, Q^N. Their estimates correspond to the market value of investment and of hiring, which—were they to be priced on the market—would be akin to the stock price of investment and the stock price of hiring.

II. 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, and the econometric methodology. We discuss data and econometric issues and the resulting alternative specifications.

A. *Parameterization*

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

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

For the adjustment costs function g, following the results of structural estimation in Yashiv (2000) and some experimentation, we adopt the following generalized convex function:

$$(2) \quad g(\cdot) = \left[f_1\frac{i_t}{k_t} + f_2\frac{h_t}{n_t} + \frac{e_1}{\eta_1}\left(\frac{i_t}{k_t}\right)^{\eta_1} + \frac{e_2}{\eta_2}\left(\frac{h_t}{n_t}\right)^{\eta_2}\right.$$

$$\left. + \frac{e_3}{\eta_3}\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3}\right]f(z_t, n_t, k_t).$$

This function is linearly homogenous in its four arguments $i, h, k,$ and n. The function postulates that costs are proportional to output, and that they increase in investment and hiring

rates.[1] The specification above 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 f_1, f_2 and e_1 through e_3 express scale, and η_1 through η_3 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 quantifying the marginal adjustment cost of investment, g_i, and hiring, g_h, which appear in the firms' FONC.

B. *The Data*

Our data sample is quarterly, corporate sector data for the US economy from 1976:1 to 2002:4. The beginning of the sample period is constrained by the availability of consistent gross worker flow data, and the end of the sample by the availability of consistent investment and capital data. In what follows we briefly describe the dataset and emphasize its distinctive features.[2] Table 1 presents summary statistics of the series used.

For output f, capital k, investment i, and depreciation δ, we use a new dataset on the nonfinancial corporate business (NFCB) sector recently published by the Bureau of Economic Analysis (BEA) of the US Department of Commerce, and quarterly investment series from the Federal Reserve Board. This dataset leaves out variables that are often used in the literature but that are not consistent with the model above, such as residential or government investment.

For gross hiring flows h and for the separation rate ψ, we use series based on Current Population Survey (CPS) data as computed by Hoyt Bleakely, Ann E. Ferris, and Jeffrey C.

TABLE 1—DESCRIPTIVE SAMPLE STATISTICS

Variable	Mean	Standard deviation
i/k	0.023	0.004
f/k	0.17	0.01
τ	0.39	0.06
δ	0.016	0.003
wn/f	0.66	0.01
h/n	0.089	0.009
ψ	0.086	0.009
s/f	6.0	2.1
m	0.989	0.06

Note: The sample size contains 108 quarterly observations from 1976:1 to 2002:4.

Fuhrer (1999), adjusted to represent the NFCB sector. Two aspects of the data merit attention. (a) We use gross flows between employment and unemployment, and between employment and out of the labor force;[3] the latter flows (out of the labor force to employment) are sizeable, and in terms of the model are not different from unemployment-to-employment flows. (b) The gross worker flows are adjusted to cater for misclassification and measurement error. For the labor share of income, $(wn)/f$, we take 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 nonfinancial corporate sector, from the National Income and Product Accounts.

We measure firms' market value s using the market value of all nonfarm, nonfinancial corporate businesses. This value equals the sum of financial liabilities and equity, less financial assets. The data are taken from Robert E. Hall (2001) based on the Federal Reserve's 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 S&P 500 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 S&P 500 rate

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[1] Recent work by Russell W. Cooper and Jonathan Willis (2003) and Cooper and John C. Haltiwanger (2006; see, in particular, 23–24) gives empirical support to the use of a convex adjustment costs function. They show that while nonconvexities may matter at the micro level, a convex formulation is appropriate at the aggregate, macroeconomic level.

[2] For definitions and sources, see Appendix B in Merz and Yashiv (2005).

[3] The difference in size between *gross* and *net* worker flows is notable. Gross flows per quarter amount to 9 percent of employment, whereas net flows equal 0.5 percent only.

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

C. *Methodology*

We structurally estimate the firms' first-order necessary conditions ($F1$) and ($F2$), and the asset pricing equation (14) using Lars Peter 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 ones, plus expectational errors j, and specifying that the errors are orthogonal to the instruments Z, i.e., $E(j_t \otimes Z_t) = 0$.[4]

We explore a number of alternative specifications:

- *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.

- *Instrument sets.* We use alternative instrument sets in terms of variables and number of lags. The instrument sets include lags of variables that appear in the equations.

- *Variables' formulation.* We check the effect of using alternative time series for some of the variables, which have multiple representations. These include $h/n, \psi, \delta$, and m.

We check whether the estimated *g* function is reasonable in that it fulfills not only the convexity requirement but also implies total and marginal adjustment costs that lie within a plausible range. Below we discuss what such a range might be and summarize our main findings.[5]

III. 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 among these three series. The literature has typically used a quadratic specification for capital adjustment costs and ignored possible interactions between hiring and investment costs. Our results suggest that modifying this specification is essential.

Table 2 reports the results of the joint GMM estimation of the firms' first-order conditions ($F1$) and ($F2$), and the asset pricing equation (14). We present the point estimates of the power parameters η_1 through η_3, the scale parameters f_1, f_2, and e_1 through e_3, the employment elasticity of output, α, the standard errors of the estimates (except where constrained), and the J statistics.

Throughout, the parameter α is estimated at 0.68 or 0.69, with low standard errors. This conforms with standard estimates and serves as a validity check on our estimation procedure.

Column 1 is the most general, with all parameters freely estimated . This means that the scale and degree of convexity of the *g* function are left for estimation and allowed to vary across the different arguments of the function. The results point to an approximately cubic specification for investment and hiring ($\eta_1 = 2.8, \eta_2 = 3.4$) and to a quadratic interaction term ($\eta_3 = 2$). Except for the estimates of the parameters of the linear terms (f_1 and f_2), which exhibit large standard errors, all parameters are relatively precisely estimated. The other columns impose more structure. Column 2, 3, and 4 allow one power parameter to be free, constraining the other two to the values estimated in column 1. In these three columns the standard errors of the scale parameters estimates go down, while the point

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[4] We elaborate on the estimation methodology in Appendix C of Merz and Yashiv (2005). We formulate the estimation equations in stationary terms by dividing ($F1$) by f_t/k_t, ($F2$) by f_t/n_t, and the asset pricing equation throughout by the level of output, f_t.

[5] Merz and Yashiv (2005) provide an extensive sensitivity analysis. Appendix C in that paper reports robustness across further specifications.

TABLE 2—GMM ESTIMATES OF (F1), (F2), AND (14)

	1	2	3	4
Constrained powers	All free	η_2, η_3	η_1, η_3	η_1, η_2
η_1	2.80	2.80	2.80	2.80
	(0.04)	(0.03)	—	—
η_2	3.40	3.40	3.41	3.40
	(0.15)	—	(0.10)	—
η_3	2.00	2.00	2.00	2.00
	(0.002)	—	—	(0.001)
e_1	16,123	16,144	15,929	15,851
	(4,784)	(3,919)	(772)	(1,460)
e_2	2,772	2,851	2,936	2,849
	(1,364)	(306)	(992)	(312)
e_3	−102,291	−102,229	−102,475	−101,529
	(25,266)	(6,873)	(6,975)	(18,553)
f_1	1.98	2.08	2.12	1.99
	(15.89)	(6.87)	(0.99)	(6.21)
f_2	−2.02	−2.01	−1.91	−2.00
	(2.78)	(0.72)	(2.08)	(0.82)
α	0.69	0.69	0.69	0.69
	(0.10)	(0.06)	(0.09)	(0.08)
J-Statistic	60.1	58.3	56.9	58.0
p-Value	0.11	0.20	0.23	0.21

	5	6	7
Constrained scale $f_1 = 2:, f_2 = -2$			
Constrained powers	η_2, η_3	η_1, η_3	η_1, η_2
η_1	2.80	2.80	2.80
	(0.003)	—	—
η_2	3.40	3.40	3.40
	—	(0.02)	—
η_3	2.00	2.00	2.00
	—	—	(0.0001)
e_1	16,197	16,024	16,049
	(847)	(742)	(636)
e_2	2,830	2,976	2,828
	(229)	(508)	(247)
e_3	−103,334	−103,352	−103,859
	(5,382)	(6,303)	(5,609)
α	0.68	0.68	0.69
	(0.02)	(0.03)	(0.02)
J-Statistic	62.2	58.2	63.1
p-value	0.16	0.26	0.14

Notes: The table reports the point estimates of the parameters and standard errors in parentheses (except where constrained). Instruments used are a constant and 6 lags of $\{i_{t-j}/k_{t-j},\ h_{t-j}/n_{t-j},\ s_{t-j}/f_{t-j}\}$. The top rows delineate which parameters are constrained.

estimates of all parameters remain very close to those of column 1. Columns 5, 6, and 7 impose a further restriction, by setting the coefficients of the linear terms at the levels estimated in col- umns 1–4, i.e., setting $f_1 = 2, f_2 = -2$. This leads to some further reduction in the standard errors, and, again, the point estimates hardly change. In those last three columns, all parameters are very

TABLE 3—GMM ESTIMATES OF (F1), (F2), AND (14); ALTERNATIVE SPECIFICATIONS

	1	2	3
	Quadratic	$\eta_1 = \eta_2 = 3$	No hiring equation
Constraints	$f_1 = f_2 = e_2 = e_3 = 0$	$e_3 = 0; f_1 = 2; f_2 = -2$	$\eta_1, \eta_3; f_1 = 2; f_2 = -2$
η_1	2	3	2.80
	–	–	–
η_2	–	3	3.40
	–	–	(0.06)
η_3	–	–	2
	–	–	–
e_1	152	7,497	15,786
	(7.8)	(213)	(1,537)
e_2	0	116	2,774
	–	(12)	(1,251)
e_3	0	0	−100,914
	–	–	(14,623)
α	0.81	0.59	0.71
	(0.04)	(0.01)	(0.16)
J-Statistic	66.0	74.3	46.4
p-Value	0.002	0.04	0.06

Note: See Table 2.

precisely estimated. Hence, across all seven columns, the point estimates lie in a narrow range. The differences across columns are mainly in the precision (standard errors) of the estimates.

Table 3 illustrates the value added of the different components of our specification by imposing restrictions.

Column 1 reports the traditional equation estimated in the Q-literature, i.e., quadratic adjustment costs of capital. This means that we impose $f_1 = f_2 = e_2 = e_3 = 0$ and $\eta_1 = 2$. The results are a precisely estimated scale parameter e_1, but the production function parameter α is estimated at a particularly high level, and the J-statistic indicates rejection. We show below that the fit of this specification is poor. Column 2 reintroduces the linear terms and takes a cubic for the power specification of η_1 and η_2. It improves on the standard quadratic by postulating a linear-cubic formulation and by taking into account hiring costs, but does not allow for any interaction between capital adjustment costs and hiring costs, i.e., $e_3 = 0$ is imposed. This restriction yields point estimates that are different from those of Table 2, a low level of α, and the J-statistic indicates rejection. As shown below, the fit of this specification turns out to be mediocre at best. In column 3 we replicate the basic specification of Table 2, but

estimate only the investment optimality equation ($F1$) and the asset pricing equation (14), i.e., we drop the hiring optimality equation ($F2$). These point estimates are close to those of Table 2, but less precise.

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. Doing so we shall evaluate the fit between the model and the data. As the results of Table 2 are very similar in terms of point estimates across specifications, we shall report one representative specification—that of column 7 in Table 2—in what follows. Whenever relevant, we shall also look at the results of Table 3, columns 1 and 2.

IV. Adjustment Costs and the Value of Hiring and Investment

In this section we look at the implications for hiring and for investment of the results using the point estimates reported in Tables 2 and 3. In particular, we look at the implied adjustment costs function.

The results allow us to construct time series for total and marginal adjustment costs by using the point estimates of the parameters of the g

TABLE 4—ESTIMATED TOTAL AND MARGINAL ADJUSTMENT COSTS

		Standard case		Representative case	
		Value at mean	Estimates std.	Value at mean	Estimates std.
Total	g/f	0.042	0.002	0.023	0.018
Marginal hiring	$g_h/(f/n)$	–	–	1.48	0.57
Marginal investment	$g_i/(f/k)$	3.55	0.18	1.31	0.54

Notes: The "value at mean" statistics refer to the relevant expression evaluated at the sample mean of i_t/k_t and h_t/n_t. Estimates standard deviation statistics refer to the root of the variance of the relevant cost expression, computed using the variance-covariance matrix of the estimated parameters. The variables are evaluated at their sample mean. All moments use the point estimates of the parameters estimated in the specification given in the first row.

function. Knowing the marginal adjustment costs is important, as they are also the asset values of investment (Q^K) and hiring (Q^N), or, put differently, these are the "stock prices" of investment and hiring.

In Table 4 we report the moments for total and marginal adjustment costs using the point estimates from the standard specification with quadratic costs, no labor, and no interaction (Table 3, column 1), and from the representative specification (Table 2, column 7), respectively. The table reports the value of each expression at the sample mean and the precision of the estimates.[6]

For the standard case, the first row reports the implied total costs g as a fraction of output f to be 4.2 percent of output. The implied marginal costs of investment, g_i, in relation to average output per unit of capital is 3.55 at the mean point. This value must be considered high compared to the vast evidence on marginal adjustment costs from the Q-literature on investment, which ranges from Lawrence H. Summers (1981) and Fumio Hayashi (1982) to Cooper and Haltiwanger (2006); this literature yields marginal costs as high as 4.0, and as low as 0.02, depending on the data sample used, the functional form assumed for marginal adjustment costs, treatment of tax issues, and reduced form versus structural estimation. The earlier contributions tended to work with quadratic

adjustment costs and yielded rather high marginal costs of investment, whereas more recent contributions generated much lower marginal costs with the help of assuming more flexible adjustment cost functions.[7]

For the representative specification, the first row reports total costs g as a fraction of GDP, f, to be 2.3 percent of output.

The second row reports the marginal costs of hiring, g_h, in terms of average output per worker, f/n. The reported value, 1.48 (value at sample mean point), is roughly equivalent to two-quarters of wage payments, as wages are 0.66 of output per worker on average (see Table 1). How does one evaluate this estimate? There is little empirical evidence on the quantitative importance of such adjustment costs. There are, however, a few surveys of broad groups of employers on some of the costs of hiring. According to Daniel S. Hamermesh (1993, 207–09), the findings are as diverse as the groups studied or the concepts underlying the measurement. Thus, expressed in 1990 US dollars, the gross costs range from \$680 for hiring a secretary by a large employer in 1979 to \$13,790 for hiring and training salaried workers in Los Angeles in 1980. Similarly, for a large pharmaceutical company, the costs of training and career development range from 1.5 to 2.5 times the annual salary. None of those surveys attempts to account for the costs of disruption to

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[6] Each adjustment cost term—g/f, $g_{nh}/(f/n)$, $g_i/(f/k)$—is some function of i_t/k_t and nh_t/n_t. The first reported expression is the cost evaluated at mean i_t/k_t and mean nh_t/n_t. The second is the standard deviation, with the variables evaluated at the same mean point; this is computed using the variance-covariance matrix of the estimators.

[7] Andrew B. Abel and Janice C. Eberly (1994) provide a more comprehensive and extensive model of investment as a function of Q, incorporating elements such as fixed costs, wedge between purchase and sales price of capital, and potential irreversibility.

TABLE 5—ACTUAL VERSUS PREDICTED ASSET VALUE *s/f*
Goodness of Fit

Panel A. Moments

	Actual $\left(\dfrac{s_t}{f_t}\right)$	Predicted $\left(\dfrac{\overline{s_t}}{f_t}\right)$		
		Full model	Quadratic	No interaction
Mean	6.15	5.97	5.80	6.79
Median	5.66	5.63	5.85	6.64
Standard deviation	2.16	1.82	0.22	0.60
Autocorrelation	0.97	0.92	0.89	0.97
Skewness	0.94	0.78	−0.54	0.78
Kurtosis	3.10	2.92	2.78	3.13

Panel B. Correlations $\rho\left[\left(\dfrac{\overline{s_t}}{f_t}\right), \dfrac{s_t}{f_t}\right]$

Full model	Quadratic	No interaction
0.89	0.14	0.71

Notes: Moments are based on the following specifications for predicted values:

$$\left(\frac{\overline{s_t}}{f_t}\right) = \left((1-\delta_t) + \frac{i_t}{k_t}\right)\left[(1-\tau_t)\frac{(g_{i_t}+p_t^I)}{f_t/k_t}\right] + \left((1-\psi_t)+\frac{h_t}{n_t}\right)\left[(1-\tau_t)\frac{g_{h_t}}{f_t/n_t}\right].$$

The predicted values use the point estimates of the following: (a) full model use the results of Table 2, column 7; (b) quadratic use the results of Table 3, column 1; (c) no interaction use the results of Table 3, column 2.

the flow of output. Almost all other studies on labor adjustment costs typically pertain to costs of net employment changes. Hence, there is no solid benchmark against which to compare the current estimates. What can be said is that the estimate above appears plausible.

The same holds true for the estimates of the marginal costs of investment, g_i, which are reported in the third row of Table 4. Expressed in terms of average output per unit of capital (f/k), the estimate is 1.31. The derivation takes into account hiring costs through the interaction between hiring and investment costs and assumes a convex specification.

We thus conclude that while the quadratic specification (with no hiring costs) yields high marginal adjustment costs, the preferred specification, with hiring costs and interaction of investment and hiring, yields relatively moderate adjustment costs. Note, too, in Table 4 that adjustment costs—both total and marginal—are estimated relatively precisely (compare the standard deviation to the value at the mean point).

V. Explaining Asset Values

In this section we derive the implications of the estimates for market asset values. In particular,

we look at the model's fit of the data. The estimates allow us to generate predicted time series of asset values. We use the asset pricing equation (13) with only time *t* variables:

(1)

$$\frac{s_t}{f_t} = \left((1-\delta_t)+\frac{i_t}{k_t}\right)$$

$$\times\left[(1-\tau_t)\left(\left[f_1+e_1\left(\frac{i_t}{k_t}\right)^{\eta_1-1}\right.\right.\right.$$

$$\left.\left.\left.+e_3\left(\frac{h_t}{n_t}\right)^{\eta_3}\left(\frac{i_t}{k_t}\right)^{\eta_3-1}\right]+\frac{p_t^I}{\frac{f_t}{k_t}}\right)\right]$$

$$+\left((1-\psi_t)+\frac{h_t}{n_t}\right)$$

$$\times\left[(1-\tau_t)\left[f_2+e_2\left(\frac{h_t}{n_t}\right)^{\eta_2-1}\right.\right.$$

$$\left.\left.+e_3\left(\frac{i_t}{k_t}\right)^{\eta_3}\left(\frac{h_t}{n_t}\right)^{\eta_3-1}\right]\right]+\xi_t.$$
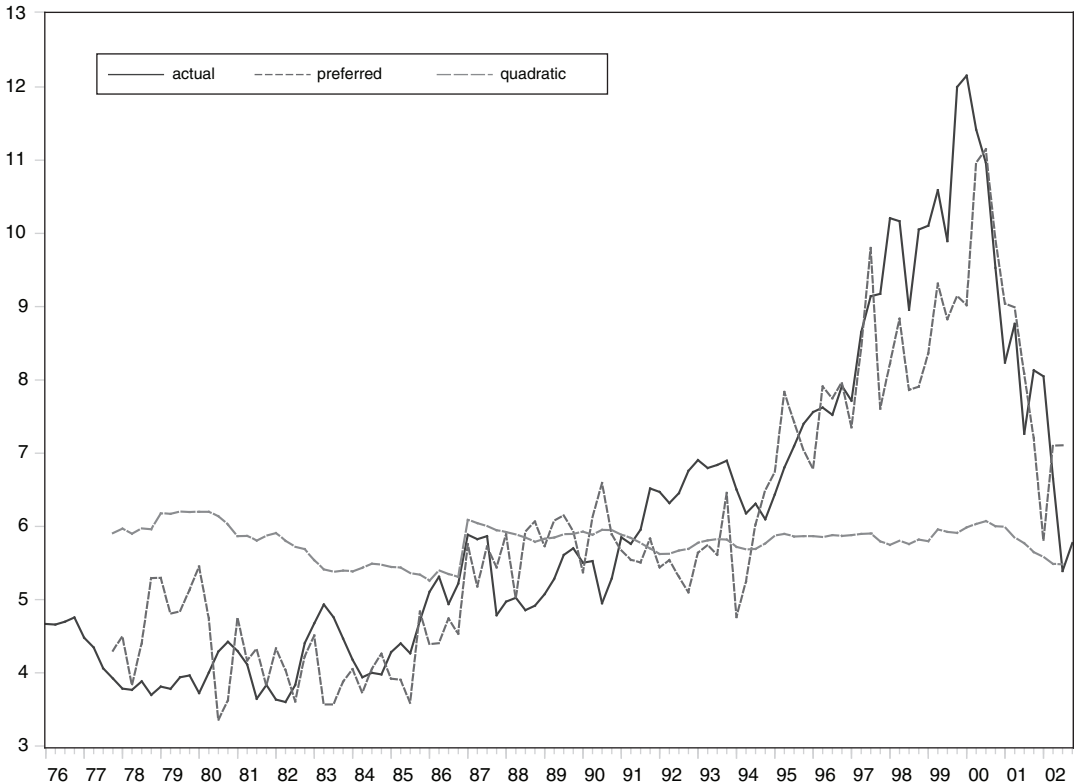
FIGURE 1. ACTUAL AND PREDICTED (*Preferred and Quadratic*) *s/f*

We denote the entire expression on the right-hand side, except for the error by $\overline{(s_t/f_t)}$ (i.e., $s_t/f_t = \overline{(s_t/f_t)} + \xi_t$). Figure 1 shows the actual series and the predicted $\overline{(s_t/f_t)}$. Table 5 reports the sample moments of the actual series and the predicted series and the correlations between them. The figure and table do this for the specification representative of Table 2 (column 7), as well as for the specifications of columns 1 and 2 of Table 3.

The key result is that the preferred specification, using the full model, performs well; the widely used quadratic with no hiring performs poorly; and the convex specification that does not allow for interaction between hiring and investment costs has mediocre performance. This can be seen on all dimensions of the analysis: the correlation statistics, the comparison of actual and predicted moments, and the graphs. More specifically, all the moments of the predicted series based on the results of Table 2 are

very close to the actual series, typically slightly lower. This applies to the first four moments, to the median, and to the autocorrelation. The correlation between the actual and predicted series is high. How do these results compare with existing formulations in the literature? One way to gauge this is to compare to the specification of column 1 in Table 3. This is the standard quadratic formulation, without hiring, prevalent in the literature. This specification does badly: it is uncorrelated with the actual series; it is much less volatile and less persistent; and its skewness does not resemble the positive skewness of the actual series. These results are in line with the discussion in the literature, which has reported a low fit with Q measures and substantial serial correlation remaining in the error term.

One key point of the current analysis is the incorporation of hiring costs and their interaction with investment costs. What is the contribution of this element to the fit? One indication was given
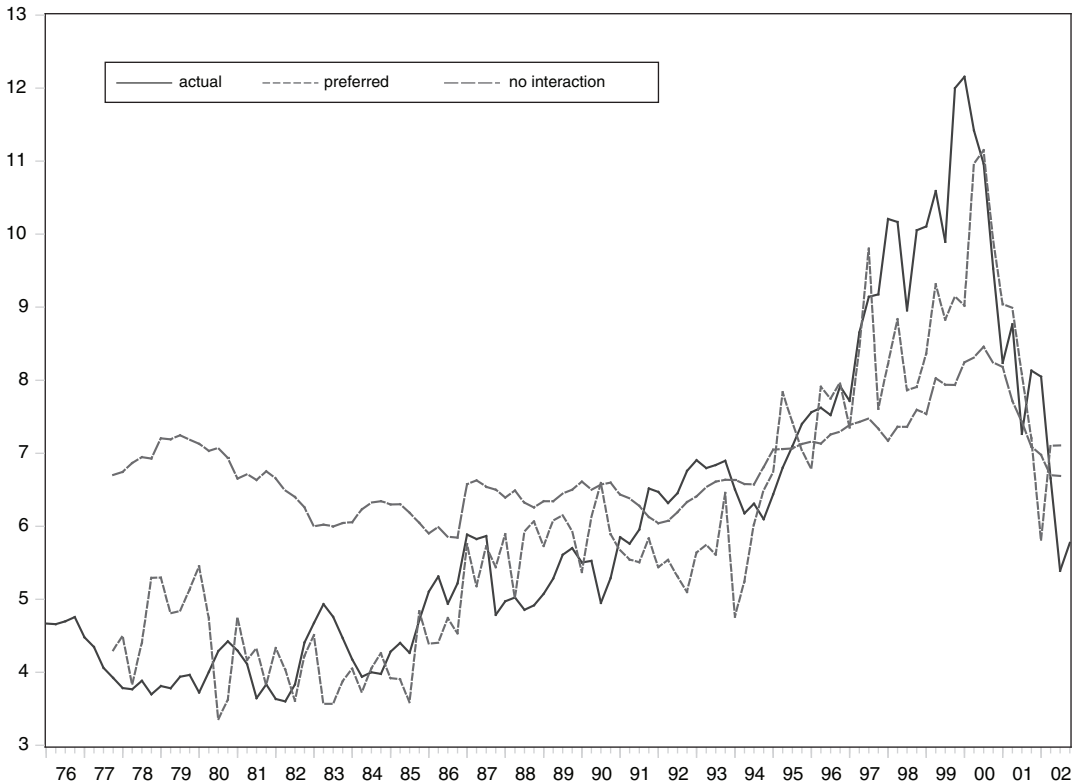
FIGURE 2. ACTUAL AND PREDICTED (*Preferred and No Interaction*) *s/f*

by the analysis above of the poor performance of the specification that ignores hiring. Another indication is obtained by comparing the results to those of column 2 in Table 3; this specification does allow for hiring costs and does posit a more convex function (relative to the quadratic), but it does not allow for any interaction between the two kinds of costs. Table 5 and Figure 1 indicate that it performs better than the quadratic with no hiring costs, but it does not provide for a very good fit: its correlation is lower and it is much less volatile. This demonstrates the important role played by the interaction between the two types of costs.

VI. Conclusions

The paper embeds factor adjustment costs in a production-based asset pricing model, focusing on the link between labor and firms' market value. The model is corroborated using structural estimation with aggregate time-series data for the US nonfinancial corporate business sector. Estimation, focusing on adjustment costs parameters, yields reasonable values for these costs. The standard specification—quadratic adjustment costs for capital and no hiring costs—performs poorly. The interaction between capital and labor adjustment costs is important, and nonlinearities matter.

The main empirical results can be summarized as follows: a convex adjustment costs function is able to account for the data, and performs much better than the prevalent quadratic specification. Restricting the same equations to standard formulations (quadratic, ignoring hiring, or ignoring the investment-hiring interaction) yields poor performance. The estimates imply adjustment costs of reasonable magnitude when compared to known estimates. The fit of the model and its improvement over the existing literature is due to the use of gross flows for

both investment and hiring, the joint consideration of hiring and investment including their interaction, and the sufficient convexity of the adjustment costs function.

The key implication of the results is that firms' market value embodies the value of hiring and investment over and above the capital stock. Investment and hiring asset 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.

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