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Hiring as Investment Behavior

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This paper explores the determinants of hiring at the macroeconomic level. It treats the hiring decision as an investment decision, similar to the one taken for physical capital or for financial assets. At its core is a present value relation which defines the worker's "asset value" for the firm and determines optimal hiring. The paper validates this relation using volatility tests and infers the unobserved asset values by estimating it. Hiring and asset values are found to be weakly correlated with the business cycle and much more volatile. The paper also demonstrates the links between models employed and issues examined in finance and the labor market. © 2000 Academic Press

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1. INTRODUCTION

While gross investment in capital has been the subject of extensive study in macroeconomics, the parallel concept for labor—the gross flow of hiring—has received much less attention. This is so because the underlying assumption in many macroeconomic models is that the labor market is frictionless; hence, employment adjustments, including hiring, are costless and instantaneous. However, theoretical work—such as the search and matching models of Diamond (1982), Mortensen (1982), and Pissarides (1985)—has emphasized the role of frictions in this market, modeling

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hiring as a time-consuming, costly activity. Empirical work on labor market flows—such as that of Blanchard and Diamond (1990), Burda and Wyplosz (1994), and Merz (1999)—has demonstrated that gross hiring is a volatile and sizable flow which is important for the understanding of the workings of the labor market.

In this paper, we undertake an empirical exploration of hiring in the presence of frictions. We treat the hiring decision as an investment decision, similar to the one taken for physical capital or for financial assets. When the firm decides to hire a worker, it is as if it buys an asset: it pays screening and training costs in the expectation of receiving a stream of returns in the form of future profits. These profits consist of the worker's productivity less the wage paid. These "dividends" are discounted by a discount factor that takes into account both the probability of worker separation from the job and interest rate. The optimal rate of hiring is derived from the present value relation linking marginal hiring costs with expected discounted marginal profits. We study this relation in an aggregate, macroeconomic context. We test its validity, quantify the asset value of workers, and explore its stochastic properties. The results enable us to explore the behavior of hiring over the business cycle and to analyze its sensitivity to various determinants.

The main difficulty in studying hiring empirically from this perspective is that, unlike investment models which use firms' market value (by computing "average q," for example), or asset pricing models which use stock prices, there is no explicit market price for the asset value of workers. Thus, we have to *infer* this value from the FOC for optimal hiring. We do so using two inference procedures and obtain two independent sets of estimates of asset values. After comparing them, we focus on a specification that holds true for both. The data used are Israeli labor market data, which are particularly useful in the present context as they provide a highly reliable gross hiring flow series covering a large segment of the market rather than a series derived from a sample.

We find that the data corroborate specific formulations of the present value relation, yielding reasonable asset values equivalent to approximately two months of worker pay. The fluctuations in asset values are shown to stem mostly from fluctuations in expected, future marginal profit rates, as well as in bank credit rates. The latter result highlights the role of financial variables in generating labor market fluctuations. We also find that hiring and asset values are weakly correlated with traditional measures of the cycle and exhibit much higher volatility. Within a certain range, the dynamic demand curve for labor is quite flat.

The paper makes several contributions: it validates the present value model of optimal hiring, demonstrates alternative ways to infer worker asset values, and offers quantitative estimates of these in a macroeconomic context. The paper then delineates the implications for the study of aggregate fluctuations. Finally, it demonstrates the links between models employed and issues examined in finance and the labor market. This demonstration has several aspects: it is shown how econometric methodologies used in finance may be applied to explore issues in the labor market, how interest rates on bank credit play a very important role in driving fluctuations in hiring, and how the study of the asset value of workers can contribute to the literature on financial asset pricing. One can look at the results of this paper as a first step toward the construction of a more comprehensive production-based asset pricing model. For example, the result obtained—that the asset value of workers is weakly related to contemporaneous measures of the business cycle, while it is strongly related to expected present value of future profits—may have important implications for characterizing the cyclical behavior of stock prices.

The paper proceeds as follows: Section 2 presents the model of firms' behavior, deriving the FOC which defines optimal hiring. Section 3 presents the data. Three sections then deal with the estimation of the unobserved asset values: Section 4 does so using structural estimation employing the GMM methodology, Section 5 approximates the present value relation and infers assets values from it, and Section 6 selects particular specifications from these alternative estimates, studies their magnitudes and stochastic properties, and examines the sources of their fluctuations using a variance decomposition analysis. Two sections then look at the implications of these results: Section 7 studies the behavior of hiring and asset values over the business cycle, while Section 8 examines the sensitivity of hiring to its driving factors using the non-stochastic steady state. Section 9 concludes.

2. THE MODEL

The following is a partial equilibrium model of optimal hiring of labor by a representative firm. It is closely related to the literature on dynamic labor demand—see Sargent (1978) and Hamermesh (1993, Chaps. 6 and 7). We regard the firm's hiring decision essentially as a problem of investment under uncertainty. Contrary to the implications of the neoclassical model, workers are not costlessly fired at the end of every period and costlessly hired at the beginning of each period. Rather, employment evolves in a way similar to the evolution of the capital stock. In the same way as capital is accumulated through gross investment, workers are "accumulated" through gross hiring; as capital depreciates, workers separate from jobs. The model thus emphasizes the *frictions* in the labor market. It is precisely these frictions, which generate the forward-looking aspect of firms' behavior, that are at the heart of the analysis.

The objective function of the firm is to maximize the sum of expected discounted profits where its decision variable is gross hiring (H). The firm's problem may be examined with the tools of stochastic dynamic programming in the same way as they have been used for capital investment problems,[2] so the model is the analogue of "Tobin's q" model of investment in physical capital. The timing is as follows: the firm makes its hiring decisions in period t using the information set Ω_t. The hired workers enter production in the following period ($t+1$). Separation of workers from jobs occurs at rate s_t. The stochastic dynamic programming problem is formulated as

$$\max_{\{H\}} E_t \sum_{j=0}^{\infty} \frac{1}{\prod_{i=0}^{j}(1+r_{t+i-1})} \times \left[F\left(N_{t+j}, \mathbf{A}_{t+j}\right) - W_{t+j}N_{t+j} - \Gamma\left(H_{t+j}, \mathbf{B}_{t+j}\right)\right], \tag{1}$$

subject to

$$N_{t+1} = N_t(1-s_t) + H_t, \tag{2}$$

where E_t denotes expectations formed in period t based on the information set Ω_t, F is the production function with employment (N) and other factors of production (contained in the vector $\mathbf{A}$) as its arguments, and real wage payments are denoted by WN. We represent by Γ the costs of hiring which are of two types: (i) the cost of advertising, screening, and selecting new workers and (ii) the cost of training. This function has as its arguments the number of hires (H) and possibly other variables (denoted by the vector $\mathbf{B}$; one such variable could be the employment stock N) and we explore it in detail in the empirical work below. The firm uses the relevant interest rate r to discount future streams.

The FOC (the so-called stochastic Euler equation) is

$$\frac{\partial \Gamma_t}{\partial H_t} = E_t \frac{1}{1+r_t}\left[\frac{\partial F_{t+1}}{\partial N_{t+1}} - W_{t+1} - \frac{\partial \Gamma_{t+1}}{\partial N_{t+1}} + (1-s_{t+1})\frac{\partial \Gamma_{t+1}}{\partial H_{t+1}}\right]. \tag{3}$$

The intuition here is that the marginal cost of hiring (the LHS) equals expected discounted marginal profits (the RHS). The latter consists of two terms: the expected marginal profit at period $t+1$, which is made up of the marginal product and the reduction in hiring costs due to the addi-

[2] See, for example, Sargent (1986, Chap. 14).

tional hire less the wage paid and the expected savings of hiring costs if the worker does not separate in the following period. Hence fluctuations in hiring reflect fluctuations in marginal profitability, the separation rate, and the interest rate.

Iterating forward the expression on the RHS of (3) and imposing the relevant transversality condition, we obtain

$$\frac{\partial \Gamma_t}{\partial H_t} = E_t\left[\sum_{j=1}^{\infty}\left\{\prod_{i=1}^{j}\frac{(1-s_{t+i-1})}{(1+r_{t+i-1})}\right\}\cdot\frac{1}{1-s_t}\cdot\left(\frac{\partial F_{t+j}}{\partial N_{t+j}} - W_{t+j} - \frac{\partial \Gamma_{t+j}}{\partial N_{t+j}}\right)\right]. \tag{4}$$

The expression in the square brackets on the RHS is the present value of future marginal profits.

While this formulation of the firm's problem could fit in a number of macroeconomic models, it is particularly relevant to the search and matching approach to labor markets [see Diamond (1982), Mortensen (1982), and Pissarides (1985)]. In that context, the model presented here formalizes costly search by firms, whereby the firm decides on the number of vacancies (V) to open and takes the probability of filling a vacancy (Q) as given so $H_t = Q_t V_t$. These models posit that wages are determined through bargaining between firms and workers over the surplus created after a match is formed. The wage solution, using generalized Nash bargaining, is thus given by

$$\beta J_t^F = (1-\beta)\left(J_t^N - J_t^U\right), \tag{5}$$

where J^F is the firm's net value of the match, $J^N - J^U$ is the worker's net value of the match (J^N being the gross value and J^U being the value of unemployment), and β is the worker's share of the match surplus. Following Eq. (3) a match that is formed and is to begin production at time t is worth to the firm

$$J_t^F = \frac{\partial F_t}{\partial N_t} - W_t - \frac{\partial \Gamma_t}{\partial N_t} + E_t\frac{(1-s_{t+1})}{1+r_t}J_{t+1}^F. \tag{6}$$

For the unemployed worker the present value of unemployment consists of the sum of (i) the value of unemployment benefits as well as any non-pecuniary value, such as that derived from leisure activities, at time t, to be denoted b_t, and (ii) the expected future value which takes into account the probability of matching into employment the next period,

$P_{t+1} = H_{t+1}/U_{t+1}$, and the continuation value of employment J^N:

$$J_t^U = b_t + E_t \frac{1}{1 + r_t} \left[P_{t+1} J_{t+1}^N + (1 - P_{t+1}) J_{t+1}^U \right]. \tag{7}$$

Similarly the present value of employment consists of the sum of (i) the wage at time t and (ii) the expected future value which takes into account the probability of separating from employment into unemployment in the next period, s_{t+1}, and the continuation value of unemployment J^U:

$$J_t^N = W_t + E_t \frac{1}{1 + r_t} \left[(1 - s_{t+1}) J_{t+1}^N + s_{t+1} J_{t+1}^U \right]. \tag{8}$$

The net value of the match for the worker is thus

$$J_t^N - J_t^U = W_t - b_t + E_t \frac{(1 - s_{t+1} - P_{t+1})}{1 + r_t} \left(J_{t+1}^N - J_{t+1}^U \right). \tag{9}$$

Inserting (6) and (9) into (5) yields

$$\beta \left[\frac{\partial F_t}{\partial N_t} - W_t - \frac{\partial \Gamma_t}{\partial N_t} + E_t \frac{(1 - s_{t+1})}{1 + r_t} J_{t+1}^F \right]$$
$$= (1 - \beta) \left[W_t - b_t + E_t \frac{(1 - s_{t+1} - P_{t+1})}{1 + r_t} \left(J_{t+1}^N - J_{t+1}^U \right) \right]. \tag{10}$$

Solving for the wage, using the fact that (5) holds true also at time $t + 1$ gives

$$W_t = \beta \left(\frac{\partial F_t}{\partial N_t} - \frac{\partial \Gamma_t}{\partial N_t} + E_t P_{t+1} \frac{J_t^F}{1 + r_t} \right) + (1 - \beta) b_t. \tag{11}$$

In the empirical work the wage equation (11) will be jointly estimated with the Euler equation (3).

In the following, it is worthwhile to note two additional features of this setup:

(i) The model describes investment in workers by firms within an aggregate, homogeneous setup and worker separation, though stochastic, is exogenous. It should be emphasized that this framework is applied to the *aggregate* labor market, where the employment stock keeps growing over time. Evidently, such "irreversible" investment in workers fits a market with high firing costs or institutional constraints on firing better than it does a more flexible market. The question of this model being a useful approximation of aggregate behavior in the real world is, therefore, an empirical one, and the results below seem to suggest a positive answer. Moreover, informal evidence relating to this data set suggests that there was very little *firing* taking place in the sample period. Note, too, that in the empirical work below s_t, the exogenous rate of worker separation, is taken at its actual value rather than being set to be some fixed parameter and that its stochastic properties (see Appendix A) seem to further justify this way of modeling.

(ii) The FOC in its two forms (Eqs. (3) and (4)) is analogous to the asset pricing equation used in the financial literature,

$$P_t = E_t\left(\frac{D_{t+1} + P_{t+1}}{1 + r_t}\right) = E_t \sum_{j=1}^{\infty} \left(\prod_{i=1}^{j} \Lambda_{t+i}\right) D_{t+j}, \qquad (12)$$

where P is the stock price, r is the discount rate, and D are dividends. In the current context P represents marginal hiring costs ($\frac{\partial \Gamma}{\partial H}$) and hence the asset value of the worker, Λ is the appropriate discount factor (including s and r), and D is marginal profits.

3. THE DATA

We use Israeli labor market data taken from the Employment Service (ES) affiliated with the Ministry of Labor. This data set has several useful qualities, due to the institutional structure that generated it. This structure may be briefly described as follows: the ES is the main institutional intermediary in the market. From 1959 until March 1991 private intermediaries were illegal, and the ES handled all job openings that did not require a university degree. The hiring of workers for these jobs was required by law to pass through the ES, making the data coverage quite comprehensive. The hiring series we use is the number of vacancies filled by the ES each month. The reliability of the series is reinforced by the availability of a similar series for workers referred to the vacant jobs. In comparison, data taken from population or labor force surveys usually suffer from a number of problems, such as misclassification of employment status generating spurious gross flows, missing observations that are correlated with labor market status, and other measurement errors [see Abowd and Zellner (1985)].

We use 180 monthly observations in the years 1975–1989. We do not use pre-1975 data, as vacancy definitions were changed; we do not use post-1989 data for two reasons: as of March 1991 vacancy posting was no longer mandatory, and the ES vacancy measure became just a partial indicator of the relevant worker flows, and in 1990 there were disruptions in data collection. The sample monthly average rate of hiring is 1.8% (out of employment). This figure is comparable to those reported for other economies: 1.7% in the U.S. [for the unemployment to employment flow (Blanchard and Diamond, 1990)], between 1.5% and 1.9% in France (Burda and Wyplosz, 1994), and 2.1% in Danish manufacturing (Albaek and Sorensen, 1998). Table III (in Section 6) below reports several descriptive statistics for this hiring rate series, in the context of a discussion of the stochastic properties of the asset value of workers.

We use standard macroeconomic data on production, employment, wages, unemployment benefits, and interest rates from the Central Bureau of Statistics, the National Insurance Agency, and the Bank of Israel. To be consistent with the model, we restrict attention to the business sector. Full definitions and a list of sources for all the data series are given in Appendix A.

4. INFERENCE OF ASSET VALUES USING EULER EQUATION ESTIMATION

In this section, we infer workers' asset values through structural estimation of the Euler equation. We briefly discuss the econometric methodology, specification issues, and the tests used, including "volatility" tests of the type employed in the asset pricing literature (4.1). We then report and discuss the results (4.2).

4.1. *Methodology*

We use Hansen's (1982) GMM methodology[3] to estimate the firms' Euler equation (Eq. (3) above), which determines the evolution of hires. Following estimation, we examine the results in terms of two tests prevalent in the asset pricing literature: the so-called "volatility" tests and an orthogonality test. The former uses the inequality $\mathrm{var}(E(x \mid y)) \leq \mathrm{var}(x)$ and posits that asset prices should vary less than the ex-post present value of dividends they forecast. Here they pertain to the asset value of the marginal worker and ex-post present value of marginal profits from the worker. The orthogonality test is a test of Euler equation's overidentifying restrictions [see the discussion in Cochrane (1991)]. This test is based on the notion that returns are unforecastable—i.e., they are orthogonal to

[3] We use the Hansen–Heaton–Ogaki GMM Package in Gauss version 3.01.

any variable in the information set. These orthogonality conditions are tested using Hansen's (1982) J-statistic test.

In order to take the model to the data, several specification issues must be addressed. These relate to the use of discount rates, functional forms, the variables to be used in the hiring cost function, the timing of hiring costs relative to production, stationarity of the variables, and the instrument set:

(i) For discounting, we explore several alternative specifications: one is the ex-post, real rate of interest charged on bank credit. This was the major form of firm financing and the most reliable market interest rate series in the sample period. Another is the rate of growth of non-durable consumption.[4] As a third alternative we use a constant rate of $r = 0.4\%$ in monthly terms, which translates into a 5% annual rate of interest, which we deem a plausible value.

(ii) The functional form of the production function (F) is to be specified. We take a "traditional" route and specify a Cobb–Douglas function; this enables us to use the average product, which is proportional to the marginal product, in estimation:

$$\frac{\partial F}{\partial N} = \delta \frac{F}{N}. \tag{13}$$

(iii) The variables to be included in the hiring cost function (Γ) have to be considered. Basically we focus here on gross hiring costs as distinct from net costs [Hamermesh (1993, Chap. 6) elaborates on this point]. By gross costs we refer to both the costs of screening (interviewing, testing, etc.) and the costs of training. In order to take into account the size of the firm in terms of employment and output, we model these costs as a function of hiring rates out of employment and as proportional to output, i.e., $\Gamma = \tilde{\Gamma}(\frac{H}{N})F$, where $\tilde{\Gamma}$ is some increasing function. This implies that costs are internal to the production process. Observed output is therefore net of hiring costs and should be modeled accordingly, i.e., $\tilde{F} = F - \Gamma$.

(iv) The functional form of hiring costs (the shape of $\tilde{\Gamma}$) is another key issue. We try two power functions (the quadratic and a general, unconstrained power which could also be linear) and polynomials of

[4] In a general equilibrium setting, such as RBC models, the rate of interest in equilibrium is defined as $g = -\ln(\rho u'(C_t)/u'(C_{t-1}))$, where ρ is a subjective discount factor of the representative consumer and $u'(C_t)$ is his/her marginal utility from consumption at period t. If this function is a CRRA function with parameter α, then $g^r = -\ln \rho + \alpha \ln(C_t/C_{t-1})$. Thus g^r is a linear function of the growth rate of consumption. In estimation we use $g^r = -\ln(C_t/C_{t-1})$ (i.e., $\rho = \alpha = 1$) and discuss the consequences of using other values for ρ or α.

degree 2, 3, or 4 as the alternative functional forms:

$$\Gamma_t = \begin{cases} \dfrac{\gamma_1}{2}\left(\dfrac{H_t}{N_t}\right)^2 F_t \\ \dfrac{\gamma_1}{\gamma_2}\left(\dfrac{H_t}{N_t}\right)^{\gamma_2} F_t \\ \displaystyle\sum_{i=1}^{d} \frac{\gamma_i}{i}\left(\frac{H_t}{N_t}\right)^i F_t \qquad d = 2, 3, 4. \end{cases} \tag{14}$$

(v) As to the timing of hiring costs, we try two formulations: in one, costs occur in the month before production takes place; in the other, we cater for the possibility that the hiring process is completed within the month and so hiring costs are incurred in the month of production.

(vi) As some of the variables are non-stationary, we run the equation divided throughout by the average product at period $t+1$. Thus all variables included in the equations are stationary.

(vii) For the instrument set, we tried different lag structures of the variables (the hiring rate and profitability) and tested the equations for robustness with respect to changes in this set.

In order to see if this equation can be linked to a matching model, where the wage that appears in the Euler equation is determined by the Nash bargaining solution, we also run the GMM procedure on the Euler equation (3) jointly with the wage equation (11). To do so we postulate that total income during unemployment, b, is given by

$$\frac{b_t}{\frac{F_t}{N_t}} = \frac{z_t}{\frac{F_t}{N_t}} + \mu + v_t, \tag{15}$$

where z are unemployment benefits on which there are data (see Appendix A); any non-pecuniary value, such as that derived from leisure activities, is captured by the constant μ (a parameter) plus an i.i.d process v_t; and the variables are expressed in terms relative to average output. Inserting this specification into (11) yields

$$\frac{W_t}{\frac{F_t}{N_t}} = \beta\left(\delta - \frac{\frac{\partial \Gamma_t}{\partial N_t}}{\frac{F_t}{N_t}} + E_t P_{t+1}\frac{\frac{\partial \Gamma_t}{\partial H_t}}{\frac{F_t}{N_t}}\right) + (1-\beta)\left(\frac{z_t}{\frac{F_t}{N_t}} + \mu + v_t\right), \tag{16}$$

where we have used the Cobb–Douglas specification for the production function (see Eq. (13)), divided the equation throughout by F_t/N_t to induce stationarity and used Eq. (3) to replace the term $J^F_{t+1}/1 + r_t$ by $(\partial \Gamma_t / \partial H_t)/(F_t/N_t)$. The error in this equation is given by $(1 - \beta)v_t$.

4.2. *Results*

We start with estimation of Eq. (3).[5] It turns out that a general power function using bank credit rate discounting performs the best. In columns 1–7 of Table I we report the key results for this specification under alternative instrument sets. We report other estimates and robustness tests in Tables BI and BII of Appendix B. The table reports the estimated parameters [the parameters of the hiring cost function (Γ) and δ, the coefficient of labor in the production function], the test statistics of the overidentifying restrictions/orthogonality tests (the J statistic), and the variance of each side of the equation to test for the variance bound condition.

The results validate the present value relation and point to a highly convex power function. The power (γ_2) estimates vary in the range 4.69–5.85, mostly around 4.7. This degree of convexity (γ_2) reflects the elasticity of hiring with respect to the expected present value, implying a relatively flat dynamic labor demand curve. The point estimates and the standard errors of the scale parameter, γ_1, exhibit much greater variation, ranging from 296,348 to and 5,209,596. The evidence presented below sheds further light on this issue. Across all specifications, the production function parameter (δ) is precisely estimated at a value of around 0.68. This value is consistent with the results of other studies, which have directly estimated the Cobb–Douglas production function.

Column 8 of Table I presents estimates of the equation jointly with estimates of the wage equation (Eq. (16)). This is a more restricted form of estimating the parameters γ_1, γ_2, and δ because while both equations use actual wage data, Eq. (3) does not restrict W in any way but Eq. (16) does. In specifying the Nash solution it adds two more parameters to be estimated: β, the worker share in the wage bargain, and the unemployment income parameter μ. The results indicate that the estimates of columns 1–7 are robust. Further experimentation with the instrument set and with the sample period—reported in Table BIII of Appendix B—shows that γ_2 varies again around 4.7, and that the estimates of γ_1 vary in the range of 67,000 to 711,000, a somewhat narrower and lower range than

[5] Note that the structural estimation methodology employed is consistent with the wage (W) being an endogenous variable, even if an explicit formulation of the determinants of wages is not estimated. We return to this issue below, when we discuss the joint estimation of the Euler equation and the wage equation.

TABLE I
The Euler Equation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
γ_1	296,348	600,252	362,874	355,856	492,567	5,209,596	325,748	159,517
	(127,876)	(221,459)	(181,279)	(159,326)	(213,963)	(13,705,868)	(145,901)	(501,591)
γ_2	4.73	4.74	4.72	4.71	4.94	5.85	4.69	4.74
	(0.01)	(0.03)	(0.02)	(0.01)	(1.14)	(0.005)	(0.02)	(0.02)
δ	0.681	0.683	0.680	0.681	0.680	0.676	0.676	0.680
	(0.006)	(0.009)	(0.006)	(0.007)	(0.006)	(0.005)	(0.009)	(0.005)
β								0.17
								(0.07)
μ								0.40
								(0.01)
J-Statistic	6.7	7.1	2.4	3.4	9.8	15.7	1.1	52.7
p-Value	0.35	0.31	0.30	0.49	0.28	0.0004	0.58	0.0002
VAR LHS	0.008	0.030	0.013	0.013	0.005	0.001	0.013	0.002
VAR RHS	0.012	0.037	0.018	0.018	0.008	0.003	0.018	0.007

Notes:
(1) In column 1 the instrument set contains a constant and four lags of $\frac{H}{N}$ and $\frac{F/N}{W}$.
In column 2 the timing of hiring costs and production is set to occur within the same month.
In columns (3)–(5) the lags used are 2, 3, and 5 respectively.
In column (6) $\frac{F/N}{W}$ is dropped and in column (7) $\frac{H}{N}$ is dropped from the instrument set.
In column (8) the equation is estimated jointly with the wage equation and the instrument set includes a constant and four lags of $\frac{H}{N}$, $\frac{F/N}{W}$, and $\frac{z}{F/N}$.
(2) Standard errors are in parentheses.
(3) VAR LHS is the variance of asset values (which appear on the LHS of the Euler equation).
VAR RHS is the variance of the ex-post present value of marginal profits (which appear on the RHS of the equation).

that reported above. The estimate of the worker share (β), which is 0.17 in column 8, varies across instrument sets in the range of 0.2 to 0.4. This seems reasonable for two reasons: the share of unemployed workers in matching is around 0.2 to 0.3 according to the results of structural estimation of the Israeli matching function reported in Yashiv (1999a); for the U.S. Mortensen (1994) presents empirical considerations that place it at 0.3.

5. INFERENCE OF ASSET VALUES USING THE PRESENT VALUE RELATION

In this section, we approximate the present value relation driving hiring [see Eq. (4) above] using a methodology proposed by Cochrane (1992) for stock price–dividend ratios. This approximation separates out the different determinants of asset values—future productivity growth, marginal profit rates, separation rates, and discount rates. We use it for several purposes:

(i) While the Euler equation estimates reported in the previous section were based on a methodology which uses information from pairs of consecutive periods along the firms' optimal path, the approximation methodology takes many more periods into account. It thus offers the opportunity to infer the hiring cost function parameters, and hence asset values, independently of the GMM results, using a different methodology and with different information.

(ii) It facilitates the decision as to which of the GMM specifications discussed above should be preferred.

(iii) It permits us to do a variance decomposition analysis to determine the relative role played by the different determinants of asset values.

We begin by discussing the approximation methodology (5.1), leaving the full derivation to Appendix C. We then report the estimates of the Γ function parameters inferred from the approximation (5.2).

5.1. *An Approximate Present Value Relation*

The approximation elaborated in Appendix C is based on the exact present value relationship (4) divided throughout by average output:

$$\frac{\dfrac{\partial \Gamma_t}{\partial H_t}}{\dfrac{F_t}{N_t}} = E_t\left[\sum_{j=1}^{\infty}\left\{\prod_{i=1}^{j}\frac{(1-s_{t+i-1})}{(1+r_{t+i-1})}\right\}\frac{1}{\dfrac{F_t}{N_t}}\left(\frac{\dfrac{\partial F_{t+j}}{\partial N_{t+j}} - W_{t+j} - \dfrac{\partial \Gamma_{t+j}}{\partial N_{t+j}}}{1-s_t}\right)\right]. \tag{17}$$

The LHS expresses the asset value in terms of average output. For notational simplicity it shall be denoted P_t. The RHS expresses the expectations of future marginal profits—the "dividends" from the job–worker match—discounted by both the separation rate and the real rate of interest. The idea is to separate out these different elements. The approximated relationship, derived in Appendix C, implies the expressions for the unconditional mean and the unconditional variance of asset values,

$$E(P) = E(MP)\left[\frac{\Omega}{1-\Omega} + \frac{\Omega}{2(1-\Omega)^2}\sum_{j=-\infty}^{\infty}\Omega^{|j|}\operatorname{cov}(w_t, w_{t-j})\right] + \sum_{j=1}^{\infty}\Omega^{j}\operatorname{cov}(MP_{t+j}, w_{t+j}) \tag{18}$$

$$\operatorname{var}(P) = \frac{E(MP)}{1-\Omega}\sum_{j=1}^{\infty}\Omega^j \operatorname{cov}\left(P_t, n^f_{t+j}\right) + \frac{E(MP)}{1-\Omega}\sum_{j=1}^{\infty}\Omega^j \operatorname{cov}\left(P_t, -g^s_{t+j}\right) + \frac{E(MP)}{1-\Omega}\sum_{j=1}^{\infty}\Omega^j \operatorname{cov}\left(P_t, -g^r_{t+j}\right) + \sum_{j=1}^{\infty}\Omega^j \operatorname{cov}\left(P_t, MP_{t+j}\right) \tag{19}$$

where

$$MP_t \equiv \frac{\delta - \dfrac{W_t N_t}{F_t} - \left(\dfrac{F_t}{N_t}\right)^{-1}\left(\dfrac{\partial \Gamma_t}{\partial N_t}\right)}{1 - s_t},$$

$$n^f_t = \ln\left(1 + g^f_t\right)$$

$$g^s_t = -\ln(1 - S_{t-1})$$

$$g^r_t = -\ln\frac{1}{(1 + r_{t-1})}$$

$$g^f_t = \frac{\dfrac{F_t}{N_t}}{\dfrac{F_{t-1}}{N_{t-1}}}$$

$$w_t \equiv \left(n^f_t - g^s_t - g^r_t\right) \qquad \text{and} \qquad \Omega = e^{E(w)}.$$

The unconditional mean (Eq. (18)) is the sum of two terms: the first, $E(MP)\frac{\Omega}{1-\Omega}$, represents asset values in a certainty world, with all variables evaluated at their mean. This is the average, discounted marginal profit. The second consists of two elements: one is a weighted sum of co-variances of "dividend" growth rates, separation rates, and real interest rates. The other element is a weighted sum of co-variances of marginal profit rates and the different rates contained in w. The greater the co-variance of dividend growth or of the marginal profit rate with separation rates or interest rates, the lower the mean asset value.

The variance of asset values (Eq. (19))—and consequently the variance of hiring—is decomposed into four terms. These are weighted infinite sums of the co-variance of asset values (P) with the future productivity growth rate (n^f), with (the negative of) the future separation rate $(-g^s)$, with (the negative of) the future real interest rate $(-g^r)$ and with the future rates of marginal profits (MP). It is important to note the particular features of this decomposition: as the co-variance terms may be negative and as the four terms are *not* orthogonal, each term as a fraction of var(P) may be above 100% or below 0. Note, too, that high asset values (and hiring rates) may be associated with *low* future productivity growth rates or with *high* future separation rates if they are also associated with much lower future interest rates or with much higher marginal profit rates.

5.2. *Estimation of Asset Values*

We now use Eqs. (18) and (19) to infer asset values. To do so, we need to postulate the functional form of hiring costs. We use a general power function, so marginal costs are given by $(\partial\Gamma_t/\partial H_t)/(F_t/N_t) = \gamma_1(H_t/N_t)^{\gamma_2-1}$. We then compute, for alternative values of the power γ_2, the γ_1 value that would satisfy Eq. (18) and, separately, the value that would satisfy (19). For the mean and variance expressions that appear in these equations we use the sample moments. The values for the power (γ_2) that we consider are 2 (the quadratic function), 3, 4, 5, and 4.7, the latter being the result of the GMM estimation in the previous section. These computations involve two further assumptions: first, we use $\delta = 0.68$ to calculate marginal profit rates, as this value was fairly robust in the Euler equation results and corresponds to standard production function estimates. Second, we need to truncate the infinite sums in the two equations at some finite period J. We did so after testing values of J from 1 to 100 months and took $J = 75$, after which the expressions did not change much. We examined the robustness of the computation to modifications in J.

Table II reports the results, including the inferred γ_1 values and asset values ($P = \gamma_1(H_t/N_t)^{\gamma_2-1}$) they imply. One set of results pertains to the values satisfying (18) and the other set to those satisfying (19). We look for values of γ_1, for a given γ_2, that satisfy both equations. We differentiate between the various discount rate models.

The key result is that only in the bank credit discounting case and only for the case $\gamma_2 = 4$ do there exist estimates of γ_1 that satisfy *both* equations. In all other cases either the γ_1 estimates are very different across the two equations, or one of the equations is not satisfied by any positive value of γ_1.[6] These results narrow down the range of specifications to a highly convex function using the bank credit interest rate.

[6] Using other consumption-based rates within a CRRA framework does not change this conclusion.

6. THE SOURCES OF FLUCTUATIONS AND STOCHASTIC PROPERTIES OF HIRING AND ASSET VALUES

The aim of this section is twofold: to determine which specifications out of all the different results reported in the preceding two sections should be preferred and to study their stochastic properties. As asset values are

TABLE II
Inferred Asset Values
Using the Approximated Present Value Relationship

a. Bank Credit Rates Discounting	variance		mean	
Specification	γ_1	P	γ_1	P
$\gamma_2 = 2$	—	—	63	1.16
$\gamma_2 = 3$	9000	3.15	3550	1.24
$\gamma_2 = 4$	210,000	1.45	195,000	1.35
$\gamma_2 = 4.7$	2,300,000	1.04	3,150,000	1.43
$\gamma_2 = 5$	6,600,000	0.93	10,300,000	1.46
b. Consumption-Based Discounting	variance		mean	
Specification	γ_1	P	γ_1	P
$\gamma_2 = 2$	90	1.65	—	—
$\gamma_2 = 3$	2700	0.95	—	—
$\gamma_2 = 4$	97,200	0.67	—	—
$\gamma_2 = 4.7$	1,230,000	0.56	—	—
$\gamma_2 = 5$	3,670,000	0.52	—	—
c. Constant Discounting	variance		mean	
Specification	γ_1	P	γ_1	P
$\gamma_2 = 2$	85	1.56	2310	42.4
$\gamma_2 = 3$	2650	0.93	—	—
$\gamma_2 = 4$	98,000	0.68	—	—
$\gamma_2 = 4.7$	1,265,000	0.57	—	—
$\gamma_2 = 5$	3,750,000	0.53	—	—

Notes:
(1) The first column specifies the γ_2 used in computing the asset value, $P = \gamma_1(\frac{H}{N})^{\gamma_2 - 1}$
(2) The second column reports the value of γ_1 that satisfies the variance decomposition.
(3) The third column reports the sample average value of P implied by this specification.
(4) The fourth column reports the value of γ_1 that satisfies the unconditional mean equation.
(5) The fifth column reports the sample average value of P implied by this specification.
(6) The sign "—" indicates that no positive γ_1 satisfies the equation.

unobservable, there is no obvious way in which the various estimates may be evaluated. However, reviewing the evidence presented in Tables I and II, there is one specification that stands out as satisfying all the criteria—the power function, using bank credit rates for discounting. This specification passes the orthogonality and variance bounds tests of the Euler equation and satisfies both the mean and variance equations of the approximated present value equation. Moreover, in the former case it proved to be robust to the modifications reported in Appendix B. As to the values of its parameters, the estimates of the degree of convexity (γ_2) are similar across inference methodologies—they are 4.7 in the GMM case and 4 in the approximation case, with 4.7 being acceptable, too. In fact, a major difference is found only in the scale (γ_1) estimates. The GMM estimates vary across specifications. In all cases they are lower than those reported for the approximation in Table II using the same power ($\gamma_2 = 4.7$). In what follows, we therefore narrow down the set of specifications and attempt to evaluate three alternative parameter sets: (i) $\gamma_2 = 4.7$, $\gamma_1 = 450{,}000$ reflecting the GMM estimates; (ii) $\gamma_2 = 4$, $\gamma_1 = 200{,}000$, which is the preferred estimate using the approximation as reported in Table II; (iii) $\gamma_2 = 4.7$, $\gamma_1 = 3{,}150{,}000$, which represents a combination of the two methodologies; the preferred specification of the power (γ_2) from the GMM estimates (Table I) and the γ_1 value that satisfies the mean equation of the approximation (Table II).

Table III reports the properties of these three specifications. Panel (a) looks at hiring rates and at marginal and total hiring costs. It presents their sample moments—mean and standard deviation—in monthly terms. Panel (b) computes the "goodness of fit" of these specifications. This is done by plugging the alternative parameter sets into the Euler equation (3) and solving for the hiring rate ($\frac{H}{N}$). The solution is obtained by solving the equation period by period, using the actual values of the exogenous variables and of lagged hiring. We then report the correlations (ρ) between the solved, "fitted" hiring series and the actual one. Panel (c) reports the autocorrelation of the different series. Panel (d) presents a variance decomposition analysis of asset values using Eq. (19).[7]

The two specifications based on the approximation [specifications (ii) and (iii) in Table II] give similar magnitudes for hiring costs: marginal costs—i.e., the costs of the marginal hire—are, on average, 140% of monthly output or a little over two months of wages. Total costs are about 0.7% of output. The specification based on the GMM estimates [set (i) above] gives far lower values, a consequence of the lower scale estimate discussed above.

[7] We do not report the variance decomposition for the GMM estimates set [(i) above] as it does not satisfy Eq. (19).

How plausible are these estimates? Based on casual observation and intuition one should expect the value of screening and training costs to be equivalent to a few weeks or months of pay. The existing micro-based empirical evidence is scarce and reports diverse estimates, but generally confirms this intuition. Surveys of micro studies in Nickell (1986, pp.

TABLE III
The Stochastic Properties of Hiring and Asset Values

a. Moments

Hiring rates $\frac{H}{N}$

mean	std.
1.84%	0.36%

Marginal costs $\frac{\partial \Gamma}{\partial H}$

specification	average output terms $\frac{\partial \Gamma}{\partial H} / \frac{F}{N}$		wage terms $\frac{\partial \Gamma}{\partial H} / w$	
	mean	std.	mean	std.
$\gamma_1 = 450{,}000;\ \gamma_2 = 4.74$	17%	13%	0.27	0.21
$\gamma_1 = 200{,}000;\ \gamma_2 = 4$	138%	82%	2.13	1.37
$\gamma_1 = 3{,}150{,}000;\ \gamma_2 = 4.7$	143%	104%	2.21	1.72

Total costs relative to output Γ / F

specification	mean	std.
$\gamma_1 = 450{,}000;\ \gamma_2 = 4.74$	0.08%	0.07%
$\gamma_1 = 200{,}000;\ \gamma_2 = 4$	0.71%	0.56%
$\gamma_1 = 3{,}150{,}000;\ \gamma_2 = 4.7$	0.63%	0.58%

b. Goodness of Fit

	specification	ρ
$\gamma_1 \left(\frac{H_t}{N_t}\right)^{\gamma_2 - 1}$	$\gamma_1 = 450{,}000;\ \gamma_2 = 4.74$	0.77
$\gamma_1 \left(\frac{H_t}{N_t}\right)^{\gamma_2 - 1}$	$\gamma_1 = 200{,}000;\ \gamma_2 = 4$	0.99
$\gamma_1 \left(\frac{H_t}{N_t}\right)^{\gamma_2 - 1}$	$\gamma_1 = 3{,}150{,}000;\ \gamma_2 = 4.7$	0.99

TABLE III—*Continued*

c. Autocorrelations

specification		ρ_1	ρ_6	ρ_{12}	ρ_{18}	ρ_{24}	ρ_{36}	ρ_{48}
$\frac{H}{N}$		0.59	0.56	0.61	0.40	0.51	0.42	0.23
$\gamma_1\left(\frac{H_t}{N_t}\right)^{\gamma_2-1}$	$\gamma_1 = 450{,}000;\ \gamma_2 = 4.74$	0.64	0.54	0.60	0.40	0.52	0.36	0.21
$\gamma_1\left(\frac{H_t}{N_t}\right)^{\gamma_2-1}$	$\gamma_1 = 200{,}000;\ \gamma_2 = 4$	0.64	0.54	0.61	0.41	0.52	0.38	0.22
$\gamma_1\left(\frac{H_t}{N_t}\right)^{\gamma_2-1}$	$\gamma_1 = 3{,}150{,}000;\ \gamma_2 = 4.7$	0.64	0.54	0.60	0.40	0.52	0.36	0.21

d. Variance Decomposition

specification		P, n^f	$P, -g^s$	$P, -g^r$	P, MP
$\gamma_1\left(\frac{H_t}{N_t}\right)^{\gamma_2-1}$	$\gamma_1 = 200{,}000;\ \gamma_2 = 4$	-0.04	-0.06	0.43	0.70
$\gamma_1\left(\frac{H_t}{N_t}\right)^{\gamma_2-1}$	$\gamma_1 = 3{,}150{,}000;\ \gamma_2 = 4.7$	-0.03	-0.05	0.35	0.62

Notes:

(1) In panel (a), the mean and standard deviation refer to the monthly sample values.

(2) In panel (b) we solve the Euler equation for $(\frac{H}{N})_{t+1}$ using the actual value of all the other variables and report the correlation ρ with the actual series.

(3) In panel (c), ρ_i is the ith autocorrelation.

(4) In panel (d), columns 3, 4, 5, and 6 report the fraction of var(P) explained by the different P, x, each of which stands for

$$\frac{\frac{E(MP)}{1-\Omega}\sum_{j=1}^{J}\Omega^j \operatorname{cov}(P_t, x_{t+j})}{\operatorname{var}(P)}$$

where $x = n^f,\ -g^s,\ -g^r,\ MP$, and $J = 75$.

475–476) and Hamermesh (1993, p. 208) indicate that costs are in the order of one to three weeks of pay for low-skilled workers and in the order of a few months of pay for medium- and high-skilled workers. From the findings of a recent detailed study by Abowd and Kramarz (1997), one can derive a *lower* bound on hiring costs in French establishment level data. This turns out to be, on average, 60% of monthly wages, inclusive of taxes, with the actual level potentially much higher. Thus both intuition and micro studies are in the range of the statistics of Table III.

The goodness of fit measures support all specifications, but in particular parameter sets (ii) and (iii), where the correlation values are quite high (0.99). The table shows that there is little difference in the stochastic properties of asset values whether we use a convexity parameter γ_2 equal to 4 or to 4.7, provided that the scale parameter (γ_1) is adjusted accordingly.

The differences across inference methodologies pertain to this scale and they are not surprising. The two methodologies relate to two different dimensions of the data: the Euler equation is based on the stochastic behavior of *returns*, i.e., changes in asset values (P_t and P_{t+1}). The approximation methodology bases inference on a *present value* specification. Thus the Euler equation is more sensitive to high frequency aspects of the data. The more persistent are marginal profits, the higher will asset values be. Therefore, the methodology that picks up more high frequency movements relates to less persistent data and infers lower asset values.

Asset values "inherit" the autocorrelation structure of hiring rates and, therefore, on this dimension there is hardly any difference between the different parameter sets. The interesting finding is that hiring and asset values are only moderately persistent: the autocorrelation is 0.6 at the first lag, weakens after one year, and diminishes considerably after three years.

Panel (d) sheds light on a key issue—the sources of fluctuations in hiring. The variance decomposition analysis of asset values shows that fluctuations in future marginal profit rates and in interest rates play an important role. The relative contribution of the marginal profit rate is around 60%, while interest rate fluctuations contribute about 40%. The latter finding highlights the role of financial variables in generating labor market fluctuations. The variance of future productivity growth rates and separation rates contributes relatively little. Moreover, the results imply that higher asset values today are associated with *lower* future productivity growth rates or *higher* rates of worker separation. As noted above, this is consistent with much lower future interest rates and/or much higher profit rates.

In the next two sections we use parameter sets (ii) and (iii) to explore some of their broader implications.

7. THE BEHAVIOR OF HIRING AND ASSET VALUES OVER THE BUSINESS CYCLE

The preceding results allow for an examination of the cyclical behavior of labor market variables in the presence of frictions. This section describes the business cycle properties of hiring and asset values. We follow the approach taken in the business cycle literature and study the co-movement and relative volatility of the relevant variables. Note that the standard analysis of fluctuations assumes a frictionless market with no adjustment costs—i.e., costless and instantaneous hiring and firing.

One idea, which has been proposed in the context of labor markets with hiring costs, is that if the firm optimizes intertemporally, then recessions represent times of low opportunity cost. Thus one should expect to see more re-structuring of the workforce, including hiring, in those times. In such a case hiring would be counter-cyclical. The current model encompasses this type of argument. Looking at Eq. (3), we see that if F_t/N_t is relatively low, then, *other things equal*, current hiring rates H_t/N_t should be relatively high. However, as it has been stressed, hiring is a forward-looking decision based on a present value expression. One should therefore examine what happens to the different components of the asset value of workers at those times when F_t/N_t is relatively low.

Table IV presents the dynamic cross correlations and relative standard deviations of hiring and asset values with traditional measures of cyclical activity and with the variables that actually appear in the present value relation.[8] The former are the stock of employment (N) and real GDP (F); we add labor productivity $(\frac{F}{N})$ in order to be consistent with the model's formulation. The latter set of variables includes profitability $(\frac{F/N}{W})$, bank credit rates (r), the separation rate (s), and the rate of productivity growth (g^f). We employ two alternative detrending methods: exponential detrending, which is relevant in the case of a deterministic trend, and the Hodrick–Prescott (HP) filter, which is relevant in the case of a stochastic trend. These are reported in two panels. All variables used pertain to the business sector and are at the quarterly frequency.

Before discussing hiring and asset values, note that, in the Israeli economy, the correlation between employment and output is low: 0.32 (contemporaneously) in the HP case. This is identical to the value Backus et al. (1995) reported for Europe and much lower than the U.S. value of 0.88 [see Backus et al. (1995, Table 11.1)]. Employment is less volatile than output; in this case, the Israeli value for the relative standard deviation of 0.67 is closer to the U.S. figure of 0.61 rather than the European figure of 0.78.

Three broad conclusions emerge from Table IV. First, the correlation of hiring with employment is weak (in the exponentially detrended case even weakly negative) and with output it is moderate. Second, hiring rates and asset values are much more volatile than the cyclical measures. Third, the co-movement with the variables included in the present value relation is

[8] Dynamic cross correlations are the same for hiring rates and for asset values, so only the former are reported.

not stronger (at most 0.3) and often switches signs across lags and leads. A closer look at the results reveals some differences between the detrending methodologies, but these do not change the picture in any essential way. The underlying result, then, is that hiring and asset values are not strongly related to traditional measures of the cycle or to the variables included in the present value relation. How can this be reconciled with the previous results, especially those of Table III? There are several, related answers to

TABLE IV
Business Cycle Properties

I Exponentially Detrended Variables
a. Dynamic Cross-Correlations

τ	−4	−3	−2	−1	0	1	2	3	4
$\rho(F_t, N_{t+\tau})$	0.51	0.52	0.54	0.57	0.59	0.53	0.49	0.45	0.38
$\rho\left(\frac{H_t}{N_t}, N_{t+\tau}\right)$	−0.18	−0.17	−0.16	−0.03	−0.11	−0.17	−0.14	−0.05	−0.10
$\rho\left(\frac{H_t}{N_t}, F_{t+\tau}\right)$	0.23	0.19	0.19	0.17	0.33	0.23	0.16	0.12	0.29
$\rho\left(\frac{H_t}{N_t}, \frac{F_{t+\tau}}{N_{t+t}}\right)$	0.43	0.39	0.36	0.21	0.48	0.43	0.32	0.15	0.41
$\rho\left(\frac{H_t}{N_t}, \frac{F_{t+\tau}}{N_{t+t}W_{t+\tau}}\right)$	0.45	0.14	0.12	−0.08	0.27	−0.01	−0.04	−0.12	0.22
$\rho\left(\frac{H_t}{N_t}, r_{t+\tau}\right)$	0.00	0.06	−0.08	−0.12	−0.29	−0.33	−0.28	−0.29	−0.32
$\rho\left(\frac{H_t}{N_t}, s_{t+\tau}\right)$	0.15	0.02	−0.29	0.20	0.25	0.06	−0.28	0.30	0.13
$\rho\left(\frac{H_t}{N_t}, g^f_{t+\tau}\right)$	0.19	−0.18	0.02	0.01	0.21	−0.18	−0.08	−0.01	0.22

b. Relative Standard Deviations

1) Relative to employment		2) Relative to output	
$\frac{\text{std } \frac{H}{N}}{\text{std } N}$	1.8	$\frac{\text{std } N}{\text{std } F}$	1.1
$\frac{\text{std } P1}{\text{std } N}$	5.3	$\frac{\text{std } \frac{H}{N}}{\text{std } F}$	1.6
$\frac{\text{std } P2}{\text{std } N}$	6.6	$\frac{\text{std } P1}{\text{std } F}$	4.8
		$\frac{\text{std } P2}{\text{std } F}$	5.9

TABLE IV—*Continued*

II HP-filtered Data

a. Dynamic Cross-Correlations

τ	−4	−3	−2	−1	0	1	2	3	4
$\rho(F_t, N_{t+\tau})$	0.08	0.04	0.07	0.24	0.32	0.12	0.14	0.14	0.00
$\rho\left(\frac{H_t}{N_t}, N_{t+\tau}\right)$	−0.12	−0.14	−0.08	0.30	0.16	0.01	−0.01	0.26	−0.06
$\rho\left(\frac{H_t}{N_t}, F_{t+\tau}\right)$	0.19	0.03	0.01	−0.06	0.32	0.15	−0.01	−0.09	0.23
$\rho\left(\frac{H_t}{N_t}, \frac{F_{t+\tau}}{N_{t+t}}\right)$	0.26	0.13	0.07	−0.20	0.29	0.16	0.02	−0.27	0.22
$\rho\left(\frac{H_t}{N_t}, \frac{F_{t+\tau}}{N_{t+t}W_{t+\tau}}\right)$	0.41	−0.01	−0.02	−0.27	0.23	−0.12	−0.13	−0.21	0.25
$\rho\left(\frac{H_t}{N_t}, r_{t+\tau}\right)$	−0.03	0.11	−0.04	−0.04	−0.23	−0.21	−0.11	−0.08	−0.12
$\rho\left(\frac{H_t}{N_t}, s_{t+\tau}\right)$	0.11	−0.05	−0.40	0.16	0.23	0.01	−0.39	0.29	0.10
$\rho\left(\frac{H_t}{N_t}, g^f_{t+\tau}\right)$	0.20	−0.23	0.01	0.00	0.25	−0.21	−0.08	0.00	0.29

b. Relative Standard Deviations

1) Relative to employment		2) Relative to output	
$\frac{\text{std } \frac{H}{N}}{\text{std } N}$	4.1	$\frac{\text{std } N}{\text{std } F}$	0.67
$\frac{\text{std } P1}{\text{std } N}$	12.4	$\frac{\text{std } \frac{H}{N}}{\text{std } F}$	2.2
$\frac{\text{std } P2}{\text{std } N}$	15.3	$\frac{\text{std } P1}{\text{std } F}$	6.7
		$\frac{\text{std } P2}{\text{std } F}$	8.3

Notes:

(1) All variables are in natural logs.

(2) $\frac{H}{N}$ is the rate of hiring. P is the asset value as defined in Table 3: $\gamma_1(H_t/N_t)^{\gamma_2-1}$

$P1$ uses $\gamma_1 = 200{,}000$; $\gamma_2 = 4$. $P2$ uses $\gamma_1 = 3{,}150{,}000$; $\gamma_2 = 4.7$

N is business sector employee posts. F is real GDP of the business sector.

For full definitions see Appendix A.

(3) For each pair of variables the longest sample period is used. For N and F this is 68:1–96:4. For $\frac{H}{N}$ and P it is 75:1–89:4.

(4) For the cross-correlations, $\frac{H}{N}$ and the P s have the same cross-correlation so only the former is reported.

this question. One is that the traditional measures of the cycle do not appear in the present value relationship. Another is that the variables that do appear are not represented in Table IV by their *present value* expression, but rather by their *contemporaneous*, *lagged*, *or lead* value; compare, for example, the statistic $\rho(P_t, r_{t+\tau})$ in Table IV to the expression $\sum_{j=1}^{J}\Omega^j \operatorname{cov}(P_t, r_{t+j})$ that appears in Table III. Finally, the present value relation is highly non-linear, so correlation coefficients are not very adequate. We use them here in order to be consistent with the methodology adopted in the business cycle literature. The positive lesson to be drawn from these findings is the need to examine hiring in terms of the relevant *present value* variables.

The results do not support "opportunity cost" arguments like the one cited above for a similar reason: while hiring rates should move countercyclically according to these arguments, we find a positive correlation between hiring and productivity. When current productivity changes, components of the asset value are changing too, and in ways which offset the predicted negative relationship.

8. THE SENSITIVITY OF HIRING

How does hiring respond to changes in asset values, and how are these affected by their various determinants? While this question may be answered in several ways, one natural case to consider is the non-stochastic steady state. Looking at the steady state, the focus of this section is fundamentally different from the cyclical issues that were just explored.[9] Through examination of the steady state, we are able to explore the sensitivity of hiring to its determinants and to point to some policy implications.

The steady state is given by

$$\gamma_1\left(\frac{H}{N}\right)^{\gamma_2-1} = \frac{\delta\left[1-\dfrac{\gamma_1}{\gamma_2}\left(\dfrac{H}{N}\right)^{\gamma_2}\right]-\dfrac{WN}{F}+\gamma_1\left(\dfrac{H}{N}\right)^{\gamma_2}}{\dfrac{r+s(1+g_f)-g_f}{1+g_f}}. \tag{20}$$

All variables are at their steady state value. It is important to recognize the dynamic, flow aspect of the hiring decision. When the asset value of workers rises, not only does the number of hires go up, but also the *rate* of

[9] Examination of this question in a cyclical, stochastic context would require lengthy analysis beyond the scope of this paper [for such analysis using U.S. data and a search and matching model see Yashiv (1999b)].

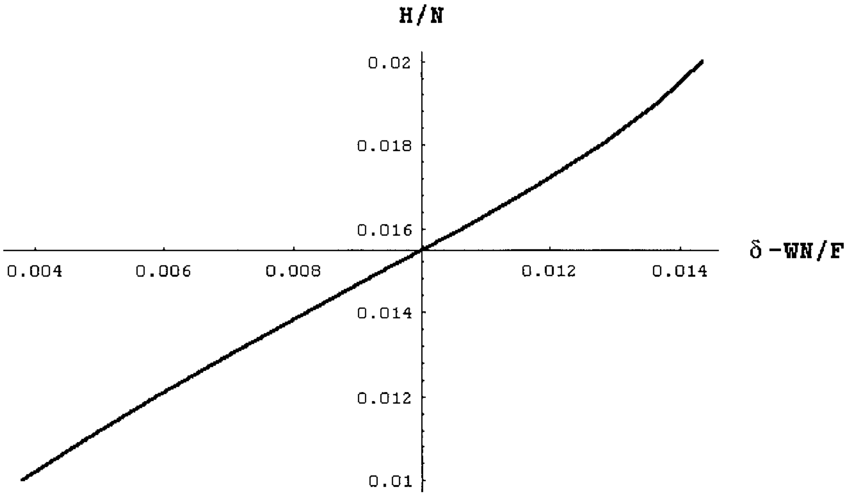

FIG. 1. Profitability.

hiring increases. The first question of interest for quantitative exploration is: what is the relationship of $\frac{H}{N}$ to each of its driving factors, i.e., $\delta - \frac{WN}{F}$, r, s, and g_f, or in other words, what is the slope of the dynamic, flow demand curve? Figures 1–4 use Eq. (20) to simulate the changes in the rate of hiring as a function of these variables, using the case of $\gamma_1 = 200{,}000$ and $\gamma_2 = 4$. In each panel the origin is the sample average of the

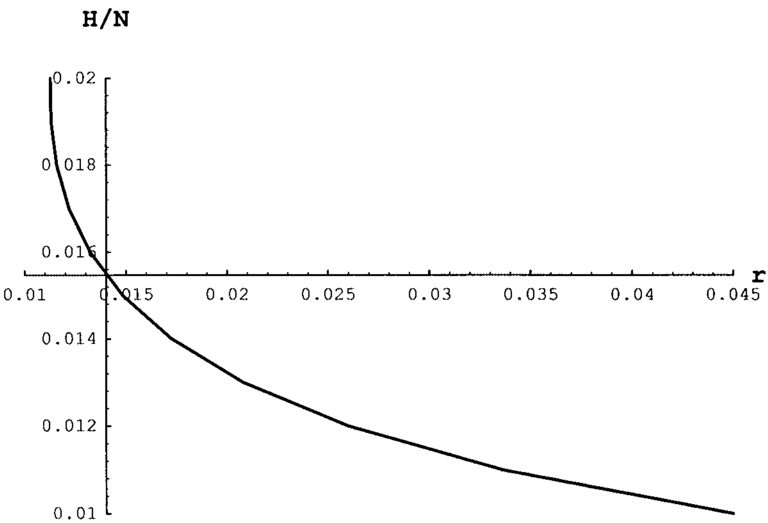

FIG. 2. Interest rate.

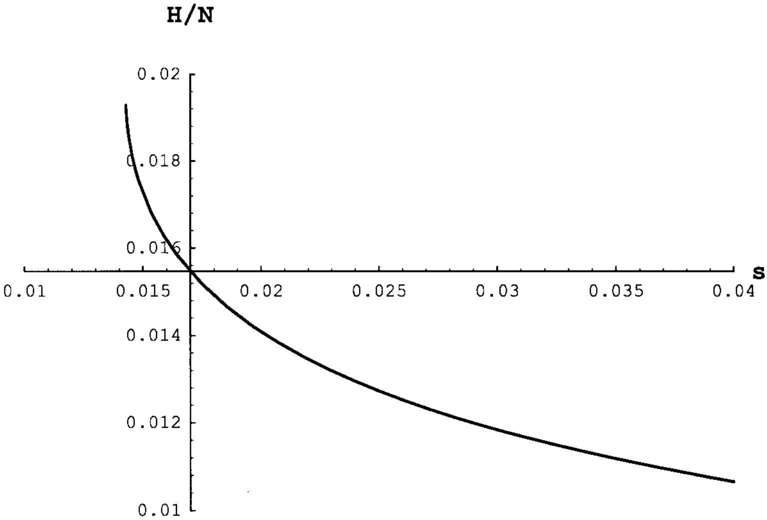

FIG. 3. Separation rate.

exogenous variable under study, and the hiring rate is the solution of Eq. (20), with all other exogenous variables valued at their sample averages.

The figures illustrate the elasticity of the rate of hiring with respect to the various determinants of asset values. While the response of hiring to changes in the profit rate is almost linear in the relevant range, the

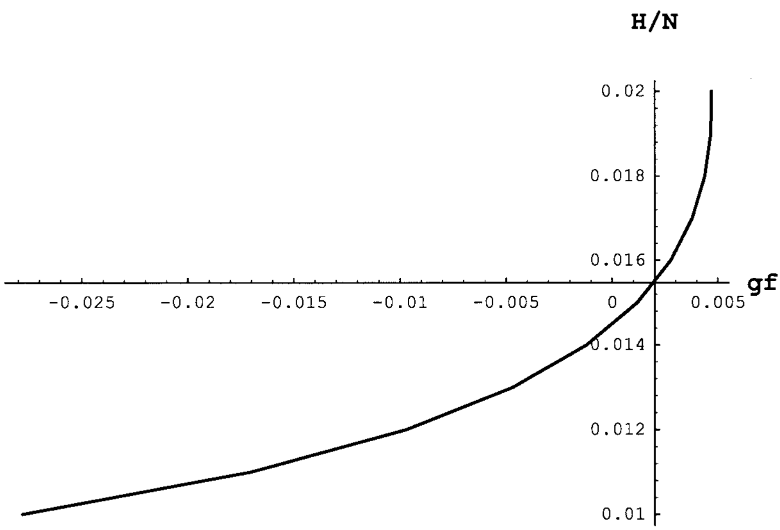

FIG. 4. Productivity growth.

response to the interest rate, separation rate, and productivity growth rate is non-linear and asymmetric. The higher hiring rates are, the more sensitive they become to changes in these rates. In the terminology of labor demand curves, at these values the demand curve is relatively "flat" (switching the variables on the axes); i.e., there is a relatively big response of labor demand to relatively small changes in the relevant determining factor.[10] However, for lower values of the hiring rate the curve is steeper. Thus if hiring rates are relatively high, small increases in interest rates can reduce them considerably. If hiring rates are low, big reductions in interest rates are required to bolster them.

This analysis may be applied to questions of policy. Two widely discussed policy instruments are subsidies or taxes on hiring costs and wages. Hiring subsidies have often been suggested or applied in dealing with European unemployment in recent years. Taxes on hiring may come in direct as well as indirect form, such as various regulations or bureaucratic procedures. The effects of these instruments may be analyzed by multiplying γ_1 by $(1 - \tau^h)$ and W by $(1 - \tau^w)$ in Eq. (20), where τ^h, τ^w are the hiring and wage subsidy rates, respectively. Figures 5 and 6 show the effects of these subsidies (or taxes) on the rate of hiring. Some numerical computations are reported in Table V.

Figure 5 shows that a subsidy for hiring (τ^h) displays increasing "returns" in terms of the hiring rate. The higher the hiring rate, the higher

[10] Note that unlike demand curves in the neo-classical model this is a case of flow demand (rather than stock demand) and that it is cast in terms of rates, not workers or hours.

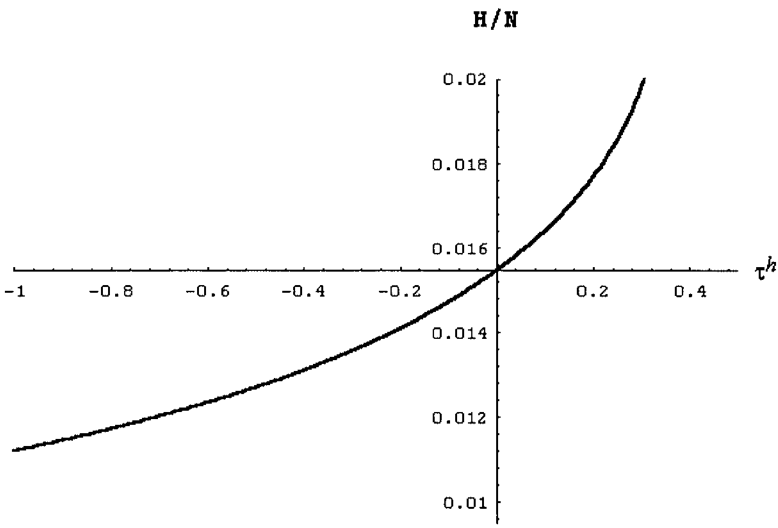

FIG. 5. Hiring subsidy/tax.

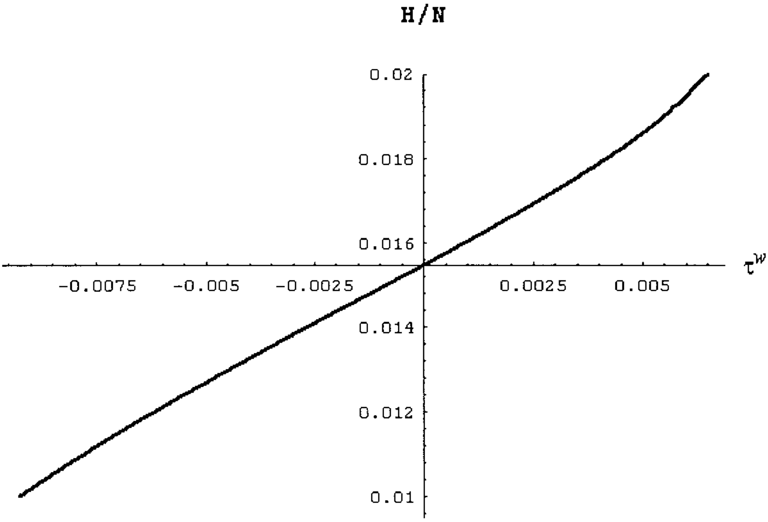

FIG. 6. Wage subsidy/tax.

the impact of a marginal increase in the subsidy. Table V quantifies this asymmetry in the response of the hiring rate: a 42.5% tax reduces the hiring rate from the benchmark of Figs. 1–4 (the origin) by 0.25 percentage points, while a 22% subsidy raises the rate of hiring by the same amount. Figure 6 shows that a subsidy for wages (τ^w) displays the same linear behavior as the rate of profit ($\delta - \frac{WN}{F}$) which it affects.

TABLE V
Subsidies and Tax Effects

$\left(\frac{H}{N}\right)$	τ^h	τ^w
1.3%	−42.5%	−0.4%
1.55%	0	0
1.8%	21.9%	0.4%

Notes:
(1) Hiring rate of 1.55% a month is the benchmark value of Figs. 1–4.
(2) $\tau > 0$ is a subsidy; $\tau < 0$ is a tax.

9. CONCLUSIONS

The paper has studied the determinants and stochastic behavior of the gross flow of hiring. The empirical work examined alternative specifications primarily with respect to the functional form of hiring costs and discount rate models. Using two alternative methods—structural estimation and approximation—it inferred the unobservable asset values of workers, quantifying them at reasonable magnitudes. The results were subjected to a variety of tests frequently used in the financial asset pricing literature—orthogonality tests, variance bounds, and mean-variance restrictions. These corroborated some of the specifications, validating the present value relationship driving hiring. It was shown that the volatility in asset values stems mostly from fluctuations in expected marginal profits and in bank credit interest rates. These fluctuations were found to be only weakly correlated with cyclical fluctuations in GDP and in employment. Hiring displays high sensitivity to its driving factors and moves asymmetrically in response to changes in the components of the discount factor.

More work is needed to fully understand the asset pricing and business cycle implications of these results. In the asset pricing context, the notion of asset value of workers could be embedded in a full-fledged production-based asset pricing model encompassing both labor and capital. Then the consequences for asset prices could be elaborated. In the business cycle context, the results pose a challenge to existing models: with frictions, firms' behavior is shaped by intertemporal relationships of the type analyzed here. This calls for analysis in terms of the relationship between the relevant present value variables and the cyclical measures. Such analysis would include examination of the shocks driving asset values and the propagation mechanisms generated by the costs involved in hiring.

APPENDIX A: DATA—SOURCES AND DEFINITIONS

The data set includes 180 monthly observations in the years 1975–1989. In what follows we use the following abbreviations for the agencies that are the sources of the data: ES (Employment Service), CBS (Central Bureau of Statistics), BOI (Bank of Israel), and NIA (National Insurance Agency).

ES data are taken from its monthly and quarterly statistical publications. All other data appear in the monthly bulletin of the CBS.

1. Hires (H). Source: ES. Number of vacancies filled by the ES each month.

2. Separation rate (s). Source: computed on the basis of NIA and CBS series. Lacking a direct measure of the time-varying separation rate

(s), we solve Eq. (2) period by period to retrieve it. It should be noted that the resulting series has no trend, is stationary around its average value (1.7% a month, in terms of rates out of business sector employment), and is uncorrelated, or at most weakly correlated, with any one of the key variables in the model (the correlations are -0.02 with employment, -0.03 with the real rate of interest, and 0.2 with the hiring rate). It turns out that the results do not change much if we use a constant s at the monthly average

3. (a) Real GDP (F), (b) employment (N), (c) average product ($\frac{F}{N}$). Source: CBS, NIA.

(a) Net domestic product of the business sector. To compute this series the following procedure was employed: the basis for computation is the real GDP of the business sector. From this series depreciation and net production taxes should be deducted as F represents firms' income in the model. As these data are not available but on annual basis, we take the average deduction (27%) and subtract it from the gross product series. One check on the validity of this procedure is possible for a limited number of quarters in the 1980s when the CBS did compute these deductions. Comparing the "true" series with the series computed in the above manner we find extremely high correlations (0.99). The product series is quarterly and is transformed into a monthly one by assuming linear geometric growth within the quarter.

(b) A measure of the labor input (N) which is the total number of business sector employee posts (jobs).

(c) The average product is obtained by dividing (a) by (b).

4. Real wages (W). Source: NIA, CBS. The average nominal wage for employee post in the business sector divided by the GDP deflator. We multiply the original monthly series by a factor of 1.26 which is the annual average for overhead costs (mostly social welfare contributions by the employer) as once more data of higher than the annual frequency are unavailable. This multiplication is needed in order to make the data internally consistent with the F series described above.

5. Unemployment benefits (z). Source: NIA, CBS. The monthly average of nominal unemployment benefits per person. This is obtained by dividing total benefit payments by the total number of days paid for the entire relevant population (benefits are paid on a working day basis) and then multiplying by 25, which is the average number of working days a month.

6. The real rate of interest (r). Source: BOI, CBS. As explained in the text we use three specifications:

(a) (1 + the basic nominal interest rate charged by banks) divided by (1 + the rate of GDP deflator inflation) minus 1. The numerator is the most reliable nominal interest rate series in the sample period and is the benchmark rate on bank credit to firms.

(b) The rate of growth of non-durable private consumption. The consumption series is quarterly; it is transformed into a monthly one by assuming linear geometric growth within the quarter.

(c) A constant interest rate set at 0.4% a month.

APPENDIX B: ALTERNATIVE ESTIMATES OF THE EULER EQUATION

Table BI reports the results for the five functional forms of the hiring cost function [see Eq. (14)] using the three alternative discount rate models (bank credit rates, non-durable consumption growth, and a constant rate).

The test statistics indicate a rejection in only one case: the J-statistic orthogonality test rejects the quadratic specification in the bank credit discounting case. Further examination, however, reveals problems with all three polynomial specifications: the standard errors of the Γ function parameter estimates—except for γ_2 in the second degree case—are large, rendering them insignificant; in several cases costs turn out to be *negative* for certain values of hiring rates and the estimates are not robust to the modifications introduced below.

TABLE BI

The Firms' Euler Equation—Alternative Specifications

a. Bank Credit Rates Discounting					
Specification	quadratic	power	poly. 2	poly. 3	poly. 4
γ_1		296,348	−0.47	0.4	−0.98
		(127,876)	(0.31)	(0.6)	(0.68)
γ_2	12	4.73	21	−118	127
	(5)	(0.01)	(8)	(105)	(521)
γ_3				4183	−10,735
				(3198)	(31,643)
γ_4					293,683
					(633,116)
δ	0.677	0.681	0.674	0.677	0.675
	(0.006)	(0.006)	(0.007)	(0.011)	(0.014)
J-Statistic	16.5	6.7	9.2	1.8	1.1
p-Value	0.02	0.35	0.16	0.87	0.89
VAR LHS	0.002	0.008	0.006	0.025	0.034
VAR RHS	0.005	0.012	0.009	0.030	0.040

TABLE BI—*Continued*

b. Consumption-Based Discounting					
Specification	quadratic	power	poly. 2	poly. 3	poly. 4
γ_1		478,539	−0.05	0.35	−0.08
		(207,802)	(0.34)	(0.53)	(2.32)
γ_2	18.3	4.82	19.1	−57.8	18
	(6.7)	(0.54)	(8.3)	(94.4)	(403)
γ_3				2,308	−2,392
				(2,853)	(24,042)
γ_4					93,532
					(470,565)
δ	0.676	0.681	0.676	0.682	0.683
	(0.007)	(0.006)	(0.007)	(0.007)	(0.006)
J-Statistic	8.8	4.6	8.5	3.9	3.3
p-Value	0.27	0.60	0.21	0.56	0.50
VAR LHS	0.004	0.011	0.005	0.013	0.014
VAR RHS	0.005	0.015	0.009	0.017	0.019

c. Constant Discounting					
Specification	quadratic	power	poly. 2	poly. 3	poly. 4
γ_1		479,516	0.16	0.39	−0.04
		(215,373)	(0.43)	(0.53)	(2.53)
γ_2	20.2	4.82	18.4	−50.3	20.1
	(7.2)	(0.92)	(8.5)	(118.1)	(415.4)
γ_3				2,085	−2,485
				(3,583)	(25,390)
γ_4					94,702
					(512,765)
δ	0.677	0.681	0.677	0.682	0.683
	(0.007)	(0.006)	(0.007)	(0.007)	(0.006)
J-Statistic	7.6	4.4	8.0	4.0	3.2
p-Value	0.37	0.63	0.24	0.55	0.52
VAR LHS	0.006	0.011	0.005	0.012	0.014
VAR RHS	0.010	0.015	0.009	0.016	0.019

Notes:
(1) Instruments used are a constant and four lags of $\frac{H}{N}$ and $\frac{F/N}{W}$.
(2) Standard errors are in parentheses.

We therefore tested for the robustness of the other two specifications—the quadratic and the general power function. It turned out that the quadratic specification is not robust. Table BII reports the results for the general power specification, beyond those presented in Table I in the main text. We modify the instrument set in terms of the variables included and the lags used and the timing of hiring costs relative to production (as explained in the table's notes).

TABLE BII

Robustness of the General Power Specification $\Gamma = (\gamma_1/\gamma_2)(H/N)^{\gamma_2}$

a. Consumption-Based Discounting

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
γ_1	478,539	733,316	386,646	410,887	312,768	322,539	353,607
	(207,802)	(280,150)	(187,427)	(181,483)	(132,131)	(385,031)	(164,513)
γ_2	4.82	4.75	4.71	4.73	4.75	4.75	4.71
	(0.5)	(0.02)	(0.02)	(0.03)	(0.06)	(0.01)	(0.03)
δ	0.681	0.681	0.680	0.681	0.681	0.681	0.676
	(0.006)	(0.01)	(0.007)	(0.007)	(0.006)	(0.006)	(0.007)
J-Statistic	4.6	5.1	1.8	2.6	7.3	4.4	0.9
p-Value	0.60	0.53	0.41	0.63	0.50	0.11	0.63
VAR LHS	0.010	0.041	0.015	0.015	0.007	0.008	0.013
VAR RHS	0.015	0.050	0.021	0.020	0.012	0.012	0.018

b. Constant Discounting

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
γ_1	479,516	773,209	475,622	474,273	332,617	538,042	352,330
	(215,373)	(302,585)	(253,269)	(224,383)	(142,391)	(637,231)	(177,740)
γ_2	4.82	4.75	4.74	4.77	4.75	4.90	4.70
	(0.92)	(0.02)	(2.58)	(1.16)	(0.008)	(0.07)	(0.03)
δ	0.681	0.681	0.681	0.681	0.681	0.681	0.677
	(0.006)	(0.01)	(0.008)	(0.007)	(0.006)	(0.006)	(0.008)
J-Statistic	4.4	5.1	1.4	2.3	7.2	4.7	0.9
p-Value	0.63	0.54	0.50	0.68	0.52	0.10	0.63
VAR LHS	0.011	0.046	0.021	0.015	0.008	0.007	0.013
VAR RHS	0.015	0.055	0.025	0.021	0.013	0.012	0.018

Notes:

(1) In column 1 the instrument set contains a constant and four lags of $\frac{H}{N}$ and $\frac{F/N}{W}$.

(2) In column 2 the timing of hiring costs and production is set to occur within the same month.

(3) In columns (3)–(5) the lags used are 2, 3, and 5, respectively.

(4) In column (6) $\frac{F/N}{W}$ is dropped and in column (7) $\frac{H}{N}$ is dropped from the instrument set.

(5) Standard errors are in parentheses.

The table shows that the results of Table I are indeed robust. For the consumption-based model the reported results pertain to the special case where $\alpha = 1$ and $\rho = 1$ in $g^r = -\ln \rho + \alpha \ln(C_t/C_{t-1})$. We checked the impact of using other values. Changing the value of ρ within reasonable ranges is too small to be of importance. Experimenting with values of α between 1 and 10 (the latter being a relatively high coefficient of risk aversion), we found that as α increases, the estimates of δ and of γ_2 do not change but the estimates of γ_1 decline. This decline in scale is to be expected as asset values decline when the effective interest rate increases because of higher risk aversion. For example, when α increases from 1 to 5, the point estimate of γ_1 drops from 478,539 to 289,413.

In Table BIII we report the results from joint estimation of the Euler equation and the wage equation (Eqs. (3) and (16)). Column 1 repeats the specification used in column 8 of Table I. The other columns vary the instrument set as explained in the notes to the table. One further variation is to estimate the period 1980:05–1989:12 rather than the full sample. The reason is that there was a major change in the unemployment benefit law in April 1980 which engendered a regime shift in the unemployment benefits series (z), which plays a key role in the wage equation.

The estimates are relatively robust as discussed in the main text and the variation in the estimates of γ_1 and γ_2 is even smaller than the variation reported in Tables BI and BII above.

TABLE BIII
Joint Estimation of Euler and Wage Equations

	(1)	(2)	(3)	(4)	(5)
γ_1	159,517	119,897	711,017	67,555	82,355
	(501,591)	(803,475)	(305,520)	(944,040)	(1,417,078)
γ_2	4.74	4.76	4.73	4.72	4.78
	(0.02)	(0.16)	(0.02)	(1.41)	(1.24)
δ	0.680	0.692	0.692	0.690	0.691
	(0.005)	(0.005)	(0.01)	(0.004)	(0.005)
β	0.17	0.36	0.15	0.22	0.27
	(0.07)	(0.13)	(0.09)	(0.11)	(0.13)
μ	0.40	0.39	0.38	0.39	0.40
	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)
J-Statistic	52.7	35.5	32.3	41.9	32.0
p-Value	0.0002	0.03	0.05	0.03	0.002
VAR LHS	0.002	0.001	0.045	0.0004	0.0004
VAR RHS	0.007	0.006	0.060	0.0046	0.0046

Notes:
(1) In columns 1 and 2 the instrument set includes a constant and four lags of $\frac{H}{N}$, $\frac{F/N}{W}$, and $\frac{z}{F/N}$.
(2) In column 3 the timing of hiring costs and production is set to occur within the same month.
(3) In column 4 five lags are used.
(4) In column 5 $\frac{H}{N}$ is dropped from the instrument set.
(5) The sample period is 1975:01–1989:12 in column 1 and 1980:05–1989:12 in columns 2–6.
(6) Standard errors are in parentheses.

APPENDIX C: THE APPROXIMATION

This appendix shows the derivation of the approximate present value relationship and its first two moments following Cochrane (1992).

Starting from the exact present value relationship:

$$\Gamma\left(\frac{H_t}{N_t}\right) = E_t\left[\sum_{j=1}^{\infty} \exp\left[\sum_{i=1}^{j}\left(n^f_{t+i} - g^s_{t+i} - g^r_{t+i}\right)\right] MP_{t+j}\right]. \tag{21}$$

Define $P_t \equiv \Gamma(H_t/N_t)$, $w_{t+i} \equiv (n^f_{t+i} - g^s_{t+i} - g^r_{t+i})$, $\tilde{w}_{t+i} = w_{t+i} - E(w)$, $\widetilde{MP}_{t+j} = MP_{t+j} - E(MP)$, and $\Omega = e^{E(w)}$.

Multiply both sides of (21) by any variable Z_t observed at time t and take expectations:

$$E(Z_t P_t) = E\left[Z_t \sum_{j=1}^{\infty} \exp\left[\sum_{i=1}^{j}(w_{t+i})\right] MP_{t+j}\right]. \tag{22}$$

We now take a second-order Taylor expansion of the expression in the brackets with respect to Z_t, MP_{t+j}, and w_{t+j} around their respective means $E(Z)$, $E(MP)$, and $E(w)$:

$$\begin{aligned} &Z_t \sum_{j=1}^{\infty} \exp\left[\sum_{i=1}^{j}(w_{t+i})\right] MP_{t+j} \\ &\quad\cong Z_t \frac{\Omega}{1-\Omega} E(MP) + Z_t \frac{E(MP)}{1-\Omega} \sum_{j=1}^{\infty}\left(\Omega^j \tilde{w}_{t+j}\right) \\ &\qquad + Z_t \sum_{j=1}^{\infty} \Omega^j \widetilde{MP}_{t+j} + E(Z) \sum_{j=1}^{\infty} \Omega^j \widetilde{MP}_{t+j} \tilde{w}_{t+j} \\ &\qquad + \frac{1}{2}\frac{E(Z)E(MP)}{1-\Omega} \sum_{j=1}^{\infty}\left[\Omega^j\left(\tilde{w}^2_{t+j} + 2\sum_{k=1}^{\infty}\Omega^k \tilde{w}_{t+j}\tilde{w}_{t+j+k}\right)\right]. \end{aligned} \tag{23}$$

Taking expectations:

$$\begin{aligned} E(Z_t P_t) &\cong E(Z)E(MP)\left[\frac{\Omega}{1-\Omega} + \frac{\Omega}{2(1-\Omega)^2} \sum_{j=-\infty}^{\infty} \Omega^{|j|} \operatorname{cov}(w_t, w_{t-j})\right] \\ &\qquad + E(Z)\left(\sum_{j=1}^{\infty} \Omega^j \operatorname{cov}\left(MP_{t+j} w_{t+j}\right)\right) \\ &\qquad + E\left(Z_t \sum_{j=1}^{\infty}\left(\Omega^j \widetilde{MP}_{t+j}\right)\right) + \frac{E(MP)}{1-\Omega} E\left(Z_t \sum_{j=1}^{\infty}\left(\Omega^j \tilde{w}_{t+j}\right)\right). \end{aligned} \tag{24}$$

Since the equation holds for all variables Z_t known at time t it is equivalent to

$$P_t \cong E(MP)\left[\frac{\Omega}{1-\Omega} + \frac{\Omega}{2(1-\Omega)^2}\sum_{j=-\infty}^{\infty}\Omega^{|j|}\operatorname{cov}(w_t, w_{t-j})\right] + \sum_{j=1}^{\infty}\Omega^j \operatorname{cov}\left(MP_{t+j}w_{t+j}\right) + E_t\left(\sum_{j=1}^{\infty}\left(\Omega^j\widetilde{MP}_{t+j}\right)\right) + \frac{E(MP)}{1-\Omega}E_t\left(\sum_{j=1}^{\infty}\left(\Omega^j\tilde{w}_{t+j}\right)\right). \qquad (25)$$

The *unconditional* expected value of (25) is

$$E(P) = E(MP)\left[\frac{\Omega}{1-\Omega} + \frac{\Omega}{2(1-\Omega)^2}\sum_{j=-\infty}^{\infty}\Omega^{|j|}\operatorname{cov}(w_t, w_{t-j})\right] + \sum_{j=1}^{\infty}\Omega^j \operatorname{cov}\left(MP_{t+j}w_{t+j}\right). \qquad (26)$$

Multiplying (25) by $P_t - E(P)$ and taking expectations yields the variance decomposition:

$$\operatorname{var}(P) = \frac{E(MP)}{1-\Omega}\sum_{j=1}^{\infty}\Omega^j\operatorname{cov}\left(P_t, n_{t+j}^f\right) + \frac{E(MP)}{1-\Omega}\sum_{j=1}^{\infty}\Omega^j\operatorname{cov}\left(P_t, -g_{t+j}^s\right) \times \frac{E(MP)}{1-\Omega}\sum_{j=1}^{\infty}\Omega^j\operatorname{cov}\left(P_t, -g_{t+j}^r\right) + \sum_{j=1}^{\infty}\Omega^j\operatorname{cov}\left(P_t, MP_{t+j}\right). \qquad (27)$$

These are Eqs. (18) and (19) in the text.

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