EUROPEAN SUMMER SYMPOSIUM IN INTERNATIONAL MACROECONOMICS (ESSIM) 2010

Hosted by
Banco de España

Tarragona, Spain; 25-28 May 2010

On The Joint Behavior of Hiring and Investment

Eran Yashiv

On The Joint Behavior of Hiring and Investment

Eran Yashiv*
Tel Aviv University and CEPR

May 10, 2010

Abstract

Investment and hiring behavior plays a key role in macroeconomic models of the business cycle. This paper examines their **joint** behavior in the aggregate U.S. economy.

Gross investment and gross hiring of workers are highly volatile and display a negative correlation – investment rates are pro-cyclical while hiring rates are weakly counter-cylical. The paper explains this behavior using a Q-type model, without resorting to stock market data, presenting new results.

Estimates of the optimality conditions driving hiring and investment include a formulation of adjustment costs, which allows for the interaction of hiring and investment costs. This formulation proves crucial for the ability of the model to fit the data. The results show why ignoring investment costs, hiring costs or their interaction yields poor empirical reults.

Using a log-linear approximation of the estimation results, a variance decomposition analysis of the present values of hiring and investment is undertaken. It shows that investment and hiring are driven differentially by their determinants – labor and capital productivites and the relevant discount rates. Productivity is important for hiring, discounting for investment.

Key Words: aggregate investment, gross hiring, business cycles, adjustment costs, Q model, present value.

*yashiv@post.tau.ac.il; www.tau.ac.il/~yashiv/

On The Joint Behavior of Hiring and Investment[1]

1 Introduction

This paper studies the joint behavior of hiring and investment using aggregate U.S. data. The importance of these decisions for aggregate activity cannot be overstated. Yet the treatment in much of the literature has either focused on the behavior of one and not both, or has posited costs pertaining to one but not the other. All too often empirical work has reported weak results, such as lack of fit or the need to postulate implausibly large adjustment costs to explain the data. This paper shows that costs matter for both capital and labor adjustment, that the interaction between them is crucial, and that the model is able to fit the data with moderate adjustment costs.

The paper uses a Q-type model for both gross investment and gross hiring. It does not rely on stock market data but rather on structural estimation of the firms' optimality conditions. This is done with private-sector U.S. data and pertains to gross investment and gross hiring flows, as distinct from net changes. A key object of estimation is the adjustment costs function, where I allow for a more general formulation of costs than typically estimated.[2] The results are used to explain the business cycle behavior (co-movement, volatility, persistence) of hiring and investment.

The analysis shows that while investment and hiring occur simultaneously they do not move together nor do they have similar cyclical properties. Moderate adjustment costs are sufficient to fit the data. Investment seems to be linked more to movements in the price of investment goods, in the interest rate and in the rate of depreciation than to changes in capital productivity. Hiring seems to be linked more to changes in labor profitability and less to the movements in the interest rate and in the rate of worker separation.

The paper proceeds as follows: Section 2 presents the business cycle facts of investment and hiring in the U.S. economy and briefly references the literature. Section 3 presents the firm's optimization problem and the resulting optimality conditions. Section 4 discusses estimation, including the data and the econometrics, and presents the results. Section 5 uses the results to look

[1] *I thank Richard Rogerson, Gianluca Violante, and conference and seminar participants at the Fundacion Rafael del Pino in Madrid (September 2009), at the LMDG meeting in Sandbjerg, Denmark (October 2009) and at Tel Aviv University for helpful comments, and Tanya Baron, Ofer Cornfeld and Darina Waisman for research assistance. All errors are my own.*

[2] In previous work, Monika Merz and I (Merz and Yashiv (2007)) have shown that knowledge of this function allows one to define asset values for hiring and for investment and that these can be used to explain equity values of firms in the U.S. economy.

at the implied magnitude of adjustment costs. Section 6 approximates and decomposes the present value of hiring and investment which drive these decisions. Section7 explores the implications of the results for the co-movement of hiring and investment. Section 8 looks at the resulting business cycle behavior of investment and hiring and their determinants. Section 9 concludes. Technical matters and data issues are examined in the appendices.

2 Background

In this section I look at the business cycle facts of investment and hiring in aggregate U.S. data and very briefly reference the literature dealing with them.

2.1 Business Cycle Facts

In the analysis below it will be shown that the relevant variables in the decision problems of firms are the gross hiring rate $\frac{h}{n}$ and the gross investment rate $\frac{i}{k}$. Figure 1 plots these series in the U.S. economy.[3] The figure has four panels. Panel (a) shows the raw series. Panels (b) and (c) show separately the logged series in levels and in HP-filtered terms together with NBER-dated recessions. Panel (d) shows the logged, HP filtered series of investment and hiring with the NBER-dated recessions.

Figure 1

Inspection of the figures reveals that the investment and hiring rates series are different in terms of volatility, do not move together, and have markedly different cyclical behavior (investment is pro-cyclical while hiring is a- or counter-cyclical).

Table 1 provides a quantitative view of these features. It looks at the stochastic behavior of investment and hiring in logged, HP-filtered terms, for the levels (h and i) and for the rates ($\frac{h}{n}$ and $\frac{i}{k}$). Panel (a) presents volatility statistics – own and relative to three measures of the cycle (non-financial business sector GDP f, labor productivity $\frac{f}{n}$ and capital productivity $\frac{f}{k}$). Panel (b) presents persistence statistics, i.e., the auto-correlations of each series. Panel (c) presents co-movement statistics, the dynamic correlations of investment and hiring and their co-movement with the three cyclical measures.

Table 1

[3] The data are further discussed in Section 4.2 below.

Several features stand out in Table 1:

Volatility. Both hiring rate and investment are highly volatile relative to the cyclical measures, though investment is much more so. There is no essential difference between levels and rates.

Persistence. Investment is highly persistent, but hiring is not. Again, there is no essential difference between levels and rates.

Co-movement. Gross hiring and gross investment rates exhibit very weak correlation, both contemporaneously and at leads and lags, tending towards weak negative correlation. Both contemporaneously and dynamically, hiring (both in levels and in rates) is basically a-cyclical, with respect to the three cyclical variables. The hiring rate even tends to be counter-cyclical at lags and leads. With respect to the same cyclical measures, investment (both in levels and in rates) is pro-cyclical, sometimes strongly so. This is so both contemporaneously and at leads and lags of up to a year. Beyond that, the relationship turns negative. Note that while all cyclical measures lead the investment rate a year ahead and have a fairly clear positive relationship with it, the hiring rate seems to move in a way unrelated to the cycle. That is, increases in productivity do not seem to be associated with increases in the hiring rate.

To put the behavior of the hiring rate in further perspective, consider other labor market variables, which are often discussed in the literature. Table 2 repeats the moments of panels (a) and (c) of Table 1 for the employment stock n_t, gross hiring flows h_t, the gross hiring rate $\frac{h_t}{n_t}$, and the job finding rate (out of unemployment (u) and the pool of workers out of the labor force (o_t)) denoted $\frac{h_t}{u_t+o_t}$.

Table 2

The table shows the following. First, there is a difference between stocks and flows. While the employment stock n is less volatile than GDP, is about as volatile as average labor productivity and is pro-cyclical, the gross hiring rate is more volatile than GDP, twice as volatile as average labor productivity and is moderately counter-cyclical. Second, the job finding rate $\frac{h_t}{u_t+o_t}$ is more volatile than GDP and average productivity and is pro-cyclical. Third, the hiring *rate* (out of employment $\frac{h_t}{n_t}$) is as volatile as the hiring flow h in levels but is somewhat more counter-cyclical than this flow; it is a-cyclical with respect to productivity and mildly counter-cyclical with respect to GDP.

In what follows, the gross hiring rate $\frac{h_t}{n_t}$ will be a key variable in the analysis. Hence it is useful to keep in mind that, in line with these features, it behaves differently from the employment stock n and is not to be confused with the job finding rate $\frac{h_t}{u_t+o_t}$.

Some of these stylized facts are not easy to explain. One needs to explain investment which is both volatile and persistent; one feature usually comes at the expense of the other. One also needs to account for the fact that hiring and investment move in opposite ways; intuitively we may think that if investment rises, hiring should rise too, at least with a lag. In fact investment is both very volatile and pro-cyclical and hiring is less volatile and a- or counter-cyclical.

Why did the literature give little, if any, attention to these facts? This is so probably because business cycle models usually do not look at gross hiring flows, but rather at the employment stock. Search and matching models look at gross hiring flows but typically do not consider investment. Hence the two – investment and hiring – are usually not examined together. This is consistent with the literature review to which I turn now.

2.2 Literature

The current paper relates to a number of strands in the literature.

Hiring in search and matching models (see Pissarides (2000), Rogerson Shimer,and Wright (2005), Yashiv (2007) and Rogerson and Shimer (2010) for surveys) feature optimal hiring decisions in the face of costs. The first order condition for optimal hiring given below is a key ingredient in these models. However, most of this literature does not include capital as a factor of production and when it does include capital, it is typically not subject to adjustment costs. Moreover, a large part of this literature posits very simple hiring costs, usually a linear function of the number of job vacancies. Thus it usually states that marginal hiring costs are fixed and their value is typically calibrated at small to moderate values.

Models with *labor adjustment costs* have been studied for half a century. Hamermesh (1993) provides a useful discussion. Most studies typically relate to net employment changes as distinct from gross changes of the type examined here, and have ignored any interaction with capital.

Tobin's-Q investment models have been studied extensively for four decades, since the seminal contribution of Tobin (1969); see Hayashi (1982), Erickson and Whited (2000) and Philippon (2009) for comprehensive discussions. The idea in these models is that adjustment costs are key to the understanding of investment behavior. Q models have encountered a lot of empirical difficulties and have engendered much debate. Like search and matching models, much of this literature does not feature the other factor of production, namely labor. Below, I present a formulation of Tobin's Q which allows for the interaction of capital adjustment costs and hiring costs; when presenting the results I provide a comparison with the results of ten key studies in this Q literature

Models of the business cycle evidently feature optimal hiring and investment decisions. Most of it does not feature adjustment costs, though a large part of the RBC literature assumed lags in the installation of capital. More recent RBC models and the latest vintage of business cycle models, such as Christiano, Eichenbaum and Evans (2005) or Smets and Wouters (2007), posit adjustment costs for investment and no frictions in hiring; there is also no explicit interaction between the two.

Finally, *New Keynesian models of the Phillips curve* (see, for example, Gali (2008)) posit that inflation is a function of future expected marginal costs. The costs discussed in this paper would be a part of such marginal costs and hence would play a role in the determination of inflation in these models.

3 The Model

I delineate a partial equilibrium model which serves as the basis for estimation.[4] There are identical workers and identical firms, who live forever and have rational expectations. It takes time and resources for firms to adjust their capital stock and hire new workers. All variables are expressed in terms of the output price level. Firms make investment (i) and hiring (h) decisions.[5] Once a new worker is hired, the firm pays her a per-period wage w. Firms use physical capital (k) and labor (n) as inputs in order to produce output goods y according to a constant-returns-to-scale production function f with productivity shock z:

$$y_t = f(z_t, n_t, k_t), \tag{1}$$

Gross hiring and gross investment are costly activities. Hiring costs include advertising, screening, and training. In addition to the purchase costs, investment involves capital installation costs, learning the use of new equipment, etc. Adjusting labor or capital involves disruptions to production, and potentially also the implementation of new organizational structure within the firm and new production practices. All of these costs reduce the firm's profits. I 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. I allow hiring costs and capital adjustment costs to interact. I spec-

[4] This follows the analysis in Merz and Yashiv (2007). The parts concerned with the labor market are consistent with the prototypical search and matching model within a stochastic framework. See Pissarides (2000) and Yashiv (2007).

[5] In the standard search and matching model, gross hires are labeled new job-matches.

ify the functional form of g and discuss its properties 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:

$$k_{t+1} = (1 - \delta_t)k_t + i_t, \quad 0 \leq \delta_t \leq 1. \tag{2}$$

Similarly, workers separate at the rate ψ_t. It is augmented by new hires h_t:

$$n_{t+1} = (1 - \psi_t)n_t + h_t, \quad 0 \leq \psi_t \leq 1. \tag{3}$$

Note that hiring and separations are both gross flows and that the latter is time-varying.

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

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

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

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

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

The discount factor between periods $t+j-1$ and $t+j$ for $j \in \{1, 2, ...\}$ is given by:

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

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

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

$$\max_{\{i_{t+j}, h_{t+j}\}} E_t \left\{ \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} \beta_{t+i} \right) cf_{t+j} \right\} \tag{6}$$

subject to the definition of cf_{t+j} in equation (5) and the constraints (2) and (3). The firm takes the paths of the variables w, p^I, δ, ψ, and β as given. The

Lagrange multipliers associated with these two constraints are Q_{t+j}^{K} and Q_{t+j}^{N}, respectively. These Lagrange multipliers can be interpreted as marginal Q for physical capital, and marginal Q for employment, respectively.

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

$$\begin{aligned}
Q_t^K &= E_t \left\{ \beta_{t+1} \left[(1-\tau_{t+1}) \left(f_{k_{t+1}} - g_{k_{t+1}} \right) + (1-\delta_{t+1}) Q_{t+1}^K \right] \right\} && (7) \\
Q_t^K &= (1-\tau_t) \left(g_{i_t} + p_t^I \right) && (8) \\
Q_t^N &= E_t \left\{ \beta_{t+1} \left[(1-\tau_{t+1}) \left(f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1} \right) + \left(1-\psi_{t+1} \right) Q_{t+1}^N \right] \right\} && (9) \\
Q_t^N &= (1-\tau_t)\, g_{h_t} && (10)
\end{aligned}$$

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

$$p_{t+j}^I = \frac{1-\chi_{t+j} - \tau_{t+j} D_{t+j}}{1-\tau_{t+j}}\, \widetilde{p}_{t+j}^I. \tag{11}$$

Dynamic optimality requires the following two transversality conditions to be fulfilled

$$\begin{aligned}
\lim_{T\to\infty} E_T \left(\beta_T\, Q_T^K\, k_{T+1} \right) &= 0 && (12) \\
\lim_{T\to\infty} E_T \left(\beta_T\, Q_T^N\, n_{T+1} \right) &= 0.
\end{aligned}$$

I can summarize the firm's first-order necessary conditions from equations (7)-(10) by the following two expressions:

$$\begin{aligned}
(1-\tau_t) \left(g_{i_t} + p_t^I \right) &= E_t \left\{ \beta_{t+1} (1-\tau_{t+1}) \left[\begin{array}{c} f_{k_{t+1}} - g_{k_{t+1}} \\ +(1-\delta_{t+1})(g_{i_{t+1}} + p_{t+1}^I) \end{array} \right] \right\} && (13) \\
(1-\tau_t)\, g_{h_t} &= E_t \left\{ \beta_{t+1} (1-\tau_{t+1}) \left[\begin{array}{c} f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1} \\ +(1-\psi_{t+1}) g_{h_{t+1}} \end{array} \right] \right\}. && (14)
\end{aligned}$$

Solving equation (7) forward and using the law of iterated expectations expresses Q_t^K as the expected present value of future marginal products of physical capital net of marginal capital adjustment costs:

$$Q_t^K = E_t \left\{ \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} \beta_{t+1+i} \right) \left(\prod_{i=0}^{j} (1-\delta_{t+1+i}) \right) (1-\tau_{t+1+j}) \left(f_{k_{t+1+j}} - g_{k_{t+1+j}} \right) \right\}. \tag{15}$$

It is straightforward to show that in the special case of time-invariant discount factors, no adjustment costs, no taxes, and a perfectly competitive market for capital, Q_t^K equals one. Similarly, solving equation (9) forward and using the law of iterated expectations expresses Q_t^N as the expected present value of the future stream of surpluses arising to the firm from an additional hire of a new worker:

$$Q_t^N = E_t\left\{\sum_{j=0}^{\infty}\left(\prod_{i=0}^{j}\beta_{t+1+i}\right)\left(\prod_{i=0}^{j}(1-\psi_{t+1+i})\right)(1-\tau_{t+1+j})\left(f_{n_{t+1+j}} - g_{n_{t+1+j}} - w_{t+1+j}\right)\right\}. \tag{16}$$

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

4 Estimation

I estimate equations (13) and (14), using structural estimation, where the adjustment cost function g is the main object. I now present the parameterization of this function (as well as of the production function), the data, and the econometric methodology.

4.1 Methodology

4.1.1 Parameterization

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

$$f(z_t, n_t, k_t) = e^{z_t} {n_t}^{\alpha} k_t^{1-\alpha},\ 0 < \alpha < 1. \tag{17}$$

For the adjustment costs function g, I use a convex function to be delineated below. Recent work by Cooper and Haltiwanger (2006), Kahn and Thomas (2008) and Bloom (2009) gives empirical support to the use of a convex adjustment costs function.[6] These papers show that while non-convexities matter at the micro level, a convex formulation is appropriate at the aggregate, macroeconomic level.

The specifications to be used capture the idea that adjustment costs increase 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 functions used postulate that costs are proportional to output, and that they increase in the investment and hiring rates. More

[6] See the discussion on pages 628 and 629 of Cooper and Haltiwanger (2006), pages 417-421 in Kahn and Thomas (2008), and page 665 in Bloom (2009).

specifically, the terms in the function relating to hiring may be justified as follows (drawing on Garibaldi and Moen (2008)): suppose each worker i makes a recruiting and training effort h_i; as this is a convex function it is optimal to spread out the efforts equally across workers so $h_i = \frac{h}{n}$; formulating the costs as a function of these efforts and putting them in terms of output per worker I get $c\left(\frac{h}{n}\right)\frac{f}{n}$; as n workers do it then the aggregate adjustment cost function is $c\left(\frac{h}{n}\right)f$.

The parametric form I use is the following, generalized convex function.

$$g(\cdot) = \left[\frac{e_1}{\eta_1}(\frac{i_t}{k_t})^{\eta_1} + \frac{e_2}{\eta_2}(\frac{h_t}{n_t})^{\eta_2} + \frac{e_3}{\eta_3}\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3}\right] f(z_z, n_t, k_t). \tag{18}$$

This function is linearly homogenous in its four arguments i, h, k and n. The term associated with e_3 expresses the interaction of capital and labor adjustment costs. The parameters e_l, $l = 1, 2, 3$ express scale, and η_l express the elasticity of adjustment costs with respect to the different arguments. The function encompasses the widely used quadratic case for which $\eta_1 = \eta_2 = 2$. Note that a standard search and matching model (as in Pissarides (2000)) postulates $e_1 = e_3 = 0, \eta_2 = 1$ and a standard Tobin's Q model postulates $e_2 = e_3 = 0$ and $\eta_1 = 2$.

The estimates of the parameters in these functions allow for the quantification of the derivatives g_{i_t} and g_{h_t} that appear in the firms' optimality equations (13) and (14).

4.1.2 Structural Estimation

I structurally estimate the firms' first-order conditions (13) and (14), using Hansen's (1982) generalized method of moments (GMM). The moment conditions estimated are those obtained under rational expectations. That is, the firms' expectational errors are orthogonal to any variable in their information set at the time of the investment and hiring decisions. The moment conditions are derived by replacing expected values with actual values plus expectational errors j and specifying that the errors are orthogonal to the instruments Z, i.e., $E(j_t \otimes Z_t) = 0$. I formulate the equations in stationary terms by dividing (13) by $\frac{f_t}{k_t}$ and (14) by $\frac{f_t}{n_t}$.

The estimating equations errors j_t are thus given by:

$$j_t^1 = \frac{(1-\tau_t)\left(g_{i_t}+p_t^I\right)}{\frac{f_t}{k_t}} - \left\{ \frac{\frac{f_{t+1}}{k_{t+1}}}{\frac{f_t}{k_t}} \beta_{t+1}\left(1-\tau_{t+1}\right) \frac{\left[f_{k_{t+1}} - g_{k_{t+1}} + (1-\delta_{t+1})(g_{i_{t+1}} + p_{t+1}^I)\right]}{\frac{f_{t+1}}{k_{t+1}}} \right\} \quad (19)$$

$$j_t^2 = \frac{(1-\tau_t)\, g_{h_t}}{\frac{f_t}{n_t}} - \left\{ \frac{\frac{f_{t+1}}{n_{t+1}}}{\frac{f_t}{n_t}} \beta_{t+1}\left(1-\tau_{t+1}\right) \frac{\left[f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1} + (1-\psi_{t+1}) g_{h_{t+1}}\right]}{\frac{f_{t+1}}{n_{t+1}}} \right\} \quad (20)$$

Appendix A spells out the first derivatives included in these equations.

I explore a number of alternative specifications:

1) *The degree of convexity of the g function.* A major issue proves to be the form and degree of convexity of the g function. The literature has for the most part assumed quadratic adjustment costs. I examine restricted and free estimation of the power parameters.

2) *Instrument sets.* I use alternative instrument sets in terms of variables and number of lags.

I compute the J-statistic test of the overidentifying restrictions proposed by Hansen (1982). I also check whether the estimated g function fulfills the convexity requirement.

4.2 The Data

The data are quarterly, pertain to the private sector of the U.S. economy, and cover the period 1976-2007. They include NIPA data on GDP and its deflator, capital, investment, the price of investment goods and depreciation, BLS data on employment and on worker flows, and Fed data on the constituents of the discount factor and on tax and depreciation allowances (Fed computations). Appendix B elaborates on the sources and on data construction. These data have the following features:

(i) The data pertain to the U.S. private sector, thus not confounding the analysis with government hiring and investment.

(ii) Both hiring h and investment i refer to gross flows. Likewise, separation of workers ψ and depreciation for capital δ are gross flows.

(iii) The estimating equations take into account taxes and depreciation allowances.

Points (ii) and (iii) require a substantial amount of computation, which is elaborated in Appendix B.

Table 3 presents key sample statistics.

Table 3

4.3 Results

Table 4 presents the estimates of the parameters and the implied adjustment costs. The table specifies the restrictions imposed, the estimates and their standard errors, Hansen's (1982) J-statistic and its p-value, and the mean and standard deviation of $\frac{g}{f}$, $\frac{g_i}{f/k}$ and $\frac{g_h}{f/n}$ in the sample.

Panel (a) fixes the power parameters in the adjustment cost function (and also sets $\alpha = 0.68$). Column (1) fixes values at $\eta_1 = 4, \eta_2 = 3.5$ and $\eta_3 = 2$; these values were obtained after some experimentation and following the unconstrained estimates reported in panel (b). To facilitate comparison with the literature, column (2) takes the standard case of the Q literature whereby there are only quadratic costs for adjusting capital ($e_2 = e_3 = 0; \eta_1 = 2$); column (3) takes the standard case from the search and matching literature with linear hiring costs ($e_1 = e_3 = 0; \eta_2 = 1$); and column (4) allows quadratic investment and hiring costs but no interaction term ($\eta_1 = \eta_2 = 2; e_3 = 0$).

Panel (b) estimates some or all of the powers, proceeding gradually. Column (5) allows for unconstrained, free estimation of η_1 and η_2, and constrains the interaction to be linear $\eta_3 = 1$. Column (6) allows for one power parameter to be freely estimated, fixing the other two in relation to the freely estimated parameter. Column (7) allows for two of the power parameters to be freely estimated, fixing the third in relation to the freely estimated parameter. Columns (8) and (9) allow for free estimation of all power parameters, with α also freely estimated in column (9).

Table 4

In panel (a), column (1) produces reasonable results and is to be used below as one benchmark specification. There are problems with all other results of this panel. Column (2), the standard quadratic investment costs specification, yields costs that are twice as high as those reported in column (1), for both total and marginal costs. This issue will be further discussed below. The J-statistic test rejects the specification of column (3), which is the linear hiring costs specification typically used in search and matching models. Column (4), with quadratic costs for both investment and hiring but no interaction, yields negative marginal investment costs.

Panel (b) shows that the powers are estimated around 4 for η_1, 3.5 for η_2 and 2 for η_3. The standard error of these estimates is low. Hence the estimated function has a higher degree of convexity than the quadratic. When α is freely estimated in column (9), the point estimate is 0.68 with a low standard error, in line with conventional results. As to the scale estimates, i.e., estimates of e_1, e_2, e_3, the more power parameters are freely estimated, the higher are the standard errors of the scale estimates. Overall the curvature of the function is more precisely estimated than the scale. Throughout the panel, p-values of the J-statistics are higher than those of panel (a). The g function implied by the estimates is reasonable across all specifications and satisfies convexity requirements. In what follows, I use column (9) as a second benchmark specification. Using both columns (1) and (9) as benchmark specifications accommodates the variation in the scale estimates.

In order to characterize the joint behavior of investment and hiring, these estimation results can be further analyzed in a number of directions. I start by looking at the magnitude of adjustment costs, comparing them to the findings in the literature (Section 5). I then look at the right hand side of the optimality equations and approximate and decompose the present value of hiring and investment which drive these decisions (Section 6). The next section (7) explores the implications of the results for the co-movement of hiring and investment. Finally, Section 8 looks at the business cycle behavior of investment and hiring and their determinants.

5 The Value of Adjustment Costs

As seen in Table 4, the results allow me to construct time series for total and marginal adjustment costs by using the point estimates of the parameters of the g function. How do these compare to the literature?

Total costs as a fraction of GDP (i.e. $\frac{g}{f}$) are around 2% of output according to all specifications, a reasonable estimate, as will be discussed below.

Marginal costs of hiring (i.e. g_h) in terms of average output per worker ($\frac{f}{n}$) have a sample mean of 0.28 in column (1) and of 0.14 in column (9) of Table 4. This is roughly equivalent to 42% (column 1) or 21% (column 9) of quarterly wages (these are 66% of output per worker on average, see Table 3). In other words, firms pay on the margin the equivalent of about 3 to 5.5 weeks of wages to hire the marginal worker. How does one evaluate this estimate? There is little empirical evidence on the quantitative importance of such adjustment costs. Mortensen and Nagypal (2006, page 30) note that "Although there is a consensus that hiring costs are important, there is no authoritative estimate of their magnitude. Still, it is reasonable to assume that in order to recoup hiring costs, the firm needs to employ a worker for at least two to three quarters. When wages are equal to their median level in the standard model (w = 0.983), hiring costs of this magnitude correspond to less than a week of wages." The widely-cited Shimer (2005) paper calibrates these costs at 0.213 in terms similar to g_h here, using a linear cost function. Hagedorn and Manovskii (2008) decompose this cost into two components: (i) the capital flow cost of posting a vacancy; they compute it to be – in steady state – 47.4 percent of the average weekly labor productivity; (ii) the labor cost of hiring one worker, which, relying on micro-evidence, they compute to be 3 percent to 4.5 percent of quarterly wages of a new hire. The first component would correspond to a figure of 0.037 here; the second component would correspond to a range of 0.02 to 0.03 in the terms used here; together this implies 0.057 to 0.067 in current terms (or around 1.1 to 1.3 weeks of wages). Thus the results of column (1) here are slightly higher than Shimer (2005), and the results of column (9) somewhat higher than those suggested by Mortensen and Nagypal (2006) or Hagedorn and Manovskii (2008).

Older, micro evidence suggests a wide range of estimates, but generally higher costs than those surveyed above (see Hamermesh (1993, pp. 207-209)). Note, too, that these latter studies typically pertain to costs of net employment changes ($n_t - n_{t-1}$), as distinct from gross hiring (h_t). Hence, there is no solid benchmark in this type of studies against which to compare the current estimates.

The marginal costs of investment (i.e. g_i) in terms of average output per unit of capital ($\frac{f}{k}$) have a sample mean of 1.24 in column (1) and of 2.04 in column (9) of Table 4.[7] How reasonable are these estimates? The most natural place to look for comparisons is the Q-literature. Table 5 presents ten estimates of the investment equation from this literature. The equation links the investment-to-capital ratio to a measure of Tobin's Q. Note that these studies differ from each other and from the current study on many dimensions: the data sample used, the functional form assumed for marginal adjustment costs, additional variables included in the cost function, treatment of tax issues, and reduced form vs. structural estimation. Estimates of the curvature of the marginal cost function may be conditional on additional variables included in the analysis and reduced form estimates may be consistent with several alternative underlying structural models. The studies often came in response to previous estimates, each trying to introduce changes so as to improve on the preceding ones; some of these changes were substantial. Hence, Table 5 cannot give more than a rough idea as to the "neighborhood" of adjustment costs estimates.

Table 5

The table shows huge variation across studies: it ranges from marginal costs as low as 0.04 to as high as 60 (in terms of $\frac{f}{k}$). It should be noted that the differences in marginal cost estimates are usually due to differences

[7] The units of measurement – in terms of output per unit of capital – were chosen so as to facilitate comparison with existing studies, as discussed below.

in the parameter estimates, and not just due to the diversity in the rate of investment used. One can divide the results into three sets:

(i) High adjustment costs, as in studies 1 and 2. Marginal costs range between 3 to 60 in terms of average output per unit of capital. The implied total costs range between 15% to 100% of output. This set characterizes the earlier studies.

(ii) Moderate adjustment costs, as in studies 3, 5 and 6b. Marginal costs are around 1 in terms of average output per unit of capital. Total costs range between 0.5% to 6% of output.

(iii) Low adjustment costs, as in the rest of the studies, namely 4, 6a, 7, 8, 9 and 10. Marginal costs are 0.04 to 0.50 of average output per unit of capital. Total costs range between 0.1% to 0.2% of output.

Coming back to the initial question of comparing these estimates to the current findings, two conclusions emerge:

(i) The specification that I run that is closest to the one used in most studies of Table 5 is the one reported in column (2) of Table 4. This is the specification positing a quadratic function and ignoring labor. The implied total costs are 4.2% of output (as in studies of the moderate adjustment costs set) and the implied marginal costs are 3.36 of average output per unit of capital (as in the high adjustment costs set).

(ii) The preferred specification – the GMM results of the full model – cannot be directly compared to the results of Table 5, as they take into account hiring costs through the interaction between hiring and investment costs and have a convex specification. In formal terms the marginal investment costs are specified by $\frac{g_i}{\frac{f}{k}} = \left[e_1 \left(\frac{i}{k}\right)^{\eta_1 - 1} + e_3 \left(\frac{h}{n}\right)^{\eta_3} \left(\frac{i}{k}\right)^{\eta_3 - 1}\right]$ while most specifications of Table 5 posit $g_i = e_1 \frac{i}{k}$. In particular, the expression in the current paper depends on $\frac{h}{n}$ in a substantial way. Nevertheless, looking at total adjustment costs as a fraction of output $(\frac{g}{f})$, estimated at 2%, and marginal costs as a fraction of output per unit of capital $(\frac{g_i}{\frac{f}{k}})$, estimated at a mean of 1.2 or 2, the findings of Table 4 correspond to the second set, i.e., to moderate adjustment costs.

6 Decomposition of the Present Values of Investment and Hiring

In this sub-section I follow the asset pricing literature in finance and decompose the present value relationships governing hiring and investment. This permits the study of the determinants of hiring and investment, using approximated relations.

Asset pricing theory shows that the stock price (P) and dividends (D) have the following two-period representation:[8]

$$\begin{aligned} P_t &= E_t\left(R_{t+1}^{-1}[D_{t+1} + P_{t+1}]\right) \\ \frac{P_t}{D_t} &= E_t\left(R_{t+1}^{-1}[\frac{D_{t+1}}{D_t} + \frac{D_{t+1}}{D_t}\frac{P_{t+1}}{D_{t+1}}]\right) \end{aligned} \tag{21}$$

where R is the gross discount rate. Iterated forward this yields:

$$\frac{P_t}{D_t} = E_t\left(\sum_{j=1}^{\infty}\left(\prod_{k=1}^{j} R_{t+k}^{-1}\frac{D_{t+k}}{D_{t+k-1}}\right)\right) \tag{22}$$

This can be approximated as:

$$p_t - d_t = k + E_t\left(d_{t+1} - d_t - r_{t+1} + \rho(p_{t+1} - d_{t+1})\right) \tag{23}$$

where:

$$\begin{aligned} p_t &\equiv \ln P_t \\ d_t &= \ln D_t \\ r_t &= \ln R_t \\ k &= \ln(1 + \frac{P}{D}) - \rho(p - d) \\ \rho &= \frac{\frac{P}{D}}{1 + \frac{P}{D}} \end{aligned}$$

and where P, D are steady state or long-term average values.

The above are ex-ante formulations using conditional expectations. Because it is based on an identity, the following ex-post equation holds true as well:

$$p_t - d_t = k + (d_{t+1} - d_t - r_{t+1} + \rho(p_{t+1} - d_{t+1})) \tag{24}$$

Based on (24), the following ex-post relations in levels and in variance hold true in approximation:

[8] The following is based on Campbell and Shiller (1988). Cochrane (2005, Chapter 20), whose notation I follow, and Lettau and Ludvigson (2009) provide surveys and discussion of its empirical implications, data evidence, significance for asset pricing, and associated issues. It is often referred to as the dynamic dividend growth model.

$$p_t - d_t \simeq \sum_{j=1}^{\infty} \rho^{j-1} k + \left(\sum_{j=1}^{\infty} \rho^{j-1} \left(d_{t+j+1} - d_{t+j} - r_{t+j} \right) \right) \tag{25}$$

$$\begin{aligned} var(p_t - d_t) &\simeq cov\left[p_t - d_t, \sum_{j=1}^{\infty} \rho^{j-1} \left(d_{t+j+1} - d_{t+j} \right) \right] \\ &\quad - cov\left[p_t - d_t, \sum_{j=1}^{\infty} \rho^{j-1} r_{t+j} \right] \end{aligned} \tag{26}$$

In the case to be examined below R has several components, so:

$$\begin{aligned} R_t &= R_t^A * R_t^B * R_t^C \\ r_t &= \ln(R_t^A * R_t^B * R_t^C) \\ &= \ln R_t^A + \ln R_t^B + \ln R_t^C \\ &= r_t^A + r_t^B + r_t^C \end{aligned}$$

and (26) becomes:

$$\begin{aligned} cov\left[p_t - d_t, \sum_{j=1}^{\infty} \rho^{j-1} r_{t+j} \right] &\simeq cov\left[p_t - d_t, \sum_{j=1}^{\infty} \rho^{j-1} (r_{t+j}^A + r_{t+j}^B + r_{t+j}^C) \right] \\ &= cov\left[p_t - d_t, \sum_{j=1}^{\infty} \rho^{j-1} r_{t+j}^A \right] + cov\left[p_t - d_t, \sum_{j=1}^{\infty} \rho^{j-1} r_{t+j}^B \right] \\ &\quad + cov\left[p_t - d_t, \sum_{j=1}^{\infty} \rho^{j-1} r_{t+j}^C \right] \end{aligned} \tag{27}$$

I cast the estimated model into this asset pricing framework by defining P, D and R for the optimal investment equation and for the optimal hiring equation. The "price" P is the value of investment or the value of hiring; this is essentially Tobin's Q for capital investment and its analog for labor hiring (each divided by the relevant productivity); the "dividend" D is the flow of net income from capital or from labor; and the discount rate R incorporates the capital depreciation rate or the worker separation rate, the interest rate and the inverse of capital or labor productivity growth.

Consider the investment equation (see equation (13)):

$$\frac{(1-\tau_t)\left(g_{i_t}+p_t^I\right)}{\frac{f_t}{k_t}} = \left\{ \frac{\frac{f_{t+1}}{k_{t+1}}}{\frac{f_t}{k_t}} \frac{\beta_{t+1}(1-\tau_{t+1})}{\frac{f_{t+1}}{k_{t+1}}} \left[f_{k_{t+1}} - g_{k_{t+1}} + (1-\delta_{t+1})(g_{i_{t+1}} + p_{t+1}^I) \right] \right\} \tag{28}$$

I define the following asset pricing terms:

$$P_t^1 \equiv \frac{(1-\tau_t)\left(g_{i_t}+p_t^I\right)}{\frac{f_t}{k_t}} \equiv \frac{Q_t^K}{\frac{f_t}{k_t}} \tag{29}$$

$$D_{t+1}^1 \equiv \frac{(1-\tau_{t+1})\frac{(f_{k_{t+1}}-g_{k_{t+1}})}{\frac{f_{t+1}}{k_{t+1}}}}{(1-\delta_{t+1})}$$

$$(R_{t+k})^1 = \frac{\frac{f_{t+k-1}}{k_{t+k-1}}}{\frac{f_{t+k}}{k_{t+k}}} \frac{1}{\beta_{t+k}} \frac{1}{(1-\delta_{t+k})}$$

Likewise for the hiring equation (see equation (14)):

$$\frac{(1-\tau_t)\, g_{h_t}}{\frac{f_t}{n_t}} = \left\{ \frac{\frac{f_{t+1}}{n_{t+1}}}{\frac{f_t}{n_t}} \frac{\beta_{t+1}(1-\tau_{t+1})}{\frac{f_{t+1}}{n_{t+1}}} \left[f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1} + (1-\psi_{t+1}) g_{h_{t+1}} \right] \right\} \tag{30}$$

I define:

$$P_t^2 \equiv \frac{(1-\tau_t)\, g_{h_t}}{\frac{f_t}{n_t}} \equiv \frac{Q_t^N}{\frac{f_t}{n_t}} \tag{31}$$

$$D_{t+1}^2 = \frac{(1-\tau_{t+1})\left(\frac{f_{n_{t+1}}-g_{n_{t+1}}-w_{t+1}}{\frac{f_{t+1}}{n_{t+1}}}\right)}{1-\psi_{t+1}}$$

$$(R_{t+k})^2 = \frac{\frac{f_{t+k-1}}{n_{t+k-1}}}{\frac{f_{t+k}}{n_{t+k}}} \frac{1}{\beta_{t+k}} \frac{1}{(1-\psi_{t+k})}$$

I use this framework to empirically decompose the variance of "price-dividend" $\frac{P}{D}$ ratios as follows: for the parameter values I employ the point estimates from Table 4, columns 1 and 9. Instead of infinite sums I use alternative truncated sums, with truncation at T. Table 6 presents the results of decomposing equation (26) for the alternative values of T, separately for the two equations – investment and hiring. It also presents the error of the approximated variance equation (26) divided by the variance of the log price-dividend ratio, $\frac{e}{var(p_t - d_t)}$, namely the difference between the LHS and the RHS divided by the LHS. Note from equation (26) that this can be positive or negative. This error comes from estimation and approximation errors and the results of truncation.

Table 6

Note that with different values of the finite truncation T, the sample size n changes, thereby changing the estimates. There are a number of results that stand out:

(i) In the truncated sums $\rho = \frac{\frac{P}{D}}{1+\frac{P}{D}}$ acts as a discount factor. Note that the price of investment P^1 includes the price of investment goods (p^I) as well as marginal adjustment costs (g_i). Hence P^1 in this equation is relatively high and so is ρ. The finite truncation thus leaves out terms that are not close to zero in the investment equation. This is reported in the table in the row of ρ^T.

(ii) The relative error variance decreases monotonically with T for the investment equation (from around 0.65 to around 0) but changes non-monotonically for the hiring equation. As T changes the sample size changes and so does the variance of the error and of the log price-dividend ratio.

(iii) In both equations the co-variation of the "price-dividend" ratio with the growth rate of "dividends" is positive and with the relevant discount rate is negative or close to zero, as should be expected.

(iv) In the investment case, the big component of the variance decomposition is the negative co-variation of the "price-dividend" ratio with the discount rate. This comes mostly from the negative co-variation with the interest rate and with the depreciation rate.

(v) In the hiring case, the big component of the variance decomposition is the positive co-variation of the "price-dividend" ratio with the growth rate of "dividends," which are essentially the profits of the firm from the job-worker match.

Points (iv) and (v) are consistent with the relative variation in the components of the present values, presented in Table 7:

Table 7

The table shows the standard deviation of each component – the discounted sum of dividend growth $\sum_{j=1}^{T} \rho^{j-1} (d_{t+j+1} - d_{t+j})$ and the discounted sum of discount rates $\sum_{j=1}^{T} \rho^{j-1} r_{t+j}$ – divided (for normalization) by the norm of the price-dividend ratio ($\| p_t - d_t \|$). In the case of investment, the volatility of the discounted sum of dividend growth is about half of that of the discounted sum of discount rates. Hence it is not surprising that the price-dividend ratio varies more with the latter. In the case of hiring, the volatility of the discounted sum of dividend growth is about 3 times bigger than that of the discounted sum of discount rates. Hence it is not surprising that price-dividend ratio varies more with the former.

7 The Co-Movement of Hiring and Investment

Across all specifications of Table 4 , the estimate of the coefficient of the interaction term, e_3, is negative. This negative point estimate implies a negative value for g_{hi} and, therefore, a positive sign for $\partial h_t/\partial Q^k$ and for $\partial i_t/\partial Q^n$ (for the full derivations of these derivatives, as well as the relevant elasticities, see Appendix A.) Note that $\partial i_t/\partial Q^k$ and $\partial h_t/\partial Q^n$ are positive due to convexity. Hence, when the marginal value of investment Q^K rises, both investment and hiring rise. A similar argument shows that they both rise when the marginal value of hiring Q^N rises.

The signs of these elasticities and derivatives imply that for given levels of investment, total and marginal costs of investment decline as hiring increases. Similarly, for given levels of hiring, total and marginal costs of hiring decline as investment increases. This finding is to be expected as it implies simultaneous hiring and investment. One interpretation of this result is that simultaneous hiring and investment is less costly than sequential hiring and investment of the same magnitude. This may be due to the fact that simultaneous action by the firm is less disruptive to production than sequential action. This feature is quantified by the following 'scope' statistic:

$$\frac{g(0, \frac{h}{n}) + g(\frac{i}{k}, 0) - g(\frac{i}{k}, \frac{h}{n})}{g(\frac{i}{k}, \frac{h}{n})}$$

The statistic measures how much – in percentage terms – is simultaneous investment and hiring cheaper than non-simultaneous action. Its sample mean and standard deviation are presented in panel (a) of Table 8 using the benchmark estimates of Table 4. On average it is 9% or 40% out of total adjustment costs, depending upon the specification.

Table 8

Panel (b) of Table 8 further quantifies the relations between hiring and investment by presenting the mean and standard deviation of the elasticities of investment i and of hiring h with respect to the present values Q^k and Q^n. The table shows that the investment is highly elastic (an elasticity of almost 3 or 4 according to the specification) with respect to the present value of investing Q^K, while hiring is relatively inelastic with respect to its present value Q^N (an elasticity of about 0.3 to 0.4). The cross elasticities are very low for investment w.r.t Q^N (an elasticity of around 0.04-0.08) and moderate for hiring w.r.t Q^K (0.25 to around unitary elasticity).

The following distinction, however, is important. The afore-going argument favors simultaneous hiring and investment, i.e., positive levels of both ($\frac{i}{k}, \frac{h}{n} > 0$). Thus the representative firm is hiring and investing at the same time. But it does **not** necessarily imply highly positive co-movement or correlation between hiring and investment. In other words investment and hiring take place at the same time, but it is possible to have one rise while the other rises, stays the same or even declines. Suppose Q^K rises and Q^N declines at the same time. The rise in Q^K will lead to higher investment and higher hiring, while the fall in Q^N will lead to lower investment and lower hiring. Based on the derivations of Appendix A and the estimates of Table 4, panel (c) in Table 8 computes the change in investment and hiring for a one standard deviation *rise* in Q^K and a one standard deviation *fall* in Q^N. The results show that in such a case investment rises by 21% to 26% while hiring rises by only 2%.

To further see these relations, Figure 2 shows the sample behavior of $\frac{i}{k}$ and $\frac{h}{n}$ and of the estimated Q^K and Q^N using the point estimates of column 9 of Table 4. The series are all normalized.

Figure 2

The figure shows that Q^K generally went up for most of the sample while Q^N declined for the most part. The investment rate usually tracks the changes in Q^K and the hiring rate usually tracks the changes in Q^N; for both pairs the correlation is 0.74. Hence the negative co-movement of Q^K and Q^N (correlation of -0.81) resulted in a negative co-movement of the investment and hiring rates (correlation of -0.60).[9]

It should be noted that Q^N estimated using either linear hiring costs with no capital or using quadratic investment and hiring costs but no interaction between them (columns 3 and 4 in Table 4) are *negatively* correlated with the series reported here. Indeed, in the sample period these estimated Q^N series go up for the most part, in a way which is inconsistent with the behavior

[9] Note that the series here are not logged or HP-filtered.

of the hiring rate. Hence prevalent specifications – linear hiring costs or no interaction between hiring and investment costs – yield poor results.

8 Investment and Hiring Along the Business Cycle

Table 9 shows the co-movement of the investment and hiring rates, the estimated marginal costs and the estimated Q^K and Q^N with real, non-financial business sector GDP; all series are logged and HP-filtered. The table shows the same benchmark specifications from Table 4 as used throughout.

Table 9

Investment rates are pro-cyclical, contemporaneously and within 4 quarters lags and leads. Likewise are marginal costs of investment and Q^K. Hiring rates are counter-cyclical, contemporaneously and in leads and within 4 quarters in lags. Likewise are marginal costs of hiring and Q^N, except for the long leads where there is a small difference. Investment and hiring rates follow the same pattern of cross correlations as do the marginal costs on that activity and its marginal Q. Hence the model shows that the costs and benefits of investment and hiring – equal at the margin – behave cyclically in the way investment and hiring themselves have been shown to behave in Section 2 above.

9 Conclusions

The paper has shown that a Q-type model of aggregate investment and hiring behavior is a consistent and reasonable model which fits U.S. data. It was shown that allowing for sufficient curvature of adjustment costs and for interaction between hiring and investment costs, enables the model to fit the data. Adjustment costs are moderate relative to what has been proposed in the literature. It appears that the use of linear costs for hiring, quadratic costs for investment, and the non-allowance of interaction between them are the elements that lead to poor empirical results. Also noteworthy is the use of gross flows data, as distinct from net flows of workers. While hiring and investment decisions have a similar structure, the actual series behave differently. This has to do with the differential behavior of the driving forces – the present values of hiring and of investment and their differential relations with the relevant components of these present values. Investment seems to be driven mostly by variables that serve to discount future streams while hiring depends mostly on labor profitability. In the sample period, the value of investment (Q^K) went up for the most part and behaved pro-cyclically while the value of hiring (Q^N) went down for the most part and behaved counter-cyclically. These patterns engendered the behavior of investment and hiring described in Section 2 above, including their negative co-movement.

Issues for future research should include an attempt to better understand the forces or shocks underlying the differential evolution of the relevant present values and the economic mechanisms underlying the interaction in costs.

References

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

[2] Bloom, Nicholas , 2009. "The Impact of Uncertainty Shocks," **Econometrica** 77, 3, 623–685.

[3] Campbell, John .Y., and Robert J. Shiller, 1988. "The dividend–price ratio and expectations of future dividends and discount factors," **Review of Financial Studies** 1, 195–227

[4] Christiano, Lawrence J., Martin. Eichenbaum, and Charles L. Evans. 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." **Journal of Political Economy,** 113(1): 1–45.

[5] Cochrane, John H. 2005. **Asset Pricing**, 2nd edition, Princeton University Press, Princeton NJ.

[6] Cooper, Russell and John Haltiwanger, 2006." On the Nature of Capital Adjustment Costs," **Review of Economic Studies** 73, 611–633.

[7] Cooper, Russell, John C. Haltiwanger, and Jonathan L. Willis, 2010. "Euler-Equation Estimation for Discrete Choice Models: A Capital Accumulation Application" NBER Working Paper No. 15675.

[8] Erickson, Timothy and Toni M. Whited, 2000. "Measurement Error and the Relationship between Investment and q," **Journal of Political Economy** 108, 1027-57.

[9] Frazis, Harley J., Edwin L. Robison, Thomas D. Evans and Martha A. Duff, 2005. "Estimating Gross Flows Consistent with Stocks in the CPS," **Monthly Labor Review**, September, 3-9.

[10] Gali, Jordi, 2008. **Monetary Policy, Inflation and the Business Cycle: An Introduction to the New Keynesian Framework.** Princeton University Press, Princeton.

[11] Garibaldi, Pietro and Espen R.Moen, 2008. "Industry Dynamics and Search in the Labor Market," working paper.

[12] Gilchrist, Simon and Charles .P. Himmelberg, 1995. "Evidence on the Role of Cash Flow for Investment," **Journal of Monetary Economics** 36:541-572.

[13] Gilchrist, Simon and Charles P. Himmelberg, 1998. "Investment: Fundamentals and Finance," **NBER Macroeconomic Annual** 223-262.

[14] Hagedorn, Marcus, and Iourii Manovskii, 2008. "The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited," **American Economic Review**, 98, 4, 1692–1706.

[15] Hall, R.E. 2004. "Measuring Factor Adjustment Costs," **Quarterly Journal of Economics,** August, 119(3), 899-927.

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

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

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

[19] Hubbard, R.Glenn., Aanil K Kashyap, and Toni .M. Whited 1995. "Internal Finance and Firm Investment," **Journal of Money, Credit and Banking** 27:683-701.

[20] Kahn, Aubhik and Julia K. Thomas, 2008. "Idiosyncratic Shocks and the Role of Nonconvexities in Plant and Aggregate Investment Dynamics," **Econometrica** 76 (2), 395–436.

[21] Lettau, Martin and Sydney C. Ludvisgon, 2009. "Measuring and Modeling Variation in the Risk-Return Tradeoff," in Yacine Ait-Sahalia and Lars Peter Hansen (eds.) **Handbook of Financial Econometrics,** Elsevier, North Holland.

[22] Merz, Monika and Eran Yashiv, 2007. "Labor and the Market Value of the Firm," **American Economic Review,** 97, 4, 1419-1431.

[23] Mortensen, Dale T. and Eva Nagypal, 2006. "More on Vacancy and Unemployment Fluctuations," working paper.

[24] Philippon, Thomas, 2009. "The Bond's Market's q," **The Quarterly Journal of Economics,** August, 1011-1056.

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

[26] Rogerson, Richard, Robert Shimer and Randall Wright, 2005. "Search Theoretic Models of the Labor Market: A Survey," **Journal of Economic Literature** XLIII, 959-988.

[27] Rogerson, Richard and Robert Shimer, 2010. "Search in Macroeconomic Models of the Labor Market," NBER WP 15901.

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

[29] Shimer, Robert, 2005. "The Cyclical Behavior of Equilibrium Unemployment and Vacancies," **American Economic Review,** 95,1, 25-49.

[30] Smets, Frank and Raf Wouters, 2007. Shocks and frictions in U.S. business cycles: a Bayesian DSGE approach," **American Economic Review** 97, 3, 586–606.

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

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

[33] Yashiv, Eran 2007. "Labor Search and Matching in Macroeconomics," **European Economic Review** 51, 8, 1859-1895,

Appendix A
The Adjustment Cost Function

The Adjustment Cost Function

$$g(\cdot) = \left[\frac{e_1}{\eta_1}\left(\frac{i_t}{k_t}\right)^{\eta_1} + \frac{e_2}{\eta_2}\left(\frac{h_t}{n_t}\right)^{\eta_2} + \frac{e_3}{\eta_3}\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3}\right] f(z_z, n_t, k_t). \tag{32}$$

First Derivatives

$$g_{i_t} = \left[e_1\left(\frac{i_t}{k_t}\right)^{\eta_{1-1}} + e_3\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3-1}\frac{h_t}{n_t}\right]\frac{f(z_z, n_t, k_t)}{k_t} \tag{33}$$

$$g_{h_t} = \left[e_2\left(\frac{h_t}{n_t}\right)^{\eta_2-1} + e_3\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3-1}\frac{i_t}{k_t}\right]\frac{f(z_z, n_t, k_t)}{n_t} \tag{34}$$

$$g_{k_t} = -\left[e_1\left(\frac{i_t}{k_t}\right)^{\eta_1} + e_3\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3}\right]\frac{f(z_z, n_t, k_t)}{k_t} + (1-\alpha)g \tag{35}$$

$$g_{n_t} = -\left[e_2\left(\frac{h_t}{n_t}\right)^{\eta_2} + e_3\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3}\right]\frac{f(z_z, n_t, k_t)}{n_t} + \alpha g \tag{36}$$

Second Derivatives

$$g_{ii_t} = \underbrace{\left[e_1(\eta_1-1)\left(\frac{i_t}{k_t}\right)^{\eta_1-2} + e_3(\eta_3-1)\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3-2}\left(\frac{h_t}{n_t}\right)^2\right]}_{\widetilde{g}_{ii}}\frac{f(z_z, n_t, k_t)}{k_t^2} \tag{37}$$

$$g_{hh_t} = \underbrace{\left[e_2(\eta_2-1)\left(\frac{h_t}{n_t}\right)^{\eta_2-2} + e_3(\eta_3-1)\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3-2}\left(\frac{i_t}{k_t}\right)^2\right]}_{\widetilde{g}_{hh}}\frac{f(z_z, n_t, k_t)}{n_t^2} \tag{38}$$

$$g_{ih_t} = g_{hi_t} = \underbrace{\left[e_3\eta_3 \left(\frac{i_t}{k_t}\frac{h_t}{n_t} \right)^{\eta_3 - 1} \right]}_{\widetilde{g}_{ih}} \frac{f(z_z, n_t, k_t)}{k_t n_t} \tag{39}$$

Elasticities
F.O.C and Their Implications

$$Q_t^K = (1 - \tau_t) \left(g_{i_t} + p_t^I \right) \tag{40}$$

$$Q_t^N = (1 - \tau_t)\, g_{h_t} \tag{41}$$

Differentiating with respect to Q^K :

$$\begin{aligned} 1 &= (1 - \tau_t) \left[\frac{\partial g_{i_t}}{\partial i_t} \frac{\partial i_t}{\partial Q_t^K} + \frac{\partial g_{i_t}}{\partial h_t} \frac{\partial h_t}{\partial Q_t^K} \right] \\ 0 &= (1 - \tau_t) \left[\frac{\partial g_{h_t}}{\partial i_t} \frac{\partial i_t}{\partial Q_t^K} + \frac{\partial g_{h_t}}{\partial h_t} \frac{\partial h_t}{\partial Q_t^K} \right] \end{aligned} \tag{42}$$

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

$$\begin{aligned} \frac{\partial i_t}{\partial Q^K} &= \frac{g_{hh}}{(1 - \tau_t)(g_{ii}g_{hh} - g_{ih}g_{hi})} \\ \frac{\partial h_t}{\partial Q^K} &= -\frac{g_{hi}}{(1 - \tau_t)(g_{ii}g_{hh} - g_{ih}g_{hi})}. \end{aligned} \tag{43}$$

Differentiating with respect to Q^N :

$$\begin{aligned} 0 &= (1 - \tau_t) \left[\frac{\partial g_{i_t}}{\partial i_t} \frac{\partial i_t}{\partial Q_t^N} + \frac{\partial g_{i_t}}{\partial h_t} \frac{\partial h_t}{\partial Q_t^N} \right] \\ 1 &= (1 - \tau_t) \left[\frac{\partial g_{h_t}}{\partial i_t} \frac{\partial i_t}{\partial Q_t^N} + \frac{\partial g_{h_t}}{\partial h_t} \frac{\partial h_t}{\partial Q_t^N} \right] \end{aligned} \tag{44}$$

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

$$\begin{aligned} \frac{\partial h_t}{\partial Q^N} &= \frac{g_{ii}}{(1 - \tau_t)(g_{ii}g_{hh} - g_{ih}g_{hi})} \\ \frac{\partial i_t}{\partial Q^N} &= -\frac{g_{ih}}{(1 - \tau_t)(g_{ii}g_{hh} - g_{ih}g_{hi})}. \end{aligned} \tag{45}$$

Elasticities With Respect to Q^K
Using (43):

$$\frac{\partial i_t}{\partial Q^K}\frac{Q^K}{i_t} = \frac{\widetilde{g}_{hh}\frac{f_t}{n_t^2}}{(1-\tau_t)\left[\widetilde{g}_{ii}\widetilde{g}_{hh}\frac{f_t}{k_t^2}\frac{f_t}{n_t^2} - \widetilde{g}_{ih}\widetilde{g}_{hi}\left(\frac{f_t}{k_t}\frac{1}{n_t}\right)^2\right]}\frac{Q^K}{i_t} \tag{46}$$

$$= \frac{\widetilde{g}_{hh}}{(1-\tau_t)\left[\widetilde{g}_{ii}\widetilde{g}_{hh} - \widetilde{g}_{ih}\widetilde{g}_{hi}\right]}\frac{\frac{Q^K}{\frac{f_t}{k_t}}}{\frac{i_t}{k_t}}$$

$$\frac{\partial h_t}{\partial Q^k}\frac{Q^K}{h_t} = -\frac{g_{hi}}{(1-\tau_t)\left[g_{ii}g_{hh} - g_{ih}g_{hi}\right]}\frac{Q^K}{h_t}$$

$$= -\frac{\widetilde{g}_{hi}}{(1-\tau_t)\left[\widetilde{g}_{ii}\widetilde{g}_{hh} - \widetilde{g}_{ih}\widetilde{g}_{hi}\right]}\frac{\frac{Q^K}{\frac{f_t}{k_t}}}{\frac{h_t}{n_t}}$$

Note that on the RHS we have $\frac{Q^K}{\frac{f_t}{k_t}}$ and the investment and hiring **rates.**
Elasticities With Respect to Q^N
Using (45):

$$\frac{\partial h_t}{\partial Q^N}\frac{Q^N}{h_t} = \frac{\widetilde{g}_{ii}\frac{f_t}{k_t^2}}{(1-\tau_t)\left[\widetilde{g}_{ii}\widetilde{g}_{hh}\frac{f_t}{k_t^2}\frac{f_t}{n_t^2} - \widetilde{g}_{ih}\widetilde{g}_{hi}\left(\frac{f_t}{k_t}\frac{1}{n_t}\right)^2\right]}\frac{Q^N}{h_t} \tag{47}$$

$$= \frac{\widetilde{g}_{ii}}{(1-\tau_t)\left[\widetilde{g}_{ii}\widetilde{g}_{hh} - \widetilde{g}_{ih}\widetilde{g}_{hi}\right]}\frac{\frac{Q^N}{\frac{f_t}{n_t}}}{\frac{h_t}{n_t}}$$

$$\frac{\partial i_t}{\partial Q^N}\frac{Q^N}{i_t} = -\frac{g_{ih}}{(1-\tau_t)\left[g_{ii}g_{hh} - g_{ih}g_{hi}\right]}\frac{Q^N}{i_t}$$

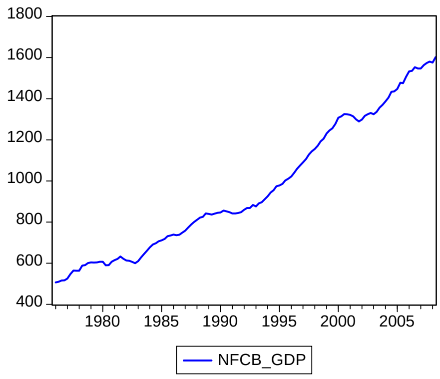
$$= -\frac{\widetilde{g}_{ih}}{(1-\tau_t)\left[\widetilde{g}_{ii}\widetilde{g}_{hh} - \widetilde{g}_{ih}\widetilde{g}_{hi}\right]}\frac{\frac{Q^N}{\frac{f_t}{h_t}}}{\frac{i_t}{k_t}}$$

Note that on the RHS we have $\frac{Q^N}{\frac{f_t}{n_t}}$ and the investment and hiring **rates.**

Appendix B: the Data

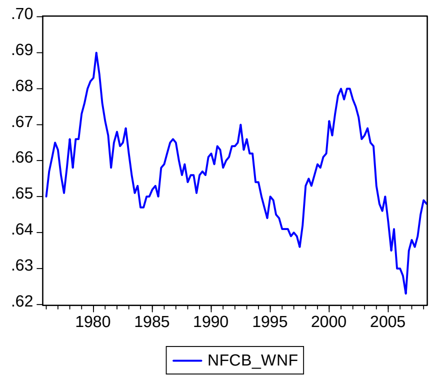
GDP and its deflator

Real GDP f pertains to nonfinancial corporate business sector. The data originate from NIPA accounts, table 1.14, line 40 (gross value added of non-financial corporate business, in billions of chained (2000) dollars). The price deflator p^f is defined as price per unit of gross value added of nonfinancial corporate business sector (NIPA table 1.15, line 1).



The labor share

For the labor share of income $\frac{wn}{f}$ I use compensation of employees in NFCB sector (NIPA table 1.14, line 20) divided by the total sector output (NIPA table 1.14, line 17).



The discount rate and the discount factor

I use several alternatives for the firms' discount rate r_t and the corresponding discount factor $\beta_t = \frac{1}{1+r_t}$:

1. The discount rate based on a DSGE model with logarithmic utility.

If the utility is given by:

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

then in general equilibrium:

$$U'(c_t) = U'(c_{t+1}) \cdot (1 + r_t)$$

Hence:

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

$$\beta_t = \frac{c_t}{c_{t+1}}$$

2. The discount rate based on the weighted average cost of capital approach in corporate finance.

Following the weighted average cost of capital approach in corporate finance, the discount rate is a weighted average of the returns to debt, r_t^b, and equity, r_t^e:

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

with

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

where:

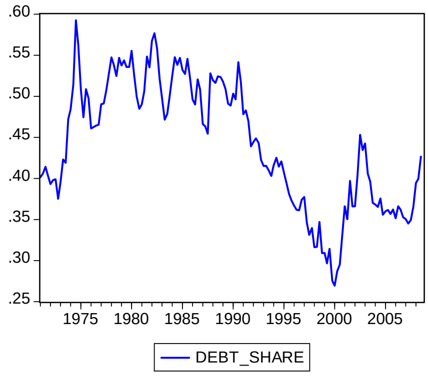
(i) ω_t is the share of debt finance. I calculate it on the basis of Level Tables of Flow of Funds accounts (files ltabs.zip). The calculations are as follows:

1. D = Credit market instruments (FL104104005 in the Coded Tables ltabs.zip, table L.102) + Trade payables (FL103170005 in the Coded Tables ltabs.zip, table L.102)

2. E = Market value of equities (FL103164003 in the Coded Tables ltabs.zip, table L.102)

3. Debt share = $D/(D + E)$.

The resulting series is:



(ii) The definition of r_t^b reflects the fact that nominal interest payments on debt are tax deductible. r_t^{CP} is Moody's seasoned Aaa commercial paper rate (Federal Reserve Board table H15). The raw data is monthly, per annum. I computed the quarterly series in the following way:

$$r^q = (1 + r_1)^{1/12}(1 + r_2)^{1/12}(1 + r_3)^{1/12} - 1$$

where $r_{1,2,3}$ are the respective month of each given quarter.

The tax rate is τ as discussed below.

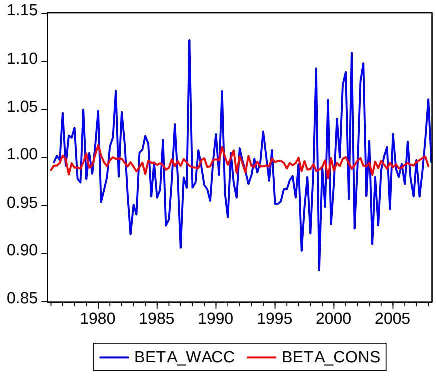
(iii) θ denotes inflation and is measured by the GDP-deflator of p^f discussed above.

(iv) For equity return I use the CRSP Value Weighted NYSE, Nasdaq and Amex nominal ex-dividend returns ($\frac{\widetilde{cf}_t}{\widetilde{s}_t} + \widetilde{s}_t$ in terms of the model, using tildes to indicate nominal variables) deflated by the inflation rate θ). The raw data is monthly. The quarterly returns are given by:

$$r^q = (1 + r_1)(1 + r_2)(1 + r_3) - 1$$

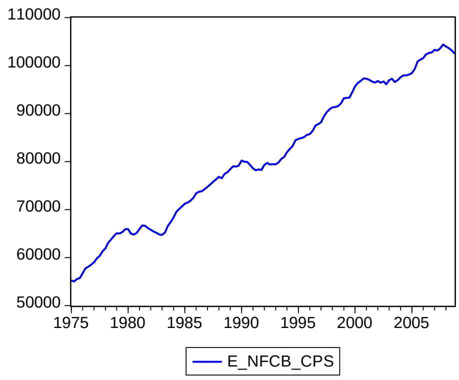
where $r_{1,2,3}$ are the respective month of each given quarter.

The graph below shows the two β series - consumption-based (see part 1 of the current section) and WACC-based (part 2).



Employment, matches and separations

As a measure of employment in nonfinancial corporate business sector (n) I take wage and salary workers in non-agricultural industries (series ID LNS12032187) less government workers (series ID LNS12032188), less self-employed workers (series ID LNS12032192), less unpaid family workers (series ID LNS12032193). All series originate from CPS databases. I do not subtract workers in private households (the unadjusted series ID LNU02032190) from the above due to lack of sufficient data on this variable.

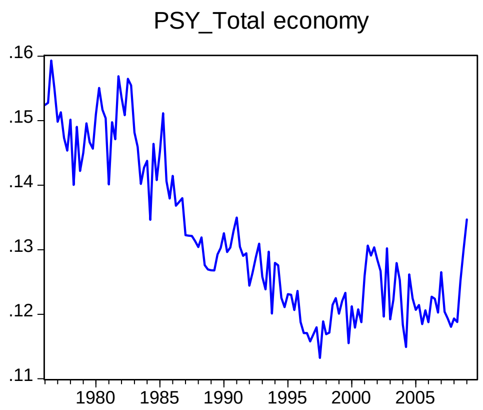


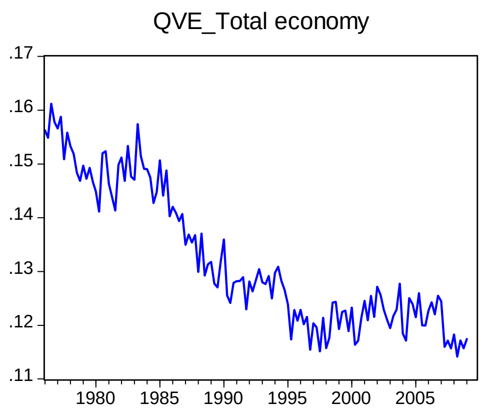
To calculate hiring and separation rates for the whole economy I use the series kindly provided by Ofer Cornfeld. This computation first builds the flows between E (employment), U (unemployment) and N (not-in-the-labor-force) that correspond to the E, U, N stocks published by CPS. The methodology of adjusting flows to stocks is taken from BLS, and is given in Frazis et al (2005). This methodology, applied by BLS for the period 1990 onward, produces a dataset that appears in **http://www.bls.gov/cps/cps_flows.htm**. Here the series have been extended back to 1976.

The quarterly separation rate (ψ) and the quarterly hiring rate (h/n) for the whole economy are defined as follows:

$$\begin{aligned} \psi &= \frac{EN + EU}{E} \\ h/n &= \frac{NE + UE}{E} \end{aligned}$$

where the employment (E) is the quarterly average of the original seasonally adjusted total employment series from BLS (LNS12000000).





Investment, capital and depreciation

The goal here is to construct the quarterly series for real investment flow i_t , real capital stock k_t , and depreciation rates δ_t. I proceed as follows:

- Construct end-of-year fixed-cost net stock of private nonresidential fixed assets in NFCB sector, K_t . In order to do this I use the quantity index for net stock of fixed assets in NFCB (FAA table 4.2, line 28, BEA). The reference year for this index is 2000. Therefore, in order to obtain the fixed-cost estimate I multiply this series by the current-cost net stock of fixed assets in NFCB in 2000 (FAA table 4.1, line 28). The logic of this procedure is as follows:

For the reference year 2000 the index is equal to 100 by definition so that the current-cost and the fixed-cost estimates coincide:

$$current_{2000} = fixed_{2000}$$

By definition of the quantity index in year t:

$$index_t = \frac{fixed_t}{fixed_{2000}}$$

so that:

$$fixed_t = index_t \cdot fixed_{2000} = index_t \cdot current_{2000}$$

- Construct annual fixed-cost depreciation of private nonresidential fixed assets in NFCB sector, D_t . Here I follow the same procedure as in the previous paragraph, with respect to depreciation series. The chain-type quantity index for depreciation originates from FAA table 4.5, line 28. The current-cost depreciation estimates are given in FAA table 4.4, line 28.

- Calculate the annual fixed-cost investment flow, I_t:

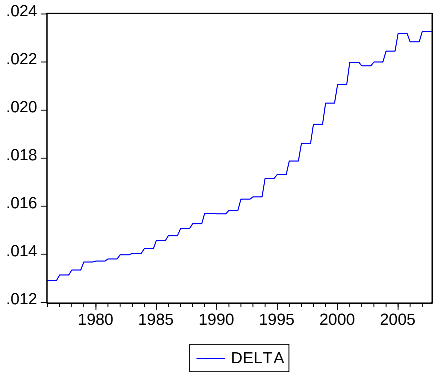
$$I_t = K_t - K_{t-1} + D_t$$

- Calculate implied annual depreciation rate, δ_a:

$$\delta_a = \frac{I_t - (K_t - K_{t-1})}{K_{t-1} + I_t/2}$$

- Calculate implied quarterly depreciation rate for each year, δ_{qt}:

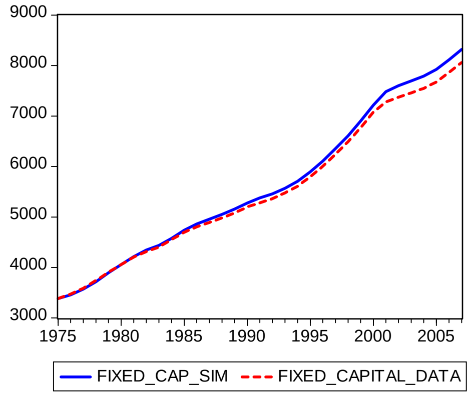
$$\delta_q + (1-\delta_q)\delta_q + (1-\delta_q)^2\delta_q + (1-\delta_q)^3\delta_q = \delta_a$$



quarterly depreciation rate δ_q

- Take historic-cost quarterly investment in private non-residential fixed assets by NFCB sector from the Flow of Funds accounts, atabs files, series FA105013005).
- Deflate it using the investment price index (the latter is calculated as consumption of fixed capital in domestic NFCB in current dollars (NIPA table 1.14, line 18) divided by consumption of fixed capital in domestic NFCB in chained 2000 dollars (NIPA table 1.14, line 41). This procedure yields the implicit price deflator for depreciation in NFCB. Conceptually it should be the same as the investment price index). The resulting quarterly series, i_t_unadj, is thus in real terms.
- Perform Denton procedure to adjust the quarterly series i_t_unadj from Federal Flow of Funds accounts to the implied annual series from BEA I_t, using the depreciation rate δ_{qt} from above. I use the simplest version of the adjustment procedure, when the discrepancies between the two series are equally spread over the quarters of each year. As a result of adjustment I get the fixed–cost quarterly series i_t.
- Simulate the quarterly real capital stock series k_t starting from k_0 (k_0 is actually the fixed-cost net stock of fixed assets in the end of 1975, this value is taken from the series K_t) , using the quarterly depreciation series δ_{qt} and investment series i_t from above:

$$k_{t+1} = k_t \cdot (1 - \delta_{qt}) + i_t$$



End-of-year simulated real capital stock vs end-of-year fixed-cost capital stock from NIPA K_t

Real price of new capital goods

In order to compute the real price of new capital goods, p^I, I use the price indices for output and for investment goods. I know that investment in NFCB Inv consists of equipment Eq and structures St. I define the time-t price-indices for good $j = Inv, Eq, St$ as p_t^j and their change between $t-1$ and t by Δp_t^j, $j = Inv, Eq, St$. These price indices are chain-weighted. Thus, we know that

$$\frac{\Delta p_t^{Inv}}{p_{t-1}^{Inv}} = \omega_t \frac{\Delta p_t^{Eq}}{p_{t-1}^{Eq}} + (1 - \omega_t) \frac{\Delta p_t^{St}}{p_{t-1}^{St}}$$

where

$$\omega_t = \frac{\begin{array}{c}(\text{nominal expenditure share of } Eq \text{ in } Inv)_{t-1} \\ + (\text{nominal expenditure share of } Eq \text{ in } Inv)_t\end{array}}{2}.$$

I start from an arbitrary value $p_0^{Inv} = 1$ and construct the sequence of prices indices $\left\{p_t^{Inv}\right\}_{t=0}^{T}$ by adding the percentage changes computed from the equations above. The weights ω_t are calculated from the NIPA table 1.1.5, lines 8,10. The price indices p_t^j for $j = Eq, St$ are from NIPA table 1.1.4, lines 9, 10. Finally, I divide the series by the price index for output, p_t^f, to obtain the real price of new capital goods, p^I.

Note that the price indices p^{Eq} and p^{St} and therefore p^I are actually adjusted for taxes. Let the parameter τ denotes the statutory corporate income tax rate as reported by the U.S. Tax Foundation.

Let ITC denote the investment tax credit on equipment and public utility structures, $ZPDE$ the present discounted value of capital depreciation allowances, and χ the percentage of the cost of equipment that cannot be depreciated if the firm takes the investment tax credit. Flint Brayton has kindly provided me with the data. Then

$$p^{Eq} = \widetilde{p}^{Eq}\left(1 - \tau_{Eq}\right), p^{St} = \widetilde{p}^{St}\left(1 - \tau_{St}\right),$$

$$\begin{aligned} 1 - \tau^{S_t} &= \frac{\left(1 - \tau\ ZPDE^{St}\right)}{1 - \tau} \\ 1 - \tau^{Eq} &= \frac{1 - ITC - \tau ZPDE^{Eq}\left(1 - \chi ITC\right)}{1 - \tau} \end{aligned}$$

Finally, as p_t^I is an index, I multiply it by a positive scaling constant e^A where I either impose or estimate A.

The resulting real price of new investment goods:

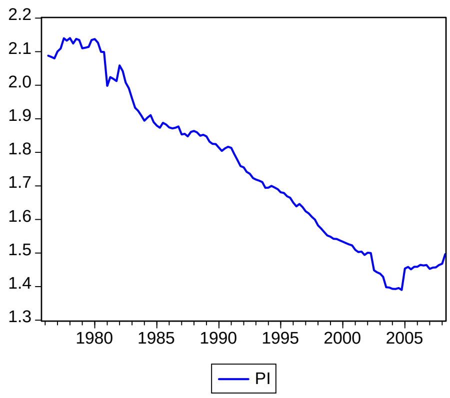


Table 1

Stochastic Behavior of Hiring and Investment
logged, HP-filtered

a. Volatility and Relative Volatility

moment	h_t	$\frac{h_t}{n_t}$	i_t	$\frac{i_t}{k_t}$
std	0.0238	0.0244	0.0526	0.0529
relative std to GDP f	1.18	1.21	2.61	2.63
relative std to $\frac{f}{n}$	1.94	1.99	4.30	4.32
relative std to $\frac{f}{k}$	1.08	1.11	2.40	2.41

b. Persistence

moment	h_t	$\frac{h_t}{n_t}$	i_t	$\frac{i_t}{k_t}$
AC 1 lag	0.06	0.14	0.90	0.90
AC 2 lags	−0.05	0.01	0.74	0.74
AC 3 lags	0.04	0.06	0.52	0.51
AC 4 lags	−0.07	−0.04	0.29	0.28

c. Co-Movement

Correlations

$\rho(\frac{i_t}{k_t}, \frac{h_{t-i}}{nt_{-i}})$

lag/lead	-12	-8	-4	-1	0	1	4	8	12
	-0.03	0.10	0.02	-0.15	-0.15	-0.18	-0.07	-0.10	-0.08

$\rho(h_t, y_{t-i})$

lag/lead	-12	-8	-4	-1	0	1	4	8	12
GDP f	-0.24	-0.10	0.07	0.06	0.12	0.11	0.04	-0.04	-0.12
labor prod. $\frac{f}{n}$	-0.20	0.01	0.20	0.14	0.13	0.02	-0.08	-0.12	-0.13
capital prod. $\frac{f}{k}$	-0.24	-0.08	0.09	0.07	0.13	0.10	0.01	-0.07	-0.12

$\rho(\frac{h_t}{n_t}, y_{t-i})$

lag/lead	-12	-8	-4	-1	0	1	4	8	12
GDP f	-0.13	-0.10	-0.12	-0.27	-0.20	-0.16	0.00	0.08	0.03
labor prod. $\frac{f}{n}$	-0.14	-0.07	0.00	-0.08	-0.03	-0.07	0.00	0.02	-0.05
capital prod. $\frac{f}{k}$	-0.15	-0.12	-0.13	-0.25	-0.17	-0.13	0.02	0.10	0.03

$\rho(i_t, y_{t-i})$

lag/lead	-12	-8	-4	-1	0	1	4	8	12
GDP f	-0.37	-0.16	0.51	0.83	0.78	0.62	0.00	-0.35	-0.25
labor prod. $\frac{f}{n}$	-0.28	0.12	0.63	0.60	0.48	0.29	-0.32	-0.44	-0.07
capital prod. $\frac{f}{k}$	-0.32	-0.03	0.62	0.81	0.72	0.51	-0.17	-0.46	-0.26

$\rho(\frac{i_t}{k_t}, y_{t-i})$

lag/lead	-12	-8	-4	-1	0	1	4	8	12
GDP f	-0.40	-0.23	0.46	0.83	0.80	0.66	0.05	-0.32	-0.25
labor prod. $\frac{f}{n}$	-0.32	0.07	0.61	0.62	0.52	0.34	-0.27	-0.43	-0.08
capital prod. $\frac{f}{k}$	-0.36	-0.10	0.58	0.84	0.76	0.57	-0.11	-0.43	-0.27

Table 2
Stochastic Behavior of Hiring and Other Labor Market Variables

a. Volatility and Relative Volatility – logged, HP-filtered

moment	n_t	h_t	$\frac{h_t}{n_t}$	$\frac{h_t}{u_t+o_t}$
std	0.0126	0.0238	0.0244	0.0290
relative std to GDP f	0.62	1.18	1.21	1.44
relative std to $\frac{f}{n}$	1.03	1.94	1.99	2.37

b. Co-Movement (contemporaneous) – logged, HP filtered

moment	n_t	h_t	$\frac{h_t}{n_t}$	$\frac{h_t}{u_t+o_t}$
correlation with GDP f	0.82	0.12	-0.20	0.51
correlation with $\frac{f}{n}$	0.32	0.13	-0.03	0.35

Table 3

Descriptive Sample Statistics

Variable	Mean	Standard Deviation
$\frac{i}{k}$	0.024	0.004
$\frac{f}{k}$	0.166	0.014
τ	0.387	0.057
δ	0.017	0.003
$\frac{wn}{f}$	0.658	0.013
$\frac{h}{n}$	0.133	0.013
ψ	0.132	0.012
β	0.990	0.043

Note: The sample size contains 127 quarterly observations from 1976:2 to 2007:4. For data definitions see Appendix B.

Table 4
GMM Estimates of The FOC (13) and (14)
Alternative Specifications
1976 Q2 – 2007 Q4

a. Fixed Powers

	1	2	3	4
η_1	4	2	–	2
η_2	3.5	–	1	2
η_3	2	–	–	–
e_1	87,440	137	0	-38.8
	(24,715)	(3.3)	–	(13.2)
e_2	48.8	0	0.24	4.02
	(9.4)	–	(0.01)	(0.42)
e_3	-353	0	0	0
	(494)	–	–	–
J-Statistic	44.0	44.3	54.9	45.9
p-Value	0.06	0.09	0.01	0.05
implied $\frac{g}{f}$	0.019	0.042	0.032	0.023
	(0.004)	(0.013)	(0.03)	(0.009)
implied $\frac{g_i}{f/k}$	1.24	3.36	-	-0.95
	(0.65)	(0.52)	-	(0.15)
implied $\frac{g_h}{f/n}$	0.28	-	0.24	0.53
	(0.07)	-	(0.00)	(0.05)

b. Estimated Powers

	5	6	7	8	9
η_1	free	free	free	free	free
η_2	free	$\eta_1 - 0.5$	$\eta_1 - 0.5$	free	free
η_3	1	$\eta_1 - 2$	free	free	free
α	0.68	0.68	0.68	0.68	free
η_1	3.99	3.99	3.97	3.97	3.92
	(0.0007)	(0.00003)	(0.01)	(0.01)	(0.04)
η_2	3.20	3.49	3.47	3.47	3.40
	(0.02)	-	-	(0.12)	(0.34)
η_3	1	1.99	2.04	2.04	2.04
	-	-	(0.0001)	(0.0004)	(0.005)
e_1	212,583	162,477	157,172	154,469	125,058
	(79,242)	(38,272)	(104,556)	(125,697)	(141,109)
e_2	42.6	62.3	53.2	52.3	33.9
	(11.1)	(12.8)	(11.3)	(23.6)	(38)
e_3	-8.5	-2,187	-2,538	-2,549	-1,895
	(5.2)	(607)	(757)	(771)	(1,774)
α	0.68	0.68	0.68	0.68	0.68
	-	-	-	-	(0.01)
J-Statistic	42.2	37.2	35.9	36.0	38.7
p-Value	0.05	0.17	0.18	0.14	0.07
implied $\frac{g}{f}$	0.016	0.021	0.021	0.021	0.021
	(0.009)	(0.007)	(0.007)	(0.007)	(0.008)
implied $\frac{g_i}{f/k}$	2.25	1.70	1.93	1.88	2.04
	(1.64)	(1.22)	(1.26)	(1.24)	(1.19)
implied $\frac{g_h}{f/n}$	0.29	0.22	0.20	0.19	0.14
	(0.12)	(0.11)	(0.10)	(0.10)	(0.07)

Notes:

1. The table reports the point estimates of the parameters and standard errors in parentheses.
2. Unless specified as estimated, the value of α is fixed at 0.68.
3. The implied values of the cost function g and its derivatives are computed using the point estimates. The sample mean is given with the standard deviation in parentheses.
4. Instruments used are a constant and 8 lags of $\{\frac{i_{t-j}}{k_{t-j}}, \frac{h_{t-j}}{n_{t-j}}\}$.

Table 5

Estimates of Marginal Adjustment Costs for Capital
Summary of Studies for the U.S. Economy

Study		Sample	Mean $\frac{i}{k}$	Mean $\frac{g_i}{\frac{f}{k}}$
1	Summers (1981)	BEA, 1932-1978	0.13	$2.5 - 60.5$
2	Hyashi (1982)	Corporate Sector, 1953-1976	0.14	3.2
3	Shapiro (1986)	Manufacturing, 1955-1980	0.08	1.33
4	Hubbard et al (1995)	Compustat, 1976-1987	$0.20 - 0.23$	$0.15 - 0.$
5	Gilchrist and Himmelberg (1995)	Compustat, 1985-1989	$0.17 - 0.18$	$0.50 - 0.9$
6a	Gilchrist and Himmelberg (1998)	Compustat, 1980-1993	0.23	$0.15 - 0.2$
6b		Split Sample		$0.13 - 1.1$
7	Barnett and Sakellaris (1999)	Compustat, 1960-1987	0.20	0.27
8	Hall (2004)	35 industry panel, 1958-1999	0.10	0.10
9	Cooper and Haltiwanger (2006)	LRD panel, 1972-1988	0.12	$0.04, 0.26$
10	Cooper et al (2010)	LRD panel, 1972-1988	0.12	

Notes:

1. Investment rates $\frac{i}{k}$ are expressed in annual terms.

2. All studies pertain to annual data except Shapiro (1986) who uses quarterly data.

3. The entries in the last column are expressed in terms of f/k, so, they are comparable to the estimated marginal costs reported in Table 4.

Table 6
Variance Decomposition of the Approximated Relation (26)
Table 4 Column 1

truncation	T	20	30	40	50
sample size	n	105	95	85	75
	investment				
discount factor	ρ^T	0.56	0.41	0.31	0.23
error size	$\frac{e}{var(p_t - d_t)}$	0.67	0.50	0.12	-0.04
	$\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1}(d_{t+j+1} - d_{t+j})\right]}{var(p_t - d_t)}$	0.19	0.23	0.20	0.19
	$\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1} r_{t+j}\right]}{var(p_t - d_t)}$	-0.14	-0.27	-0.68	-0.85
	$\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1} r^A_{t+j}\right]}{var(p_t - d_t)}$	0.01	0.00	0.08	0.12
	$\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1} r^B_{t+j}\right]}{var(p_t - d_t)}$	0.12	0.07	-0.35	-0.52
	$\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1} r^C_{t+j}\right]}{var(p_t - d_t)}$	-0.27	-0.35	-0.41	-0.45
	hiring				
discount factor	ρ^T	0.03	0.005	0.0008	0.0001
error size	$\frac{e}{var P/D}$	0.25	0.42	0.36	0.38
	$\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1}(d_{t+j+1} - d_{t+j})\right]}{var(p_t - d_t)}$	0.64	0.59	0.69	0.65
	$\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1} r_{t+j}\right]}{var(p_t - d_t)}$	-0.11	0.01	0.05	0.04
	$\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1} r^A_{t+j}\right]}{var(p_t - d_t)}$	0.01	0.02	0.02	0.00
	$\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1} r^B_{t+j}\right]}{var(p_t - d_t)}$	-0.14	-0.20	-0.19	-0.13
	$\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1} r^C_{t+j}\right]}{var(p_t - d_t)}$	0.02	0.19	0.22	0.17

Table 4 Column 9

truncation	T	20	30	40	50
sample size	n	105	95	85	75
	investment				
discount factor	ρ^T	0.56	0.42	0.31	0.23
error size	$\frac{e}{var(p_t-d_t)}$	0.63	0.48	0.19	0.10
	$\frac{cov\left[p_t-d_t,\sum_{j=1}^{T}\rho^{j-1}(d_{t+j+1}-d_{t+j})\right]}{var(p_t-d_t)}$	0.22	0.22	0.09	0.01
	$\frac{cov\left[p_t-d_t,\sum_{j=1}^{T}\rho^{j-1}r_{t+j}\right]}{var(p_t-d_t)}$	−0.15	−0.30	−0.72	−0.89
	$\frac{cov\left[p_t-d_t,\sum_{j=1}^{T}\rho^{j-1}r^A_{t+j}\right]}{var(p_t-d_t)}$	0.01	0.00	0.09	0.12
	$\frac{cov\left[p_t-d_t,\sum_{j=1}^{T}\rho^{j-1}r^B_{t+j}\right]}{var(p_t-d_t)}$	0.13	0.07	−0.37	−0.54
	$\frac{cov\left[p_t-d_t,\sum_{j=1}^{T}\rho^{j-1}r^C_{t+j}\right]}{var(p_t-d_t)}$	−0.29	−0.37	−0.44	−0.47
	hiring				
	ρ^T				
	$\frac{e}{varP/D}$				
	$\frac{cov\left[p_t-d_t,\sum_{j=1}^{T}\rho^{j-1}(d_{t+j+1}-d_{t+j})\right]}{var(p_t-d_t)}$				
	$\frac{cov\left[p_t-d_t,\sum_{j=1}^{T}\rho^{j-1}r_{t+j}\right]}{var(p_t-d_t)}$				
	$\frac{cov\left[p_t-d_t,\sum_{j=1}^{T}\rho^{j-1}r^A_{t+j}\right]}{var(p_t-d_t)}$				
	$\frac{cov\left[p_t-d_t,\sum_{j=1}^{T}\rho^{j-1}r^B_{t+j}\right]}{var(p_t-d_t)}$				
	$\frac{cov\left[p_t-d_t,\sum_{j=1}^{T}\rho^{j-1}r^C_{t+j}\right]}{var(p_t-d_t)}$				

Table 7
Standard Deviations of Present Value Components

Table 4 Column 1

truncation	T	20	50
investment	$std\left(\frac{\sum_{j=1}^{T}\rho^{j-1}(d_{t+j+1}-d_{t+j})}{\|p_t-d_t\|}\right)$	0.002	0.002
	$std\left(\frac{\sum_{j=1}^{T}\rho^{j-1}r_{t+j}}{\|p_t-d_t\|}\right)$	0.004	0.004
hiring	$std\left(\frac{\sum_{j=1}^{T}\rho^{j-1}(d_{t+j+1}-d_{t+j})}{\|p_t-d_t\|}\right)$	0.018	0.012
	$std\left(\frac{\sum_{j=1}^{T}\rho^{j-1}r_{t+j}}{\|p_t-d_t\|}\right)$	0.005	0.005

Notes:
1. The norm $\| p_t - d_t \|$ is computed as $\sqrt{\sum(p_t - d_t)^2}$.

Table 8
Co-Movement of Hiring and Investment

a. Scope

Table 4 column	1	9
scope	0.09	0.39
	(0.01)	(0.06)

b. Elasticities

Table 4 column	1	9
$\frac{\partial i_t}{\partial Q^K}\frac{Q^K}{i_t}$	3.96	2.59
	(2.03)	(1.28)
$\frac{\partial i_t}{\partial Q^N}\frac{Q^N}{i_t}$	0.04	0.08
	(0.02)	(0.05)
$\frac{\partial h_t}{\partial Q^k}\frac{Q^K}{h_t}$	0.25	1.07
	(0.04)	(0.10)
$\frac{\partial h_t}{\partial Q^N}\frac{Q^N}{h_t}$	0.38	0.30
	(0.01)	(0.09)

c. Implied Changes
A 1 std deviation rise in Q^K and fall in Q^N

Table 4 column	1	9
Q^K 1 std	0.08	0.12
Q^N 1 std	0.0002	0.0004
percentage change in i	0.26	0.21
percentage change in h	0.021	0.020

Notes:

1. All computations are based on the point estimates of Table 4 columns 1 and 9.

2. Panel (a) computes the scope defined as

$$\frac{g(0,\frac{h}{n}) + g(\frac{i}{k},0) - g(\frac{i}{k},\frac{h}{n})}{g(\frac{i}{k},\frac{h}{n})}$$

3. Panel (b) computes the elasticities derived in Appendix A.

4. Panel (c) computes the changes following a 1 std **rise** in Q^K and a 1std **fall** in Q^N. It uses the formulation $\frac{\partial i_t}{\partial Q^K}\frac{Q^K}{i_t} + \frac{\partial i_t}{\partial Q^N}\frac{Q^N}{i_t}$ to compute the percentage change in i and the formulation $\frac{\partial h_t}{\partial Q^N_t}\frac{Q^N}{h_t} + \frac{\partial h_t}{\partial Q^K_t}\frac{Q^K}{h_t}$ to compute the percentage change in h. It reports the 1 std change in Q^K and in Q^N and the computed percentage change in i and in h.

Table 9

Co-Movement of Series with Business Sector GDP

logged, HP filtered

Table 4 Column 1

j	-12	-8	-4	-1	0	1	4	8	12
$\frac{i}{k}$	-0.23	-0.33	0.03	0.65	0.79	0.82	0.76	-0.23	-0.40
$\frac{g_i}{f/k}$	-0.38	-0.23	0.45	0.83	0.80	0.65	0.02	-0.33	-0.22
Q^K	0.02	0.10	0.43	0.59	0.57	0.49	0.12	-0.29	-0.42
$\frac{h}{n}$	0.03	0.08	-0.02	-0.17	-0.21	-0.28	-0.12	-0.09	-0.12
$\frac{g_h}{f/n}$	-0.05	-0.06	-0.20	-0.39	-0.32	-0.26	-0.03	0.12	0.07
Q^N	0.04	-0.07	-0.22	-0.27	-0.14	-0.08	0.08	0.09	-0.06

Table 4 Column 9

j	-12	-8	-4	-1	0	1	4	8	12
$\frac{i}{k}$	-0.23	-0.33	0.03	0.65	0.79	0.82	0.76	-0.23	-0.40
$\frac{g_i}{f/k}$	-0.35	-0.23	0.43	0.83	0.80	0.75	0.005	-0.34	-0.21
Q^K	-0.07	0.04	0.46	0.68	0.66	0.56	0.13	-0.30	-0.42
$\frac{h}{n}$	0.03	0.08	-0.02	-0.17	-0.21	-0.28	-0.12	-0.09	-0.12
$\frac{g_h}{f/n}$	0.08	0.01	-0.25	-0.48	-0.46	-0.39	-0.03	0.20	0.22
Q^N	0.10	-0.003	-0.26	-0.46	-0.43	-0.36	-0.01	0.20	0.20

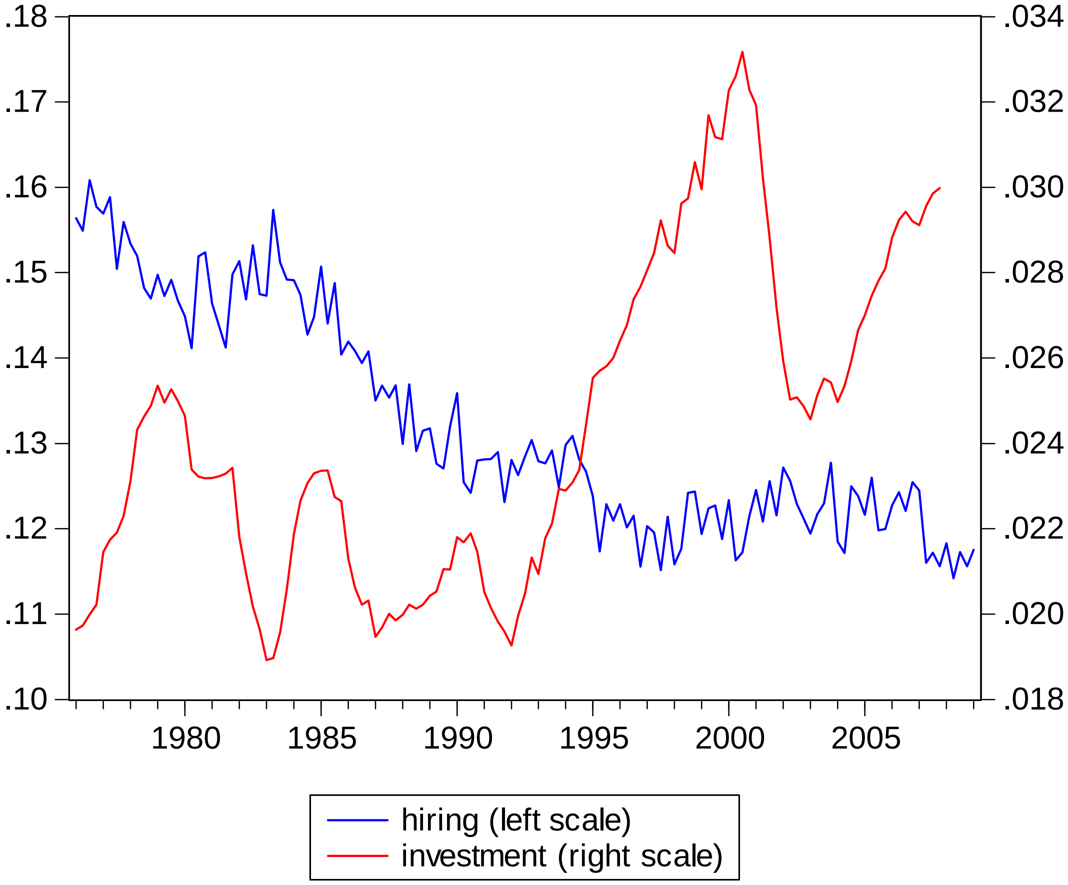


Figure 1a: U.S. Hiring $\frac{h}{n}$ and investment $\frac{i}{k}$ rates

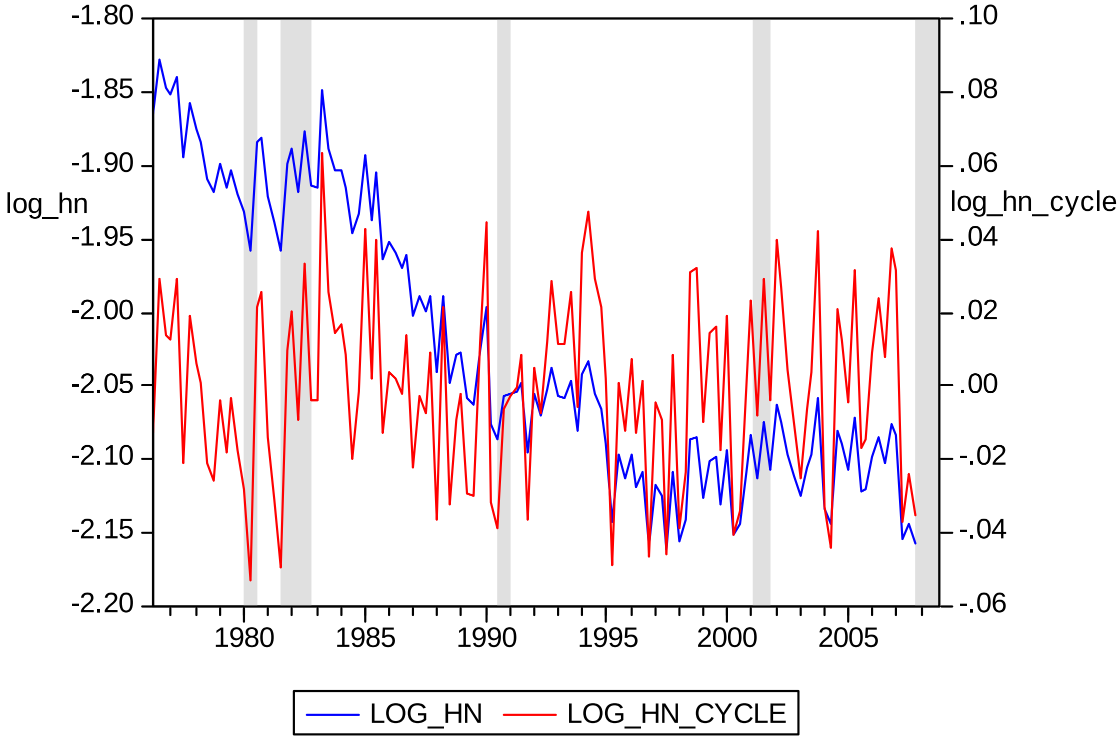


Figure 1b: Log Hiring Rates (levels and HP filtered)

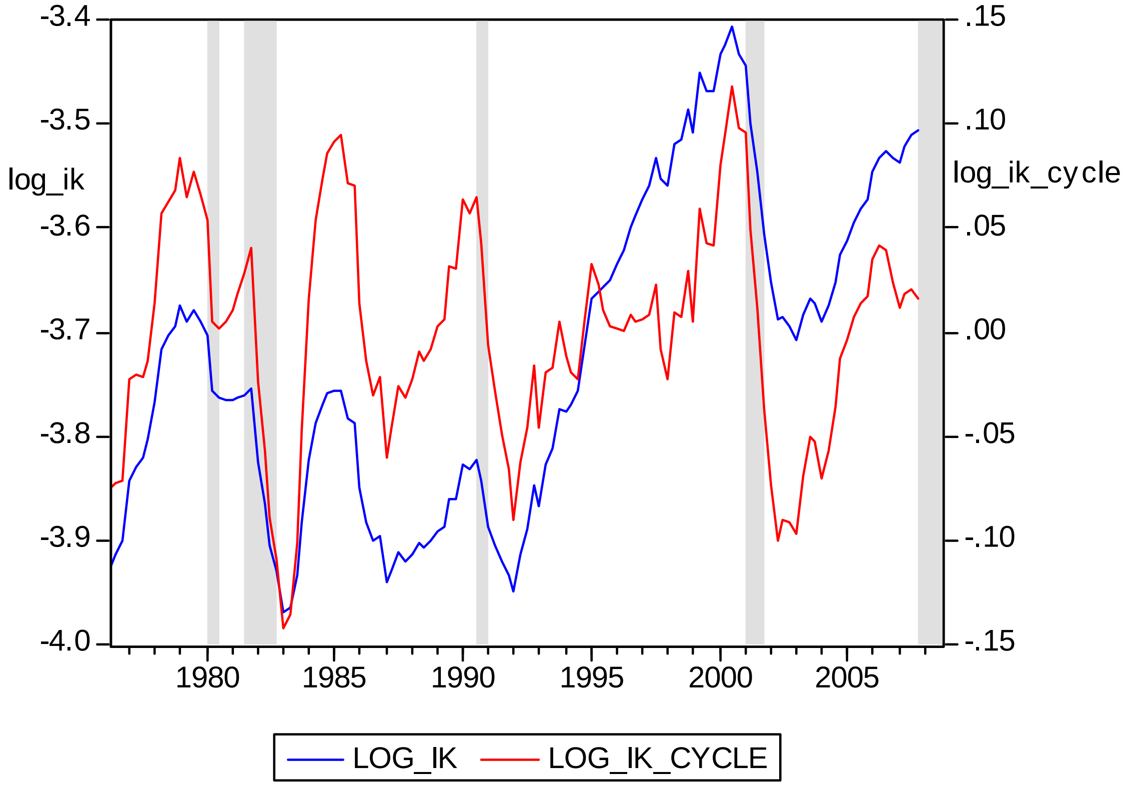


Figure 1c: Log Investment Rates (levels and HP filtered)

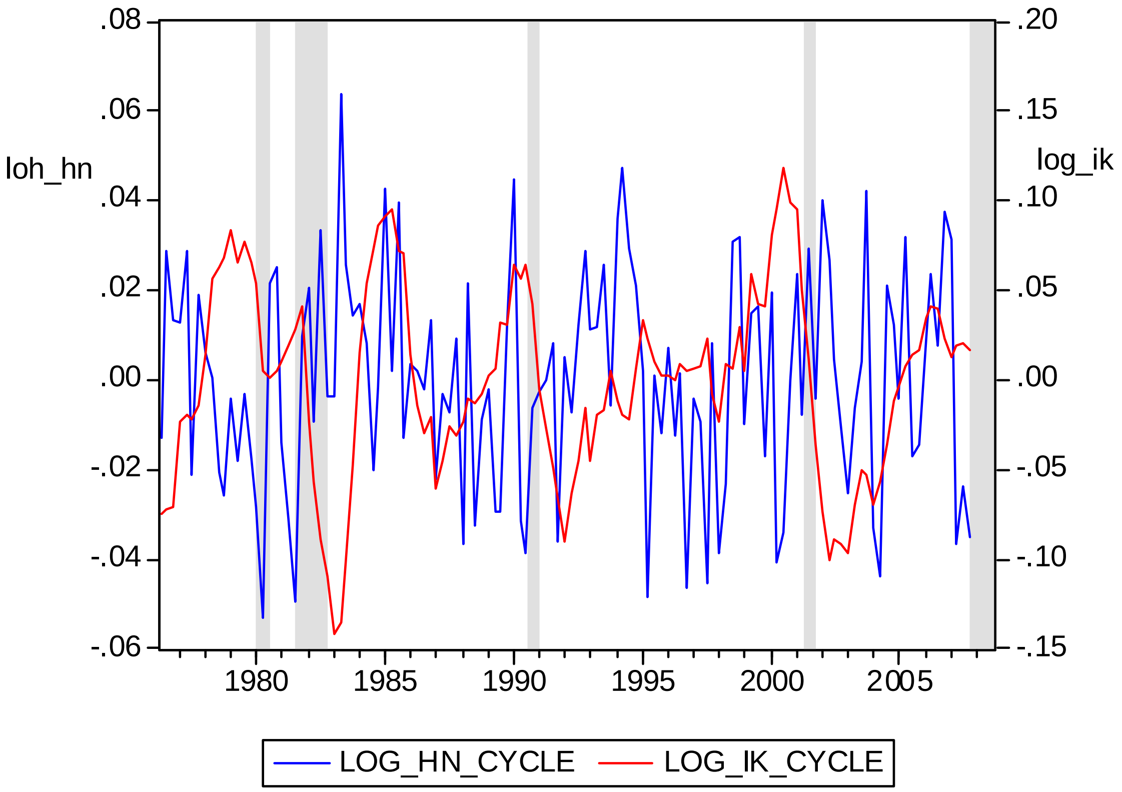


Figure 1d: Hiring and Investment Rates (logged, HP filtered)

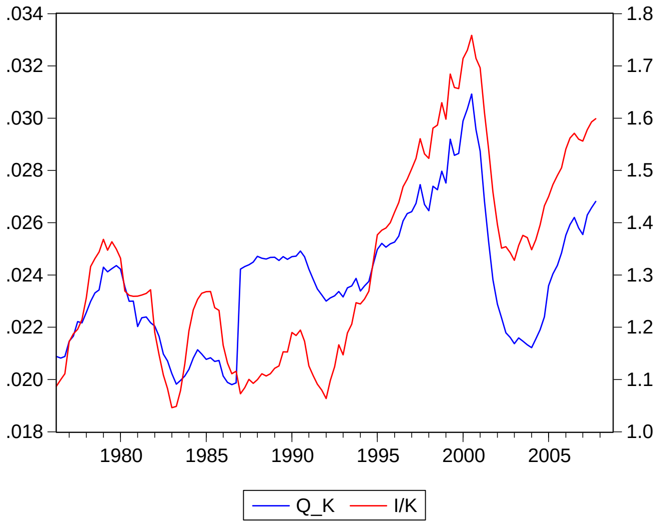


Figure 2a: $\frac{i}{k}$(left axis), Q^K (right axis)

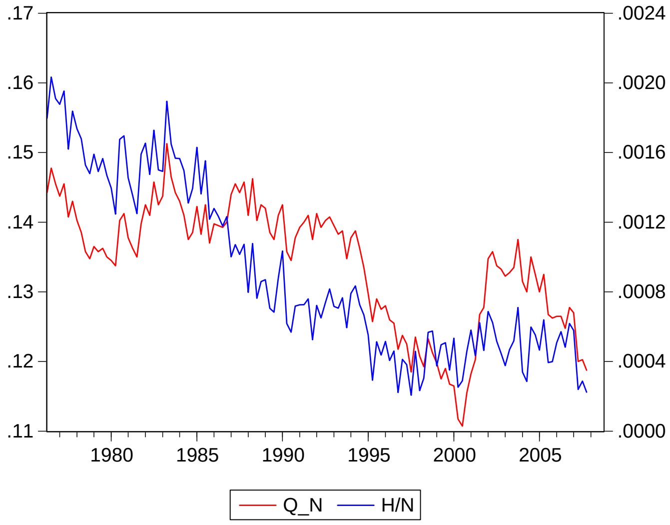


Figure 2b: $\frac{h}{n}$(left axis), Q^N (right axis)