# On The Joint Behavior of Hiring and Investment

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**Abstract**

An overlooked fact of the aggregate U.S. economy is that gross investment and gross hiring are negatively related and move in cyclically different ways. The paper explains this joint behavior. The paper structurally estimates the optimality conditions guiding the firms decisions on hiring and investment. It succeeds in matching the data, without recourse to high adjustment costs. It does so relying on postulating the interaction between costs of investment and costs of hiring. Estimation yields time-series for the key unobserved variables: marginal costs of investment and hiring and the present values to which they are equal in optimum. Using a log-linear approximation of the estimation results, a variance decomposition analysis of the relevant present values is undertaken. It shows that investment and hiring are driven differentially by their determinants. Labor profitability is important for hiring, capital productivity growth for investment.

*Key Words:* gross investment, gross hiring, business cycles, adjustment costs, present value.

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**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 without implying high adjustment costs.

The paper uses an adjustment cost 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 experiment with alternative formulations of costs. [2] The results are used to explain the business cycle behavior of hiring and investment. Understanding hiring has been deemed as key for understanding cyclical movements in employment and unemployment (see, for example, Hall (2007)).

The analysis shows that while investment and hiring occur simultaneously they do not move together nor do they have similar cyclical properties. Small adjustment costs are sufficient to fit the data. Investment seems to be linked more to movements in the relevant discount rate, including the inverse of capital productivity growth, rather than to movements in the level of the marginal product of capital. Hiring seems to be linked more to changes in labor profitability (marginal product less the wage) and less to the movements in the relevant discount rate (which includes the interest rate, the rate of worker separation and the inverse of labor productivity growth).

[1] *I thank Russell Cooper, Giuseppe Moscarini, Richard Rogerson, Gianluca Violante, and conference and seminar participants at the NBER Summer Institute 2010, Birbeck College, ESSIM, CEPR (May 2010), EUI, the LMDG meeting in Sandbjerg, Denmark (October 2009), the Fundacion Rafael del Pino in Madrid (September 2009), and 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.

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 at the implied magnitude of adjustment costs. Section 6 approximates and decomposes the present value of hiring and investment which drive these decisions. Section 7 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 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 do not move together and have markedly different cyclical behavior – investment is pro-cyclical while hiring is counter-cyclical.

Table 1 provides a quantitative summary of these features. It looks at the stochastic behavior of investment and hiring rates in logged, HP-filter terms and BP-filter terms. It presents co-movement statistics, the dynamic correlations of investment and hiring and their co-movement with three cyclical measures (real GDP, labor productivity and capital productivity).

**Table 1**

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

Gross hiring and gross investment rates exhibit negative correlation, both contemporaneously and at some leads and lags. Both contemporaneously and dynamically, hiring is counter-cyclical with respect to the three cyclical variables. With respect to the same cyclical measures, investment is pro-cyclical, sometimes strongly so. This is so both contemporaneously and at some leads and lags. The correlations are stronger with the BP filter relative to the HP filter.

To put the behavior of the hiring rate in further perspective, consider other labor market variables, which are often discussed in the literature. Note that in steady state, hiring to employment $h$ equals separations from employment $s$:

$$h = s \tag{1}$$

Hence non-employment, unemployment $u$ plus the pool out of the labor force $o$, is given by:

$$\frac{u+o}{pop} = \frac{\psi}{\frac{h}{u+o} + \psi} \tag{2}$$

where $pop$ is the working age population and $\psi$ is the separation rate from employment $n$.

Hiring rates may be defined as:

$$\frac{h}{n} = \frac{h}{u+o} \times \frac{u+o}{pop} \times \frac{pop}{n} \tag{3}$$

In steady state:

$$\underbrace{\frac{h}{n}}_{\text{hiring rate}} = \underbrace{\frac{h}{u+o}}_{\text{job finding}} \times \underbrace{\frac{\psi}{\frac{h}{u+o} + \psi}}_{\text{ss non-emp}} \times \underbrace{\frac{1}{\frac{n}{pop}}}_{\text{inv emp ratio}} \tag{4}$$

Table 2 repeats the moments of Table 1 for these variables.

**Table 2**

The table shows that the employment stock $n$ and the job finding rate $\frac{h_t}{u_t+o_t}$ are pro-cyclical, as is well known. At the same time the gross hiring rate $\frac{h_t}{n_t}$ is counter-cyclical as steady state non-employment $\frac{\psi}{\frac{h}{u+o}+\psi}$ and the inverse employment ratio $\frac{1}{\frac{n}{pop}}$ are counter-cyclical. In what follows, the gross hiring rate $\frac{h_t}{n_t}$ will be a key variable in the analysis. 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. In particular, one 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, but this is not what we observe. 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.

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 $z$:

$$y_t = f(z_t, n_t, k_t), \tag{5}$$

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 $\delta_t$ and is augmented by new investment $i_t$. The capital stock's law of motion equals:

$$k_{t+1} = (1-\delta_t)k_t + i_t, \quad 0 \leq \delta_t \leq 1. \tag{6}$$

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

$$n_{t+1} = (1-\psi_t)n_t + h_t, \quad 0 \leq \psi_t \leq 1. \tag{7}$$

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

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

$$\pi_t = [f(z_t,n_t,k_t) - g\,(i_t,k_t,h_t,n_t)] - w_t n_t\,. \tag{8}$$

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:

$$cf_t = (1-\tau_t)\pi_t - (1-\chi_t-\tau_t D_t)\,\tilde{p}_t^I\, i_t \tag{9}$$

where $\tau_t$ is the corporate income tax rate, $\chi_t$ 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 $cf_t+\,s_t$ :

$$\max_{\{i_{t+j},h_{t+j}\}} E_t\left\{\sum_{j=0}^{\infty}\left(\prod_{i=0}^{j}\beta_{t+i}\right)cf_{t+j}\right\} \tag{10}$$

subject to the definition of $cf_{t+j}$ in equation (9) and the constraints (6) and (7). The firm takes the paths of the variables $w, p^I, \delta, \psi,\ \tau$ and $\beta$ as given.

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

The 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:

$$
\begin{aligned}
Q^K_t &= E_t \left\{ \beta_{t+1} \left[ (1-\tau_{t+1}) \left( f_{k_{t+1}} - g_{k_{t+1}} \right) + (1-\delta_{t+1}) Q^K_{t+1} \right] \right\} && (11) \\
Q^K_t &= (1-\tau_t) \left( g_{i_t} + p^I_t \right) && (12) \\
Q^N_t &= E_t \left\{ \beta_{t+1} \left[ (1-\tau_{t+1}) \left( f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1} \right) + \left(1-\psi_{t+1}\right) Q^N_{t+1} \right] \right\} && (13) \\
Q^N_t &= (1-\tau_t)\, g_{h_t} && (14)
\end{aligned}
$$

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

$$
p^I_{t+j} = \frac{1-\chi_{t+j} - \tau_{t+j} D_{t+j}}{1-\tau_{t+j}} \widetilde{p}^I_{t+j}. \qquad (15)
$$

Dynamic optimality requires the following two transversality conditions to be fulfilled

$$
\begin{aligned}
\lim_{T\to\infty} E_T \left( \beta_T \, Q^K_T \, k_{T+1} \right) &= 0 && (16) \\
\lim_{T\to\infty} E_T \left( \beta_T \, Q^N_T \, n_{T+1} \right) &= 0.
\end{aligned}
$$

I can summarize the firm's first-order necessary conditions from equations (11)-(14) by the following two expressions:

$$
\begin{aligned}
(1-\tau_t) \left( g_{i_t} + p^I_t \right) &= E_t \left\{ \beta_{t+1} (1-\tau_{t+1}) \left[ \begin{array}{c} f_{k_{t+1}} - g_{k_{t+1}} \\ +(1-\delta_{t+1})(g_{i_{t+1}} + p^I_{t+1}) \end{array} \right] \right\} && (17) \\
(1-\tau_t)\, g_{h_t} &= E_t \left\{ \beta_{t+1} (1-\tau_{t+1}) \left[ \begin{array}{c} f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1} \\ +(1-\psi_{t+1}) g_{h_{t+1}} \end{array} \right] \right\}. && (18)
\end{aligned}
$$

Solving equation (11) forward and using the law of iterated expectations expresses $Q^K_t$ as the expected present value of future marginal products of physical capital net of marginal capital adjustment costs:

$$
Q^K_t = E_t \left\{ \sum_{j=0}^{\infty} \left( \prod_{i=0}^{j} \beta_{t+1+i} \right) \left( \prod_{i=0}^{j} (1-\delta_{t+1+i}) \right) (1-\tau_{t+1+j}) \left( f_{k_{t+1+j}} - g_{k_{t+1+j}} \right) \right\}. \qquad (19)
$$

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 (13) 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:

$$Q_t^N = E_t \left\{ \sum_{j=0}^{\infty} \left( \prod_{i=0}^{j} \beta_{t+1+i} \right) \left( \prod_{i=0}^{j} (1 - \psi_{t+1+i}) \right) (1 - \tau_{t+1+j}) \left( f_{n_{t+1+j}} - g_{n_{t+1+j}} - w_{t+1+j} \right) \right\}. \tag{20}$$

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

# 4 Estimation

The empirical work proceeds in the following steps: first, I estimate alternative versions of the model. The alternatives pertain to four issues: one is the degree of convexity of the adjustment costs function; a second is the possibility that hiring costs may depend on labor market conditions; a third is the set of instruments used in structural estimation; the fourth is the discount rate used in estimation. Following estimation, I use the results to analyze the value of adjustment costs and the cyclical behavior of investment and hiring.

I estimate equations (17) and (18), 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) 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:

$$f(z_t, n_t, k_t) = e^{z_t} {n_t}^{\alpha} k_t^{1-\alpha}, \ 0 < \alpha < 1. \tag{21}$$

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-

[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).

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 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.

$$g(\cdot) = \left[ \begin{array}{c} \frac{e_1}{\eta_1}\left(\frac{i_t}{k_t}\right)^{\eta_1} \\ +\left[\frac{e_{20}+e_{21}\frac{v_t}{u_t+o_t}}{\eta_2}\right]\left(\frac{h_t}{n_t}\right)^{\eta_2} \\ +\left[\frac{e_{30}+e_{31}\frac{v_t}{u_t+o_t}}{\eta_3}\right]\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3} \end{array} \right] f(z_t, n_t, k_t). \tag{22}$$

This function is linearly homogenous in its arguments $i, k, h, n, v, o,$ and $u$. The parameters $e_l$, $l = 1, 20, 21, 30, 31$ express scale, and $\eta_l$ express the elasticity of adjustment costs with respect to the different arguments. The terms $e_{21}\frac{v_t}{u_t+o_t}$ and $e_{31}\frac{v_t}{u_t+o_t}$ allow for the scale of costs to depend on market tightness $\frac{v_t}{u_t+o_t}$. This allows for the possibility that hiring costs – by themselves and by their interaction with investment costs – depend on the state of the labor market (captured by market tightness) for any given hiring rate $\frac{h}{n}$.The term $\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3}$ expresses the interaction of capital and labor adjustment costs. The function encompasses the widely used quadratic case for which $\eta_1 = \eta_2 = 2$. Note that a standard Tobin's Q model postulates $e_{20} = e_{21} = e_{30} = e_{31} = 0$ and $\eta_1 = 2$.

I explore a number of alternative specifications:

1) *The degree of convexity of the g function.* I examine restricted and free estimation of the power parameters $\eta_1, \eta_2$ and $\eta_3$.

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

3) *Scale as a function of market conditions.* I examine the above as well as the case where market conditions do not matter, namely $e_{21} = e_{31} = 0$.

4) *Standard specifications.* I set $e_{20} = e_{21} = e_{30} = e_{31} = 0$ and look at

investment costs only and then I set $e_1 = 0$ and look at hiring costs only. I also examine the case of no interaction $e_{30} = e_{31} = 0$.

Estimation of the parameters in these functions allows for the quantification of the derivatives $g_{i_t}$ and $g_{h_t}$ that appear in the firms' optimality equations (17) and (18).

### 4.1.2 Structural Estimation

I structurally estimate the firms' first-order conditions (17) and (18), 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 (17) by $\frac{f_t}{k_t}$ and (18) by $\frac{f_t}{n_t}$.

The estimating equations errors $j_t$ are thus given by:

$$j_t^1 = \frac{(1-\tau_t)\left(g_{i_t} + p_t^I\right)}{\frac{f_t}{k_t}} - \left\{ \frac{\frac{f_{t+1}}{k_{t+1}}}{\frac{f_t}{k_t}} \beta_{t+1} (1-\tau_{t+1}) \frac{\left[f_{k_{t+1}} - g_{k_{t+1}} + (1-\delta_{t+1})(g_{i_{t+1}} + p_{t+1}^I)\right]}{\frac{f_{t+1}}{k_{t+1}}} \right\} \quad (23)$$

$$j_t^2 = \frac{(1-\tau_t)\, g_{h_t}}{\frac{f_t}{n_t}} - \left\{ \frac{\frac{f_{t+1}}{n_{t+1}}}{\frac{f_t}{n_t}} \beta_{t+1} (1-\tau_{t+1}) \frac{\left[f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1} + (1-\psi_{t+1}) g_{h_{t+1}}\right]}{\frac{f_{t+1}}{n_{t+1}}} \right\} \quad (24)$$

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

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 $\psi$ and depreciation for capital $\delta$ 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**

I explore two alternatives for the discount rate $\beta$ in estimation: one is based on a DSGE model with logarithmic utility; the other is based on the weighted average cost of capital approach in corporate finance. Appendix B elaborates on the definitions of these variables.

## 4.3 Results

Table 4a presents the estimates of the parameters. The table uses $\eta_1 = \eta_2 = 2, \eta_3 = 1$ and $\alpha = 0.68$ throughout. It specifies the restrictions imposed, the estimates and their standard errors, Hansen's (1982) J-statistic and its p-value.

The first row estimates a standard Tobin's Q quadratic investment adjustment costs function with no role for hiring. The second row does the same for hiring with no investment. The third row allows for both but without any interaction between them. The fourth row is the same but allows hiring costs to depend on market tightness. The fifth row allows for interaction and the sixth row allows for interaction and dependence on market tightness.

**Table 4a**

Row 1 with the standard Q specification has precise estimates but they imply very high adjustment costs; the $e_1$ estimate is big, about three times as high as the estimate of row 6. This has been the usual case in this literature. Row 2 provides for a reasonable estimate but does not allow for investment by construction. Row 3, which allows for both, implies negative investment adjustment costs. Row 4, which does not allow for interaction either, adds the dependence of hiring on market conditions. Here $e_1$ is insignificant. Hence rows 1–4 do not provide for a satisfactory formulation of investment adjustment costs. This is provided by rows 5 and 6, which allow for investment and hiring costs to interact. This interaction is negatively signed (see the estimate of $e_{30}$) and it is the ingredient which allows the model to fit the data. Row 6 also allows for dependence of hiring costs and their interaction with investment to depend on market conditions. It is not clear whether this dependence helps. On the one hand $e_{21}$ is significant but $e_{31}$ is not and the p-value of the J-statistic falls relative to row 5.

In order to see the implications of the estimates and characterize the joint behavior of investment and hiring, I analyze the estimation results further. 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

The results of Table 4a allow me to construct time series for total and marginal adjustment costs by using the point estimates of the parameters of the $g$ function. These are presented in Table 4b.

**Table 4b**

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 but the first row, 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 0.33 in row 5 and 0.19 in row 6, the preferred specifications. This is roughly equivalent to 50% (row 5) or 29% (row 6) 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 3.8 to 6.5 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. In what follows I cite some estimates on **average** hiring 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). Note that the results here refer to the marginal hire with convex costs; hence they are consistent with the cited estimates of average costs.

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 0.20 in row 5 and of 0.60 in row 6 of Table 4b.[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**

[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.

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 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 row 1 of Table 4. This is the specification positing a quadratic function and ignoring labor. The implied total costs are 4% of output (as in studies of the moderate adjustment costs set) and the implied marginal costs are 3.3 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 $\frac{g_i}{\frac{f}{k}} = \left[e_1\left(\frac{i}{k}\right)^{\eta_1-1} + (e_{30} + e_{31}\frac{v}{u+o})\left(\frac{h}{n}\right)^{\eta_3}\left(\frac{i}{k}\right)^{\eta_3-1}\right]$ 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 marginal costs as a fraction of output per unit of capital ($\frac{g_i}{\frac{f}{k}}$), estimated at a mean of 0.2 or 0.6, the findings of Table 4b correspond to the third set, i.e., to low 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]

$$\begin{aligned} P_t &= E_t\left(R_{t+1}^{-1}[D_{t+1}+P_{t+1}]\right) \\ \frac{P_t}{D_t} &= E_t\left(R_{t+1}^{-1}[\frac{D_{t+1}}{D_t}+\frac{D_{t+1}}{D_t}\frac{P_{t+1}}{D_{t+1}}]\right) \end{aligned} \quad (25)$$

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

$$\frac{P_t}{D_t} = E_t\left(\sum_{j=1}^{\infty}\left(\prod_{k=1}^{j} R_{t+k}^{-1}\frac{D_{t+k}}{D_{t+k-1}}\right)\right) \quad (26)$$

This can be approximated as:

$$p_t - d_t = k + E_t\left(d_{t+1} - d_t - r_{t+1} + \rho(p_{t+1} - d_{t+1})\right) \quad (27)$$

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:

$$p_t - d_t = k + \left(d_{t+1} - d_t - r_{t+1} + \rho(p_{t+1} - d_{t+1})\right) \quad (28)$$

Based on (28), 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.

$$p_t - d_t \simeq \sum_{j=1}^{\infty} \rho^{j-1} k + \left( \sum_{j=1}^{\infty} \rho^{j-1} \left( d_{t+j+1} - d_{t+j} - r_{t+j} \right) \right) \tag{29}$$

$$\begin{aligned} var(p_t - d_t) \quad \simeq \quad & cov \left[ p_t - d_t, \sum_{j=1}^{\infty} \rho^{j-1} \left( d_{t+j+1} - d_{t+j} \right) \right] \\ & - cov \left[ p_t - d_t, \sum_{j=1}^{\infty} \rho^{j-1} r_{t+j} \right] \end{aligned} \tag{30}$$

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 (17)):

$$\frac{(1-\tau_t)\left(g_{i_t} + p_t^I\right)}{\frac{f_t}{k_t}} = \left\{ \frac{\frac{f_{t+1}}{k_{t+1}}}{\frac{f_t}{k_t}} \frac{\beta_{t+1}(1-\tau_{t+1})}{\frac{f_{t+1}}{k_{t+1}}} \left[ f_{k_{t+1}} - g_{k_{t+1}} + (1-\delta_{t+1})(g_{i_{t+1}} + p_{t+1}^I) \right] \right\} \tag{31}$$

I define the following asset pricing terms:

$$\begin{aligned} P_t^1 \quad & \equiv \quad \frac{(1-\tau_t)\left(g_{i_t} + p_t^I\right)}{\frac{f_t}{k_t}} \equiv \frac{Q_t^K}{\frac{f_t}{k_t}} \\ D_{t+1}^1 \quad & \equiv \quad \frac{(1-\tau_{t+1}) \frac{(f_{k_{t+1}} - g_{k_{t+1}})}{\frac{f_{t+1}}{k_{t+1}}}}{(1-\delta_{t+1})} \\ (R_{t+k})^1 \quad & = \quad \frac{\frac{f_{t+k-1}}{k_{t+k-1}}}{\frac{f_{t+k}}{k_{t+k}}} \frac{1}{\beta_{t+k}} \frac{1}{(1-\delta_{t+k})} \end{aligned} \tag{32}$$

Likewise for the hiring equation (see equation (18)):

$$\frac{(1-\tau_t)\, g_{h_t}}{\frac{f_t}{n_t}} = \left\{ \frac{\frac{f_{t+1}}{n_{t+1}}}{\frac{f_t}{n_t}} \frac{\beta_{t+1}(1-\tau_{t+1})}{\frac{f_{t+1}}{n_{t+1}}} \left[ f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1} + (1-\psi_{t+1}) g_{h_{t+1}} \right] \right\} \tag{33}$$

I define:

$$P_t^2 \equiv \frac{(1-\tau_t)\, g_{h_t}}{\frac{f_t}{n_t}} \equiv \frac{Q_t^N}{\frac{f_t}{n_t}} \tag{34}$$

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

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

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 row 6 of Table 4a. Instead of infinite sums I use alternative truncated sums, with truncation at $T$. Table 6 presents the results of decomposing equation (30) for alternative values of $T$, separately for the two equations – investment and hiring. It also presents the error of the approximated variance equation (30) 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 (30) 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 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 $\rho$. 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 $\rho^T$.

(ii) The relative error variance is not low till high levels of $T$. I report results for a $T$ which is not too high ($T = 45$) and for two values of $T$ $(75, 80)$ where the error is small.

(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 inverse of capital productivity growth $\frac{1}{\frac{\frac{f_t}{k_t}}{\frac{f_{t-1}}{k_{t-1}}}}$.

(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, i.e. the marginal product less the wage.

# 7 The Co-Movement of Hiring and Investment

Across all specifications of Table 4 , the estimate of the coefficient of the interaction term, $e_{30}$, 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 the first column of Table 7.

**Table 7**

It is on average 27% for row 5 and 39% for row 6, out of total adjustment costs. These are substantial estimates.

Table 7 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 very highly elastic with respect to the present value of investing $Q^K$, while hiring has around unitary elasticity with respect to its present value $Q^N$. The cross elasticities are low for investment w.r.t $Q^N$ (an elasticity of around 0.3-0.5) and high for hiring w.r.t $Q^K$ (over 3).

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.

To further see these relations, Figure 2 shows (in two panels) the sample behavior of $\frac{i}{k}$ and $\frac{h}{n}$,of the estimated $Q^K$ (net of $p^I$) and $Q^N$ using the point estimates of column row 6 of Table 4, and of non-financial business sector GDP $f$. The series are all logged and HP filtered. A correlation matrix for each panel is provided.

**Figure 2**

The figure and correlation matrix shows that the investment rate moves together with the estimated $Q^K$ (net of $p^I$) and that both are pro-cyclical. Likewise, hiring moves together with $Q^N$ (although less strongly so) and both are counter-cyclical. There is a negative co-movement of $Q^K$ (net) and $Q^N$ – correlation of $-0.83$ – that is consistent with a negative co-movement of the investment and hiring rates – correlation of $-0.15$.

# 8 Investment and Hiring Along the Business Cycle

Table 8 shows the co-movement of the investment and hiring rates, the estimated marginal costs and the estimated $Q^K$ (net of $p^I$) and $Q^N$ with real, non-financial business sector GDP; all series are logged and HP-filtered. The table shows the same specifications from Table 4 as used throughout.

**Table 8**

Investment rates are pro-cyclical, contemporaneously and within 4 quarters lags and leads. Likewise are marginal costs of investment $g_i$ and $Q^K$ (net of $p^I$). Hiring rates are counter-cyclical, contemporaneously and in leads and within 4 quarters in lags. Marginal costs of hiring $g_h$ and $Q^N$ behave similarly. 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 results indciate 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 model of aggregate investment and hiring with adjustment costs is a consistent and reasonable model which fits U.S. data. It was shown that allowing for interaction between hiring and investment costs enables the fit. Adjustment costs are moderate or even small relative to what has been proposed in the literature. It appears that not allowing for interaction between investment and hiring costs leads 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 ($Q^K$) behaved pro-cyclically while the value of hiring ($Q^N$) 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 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, Robert E. 2004. "Measuring Factor Adjustment Costs," **Quarterly Journal of Economics,** August, 119(3), 899-927.

[16] Hall, Robert E., 2007. " How Much Do We Understand about the Modern Recession?" **Brookings Papers on Economic Activity** 2, 13-28.

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

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

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

[20] 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.

[21] 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.

[22] 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.

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

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

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

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

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

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

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

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

[31] 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.

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

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

[34] 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

$$g(\cdot) = \left[\frac{e_1}{\eta_1}(\frac{i_t}{k_t})^{\eta_1} + \frac{(e_{20} + e_{21}\frac{v_t}{u_t+o_t})}{\eta_2}(\frac{h_t}{n_t})^{\eta_2} + \frac{(e_{30} + e_{31}\frac{v_t}{u_t+o_t})}{\eta_3}\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3}\right] f(z_t, n_t, k_t). \tag{35}$$

### First Derivatives

$$g_{i_t} = \left[e_1(\frac{i_t}{k_t})^{\eta_1 - 1} + (e_{30} + e_{31}\frac{v_t}{u_t + o_t})\left(\frac{h_t}{n_t}\right)^{\eta_3} \frac{i_t}{k_t}^{\eta_3 - 1}\right] \frac{f_t}{k_t} \tag{36}$$

$$g_{h_t} = \left[(e_{20} + e_{21}\frac{v_t}{u_t + o_t})(\frac{h_t}{n_t})^{\eta_2 - 1} + (e_{30} + e_{31}\frac{v_t}{u_t + o_t})\left(\frac{i_t}{k_t}\right)^{\eta_3} \frac{h_t}{n_t}^{\eta_3 - 1}\right] \frac{f_t}{n_t} \tag{37}$$

$$\begin{aligned} g_{k_t} &= -\left[e_1(\frac{i_t}{k_t})^{\eta_1} + (e_{30} + e_{31}\frac{v_t}{u_t + o_t})\left(\frac{h_t}{n_t}\frac{i_t}{k_t}\right)^{\eta_3}\right] \frac{f_t}{k_t} \\ &\quad +(1-\alpha)\left[\frac{e_1}{\eta_1}(\frac{i_t}{k_t})^{\eta_1} + \frac{(e_{20} + e_{21}\frac{v_t}{u_t+o_t})}{\eta_2}(\frac{h_t}{n_t})^{\eta_2} + \frac{(e_{30} + e_{31}\frac{v_t}{u_t+o_t})}{\eta_3}\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3}\right] \frac{f_t}{k_t} \end{aligned} \tag{38}$$

$$\begin{aligned} g_{n_t} &= -\left[(e_{20} + e_{21}\frac{v_t}{u_t + o_t})(\frac{h_t}{n_t})^{\eta_2} + (e_{30} + e_{31}\frac{v_t}{u_t + o_t})\left(\frac{h_t}{n_t}\frac{i_t}{k_t}\right)^{\eta_3}\right] \frac{f_t}{n_t} \\ &\quad +\alpha\left[\frac{e_1}{\eta_1}(\frac{i_t}{k_t})^{\eta_1} + \frac{(e_{20} + e_{21}\frac{v_t}{u_t+o_t})}{\eta_2}(\frac{h_t}{n_t})^{\eta_2} + \frac{(e_{30} + e_{31}\frac{v_t}{u_t+o_t})}{\eta_3}\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3}\right] \frac{f_t}{n_t} \end{aligned} \tag{39}$$

### Second Derivatives

$$g_{ii_t} = \underbrace{\left[e_1(\eta_1 - 1)\left(\frac{i_t}{k_t}\right)^{\eta_1 - 2} + e_3(\eta_3 - 1)\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3 - 2}\left(\frac{h_t}{n_t}\right)^2\right]}_{\widetilde{g}_{ii}} \frac{f(z_z, n_t, k_t)}{k_t^2} \tag{40}$$

$$g_{hh_t} = \underbrace{\left[ e_2(\eta_2 - 1) \left(\frac{h_t}{n_t}\right)^{\eta_2 - 2} + e_3(\eta_3 - 1) \left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3 - 2} \left(\frac{i_t}{k_t}\right)^2 \right]}_{\widetilde{g}_{hh}} \frac{f(z_z, n_t, k_t)}{n_t^2} \tag{41}$$

$$g_{ih_t} = g_{hi_t} = \underbrace{\left[ e_3\eta_3 \left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3 - 1} \right]}_{\widetilde{g}_{ih}} \frac{f(z_z, n_t, k_t)}{k_t n_t} \tag{42}$$

**Elasticities**
F.O.C and Their Implications

$$Q_t^K = (1 - \tau_t)\left(g_{i_t} + p_t^I\right) \tag{43}$$

$$Q_t^N = (1 - \tau_t)\, g_{h_t} \tag{44}$$

Differentiating with respect to $Q^K$ :

$$\begin{aligned} 1 &= (1 - \tau_t)\left[\frac{\partial g_{i_t}}{\partial i_t}\frac{\partial i_t}{\partial Q_t^K} + \frac{\partial g_{i_t}}{\partial h_t}\frac{\partial h_t}{\partial Q_t^K}\right] \\ 0 &= (1 - \tau_t)\left[\frac{\partial g_{h_t}}{\partial i_t}\frac{\partial i_t}{\partial Q_t^K} + \frac{\partial g_{h_t}}{\partial h_t}\frac{\partial h_t}{\partial Q_t^K}\right] \end{aligned} \tag{45}$$

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

$$\begin{aligned} \frac{\partial i_t}{\partial Q^K} &= \frac{g_{hh}}{(1 - \tau_t)\left(g_{ii}g_{hh} - g_{ih}g_{hi}\right)} \\ \frac{\partial h_t}{\partial Q^K} &= -\frac{g_{hi}}{(1 - \tau_t)\left(g_{ii}g_{hh} - g_{ih}g_{hi}\right)}. \end{aligned} \tag{46}$$

Differentiating with respect to $Q^N$ :

$$\begin{aligned} 0 &= (1 - \tau_t)\left[\frac{\partial g_{i_t}}{\partial i_t}\frac{\partial i_t}{\partial Q_t^N} + \frac{\partial g_{i_t}}{\partial h_t}\frac{\partial h_t}{\partial Q_t^N}\right] \\ 1 &= (1 - \tau_t)\left[\frac{\partial g_{h_t}}{\partial i_t}\frac{\partial i_t}{\partial Q_t^N} + \frac{\partial g_{h_t}}{\partial h_t}\frac{\partial h_t}{\partial Q_t^N}\right] \end{aligned} \tag{47}$$

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

$$\begin{aligned}\frac{\partial h_t}{\partial Q^N} &= \frac{g_{ii}}{(1-\tau_t)\left(g_{ii}g_{hh}-g_{ih}g_{hi}\right)} \\ \frac{\partial i_t}{\partial Q^N} &= -\frac{g_{ih}}{(1-\tau_t)\left(g_{ii}g_{hh}-g_{ih}g_{hi}\right)}.\end{aligned} \tag{48}$$

*Elasticities With Respect to $Q^K$*
Using (46):

$$\begin{aligned}\frac{\partial i_t}{\partial Q^K}\frac{Q^K}{i_t} &= \frac{\widetilde{g}_{hh}\frac{f_t}{n_t^2}}{(1-\tau_t)\left[\widetilde{g}_{ii}\widetilde{g}_{hh}\frac{f_t}{k_t^2}\frac{f_t}{n_t^2}-\widetilde{g}_{ih}\widetilde{g}_{hi}\left(\frac{f_t}{k_t}\frac{1}{n_t}\right)^2\right]}\frac{Q^K}{i_t} \\ &= \frac{\widetilde{g}_{hh}}{(1-\tau_t)\left[\widetilde{g}_{ii}\widetilde{g}_{hh}-\widetilde{g}_{ih}\widetilde{g}_{hi}\right]}\frac{\frac{Q^K}{\frac{f_t}{k_t}}}{\frac{i_t}{k_t}} \\ \frac{\partial h_t}{\partial Q^k}\frac{Q^K}{h_t} &= -\frac{g_{hi}}{(1-\tau_t)\left[g_{ii}g_{hh}-g_{ih}g_{hi}\right]}\frac{Q^K}{h_t} \\ &= -\frac{\widetilde{g}_{hi}}{(1-\tau_t)\left[\widetilde{g}_{ii}\widetilde{g}_{hh}-\widetilde{g}_{ih}\widetilde{g}_{hi}\right]}\frac{\frac{Q^K}{\frac{f_t}{k_t}}}{\frac{h_t}{n_t}}\end{aligned} \tag{49}$$

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 (48):

$$\begin{aligned}\frac{\partial h_t}{\partial Q^N}\frac{Q^N}{h_t} &= \frac{\widetilde{g}_{ii}\frac{f_t}{k_t^2}}{(1-\tau_t)\left[\widetilde{g}_{ii}\widetilde{g}_{hh}\frac{f_t}{k_t^2}\frac{f_t}{n_t^2}-\widetilde{g}_{ih}\widetilde{g}_{hi}\left(\frac{f_t}{k_t}\frac{1}{n_t}\right)^2\right]}\frac{Q^N}{h_t} \\ &= \frac{\widetilde{g}_{ii}}{(1-\tau_t)\left[\widetilde{g}_{ii}\widetilde{g}_{hh}-\widetilde{g}_{ih}\widetilde{g}_{hi}\right]}\frac{\frac{Q^N}{\frac{f_t}{n_t}}}{\frac{h_t}{n_t}}\end{aligned} \tag{50}$$

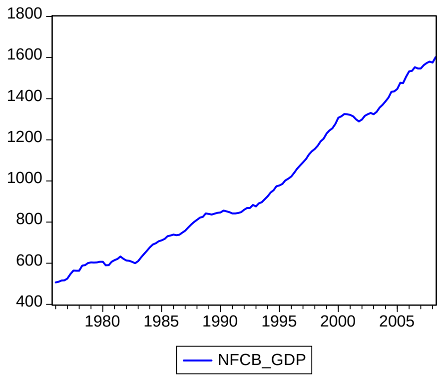
$$\begin{aligned}\frac{\partial i_t}{\partial Q^N}\frac{Q^N}{i_t} &= -\frac{g_{ih}}{(1-\tau_t)\left[g_{ii}g_{hh}-g_{ih}g_{hi}\right]}\frac{Q^N}{i_t} \\ &= -\frac{\widetilde{g}_{ih}}{(1-\tau_t)\left[\widetilde{g}_{ii}\widetilde{g}_{hh}-\widetilde{g}_{ih}\widetilde{g}_{hi}\right]}\frac{\frac{Q^N}{\frac{f_t}{h_t}}}{\frac{i_t}{k_t}}\end{aligned}$$

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

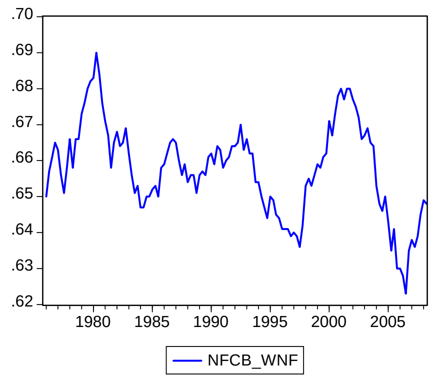
*GDP and its deflator*

Real GDP $f$ pertains to nonfinancial corporate business sector. The data originate from NIPA accounts, table 1.14, line 40 (gross value added of nonfinancial 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:

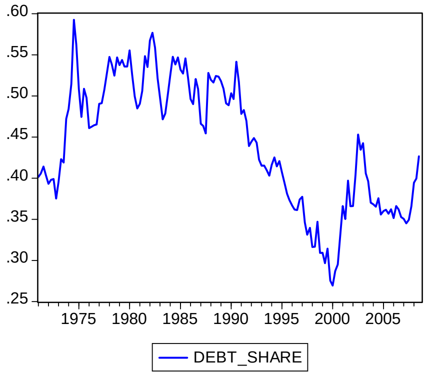
(i) $\omega_t$ is the share of debt finance. I calculate it on the basis of Level Tables of Flow of Funds accounts (files ltabs.zip). The calculations are as follows:

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 $\tau$ as discussed below.

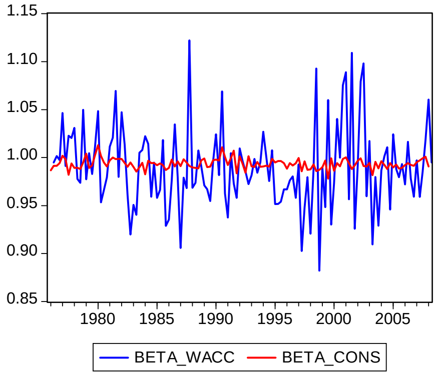
(iii) $\theta$ denotes inflation and is measured by the GDP-deflator of $p^f$ discussed above.

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

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

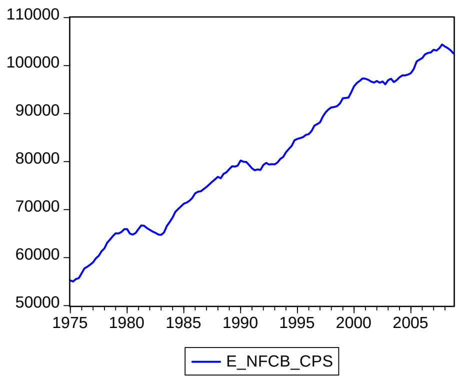
where $r_{1,2,3}$ are the respective month of each given quarter.

The graph below shows the two $\beta$ 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.

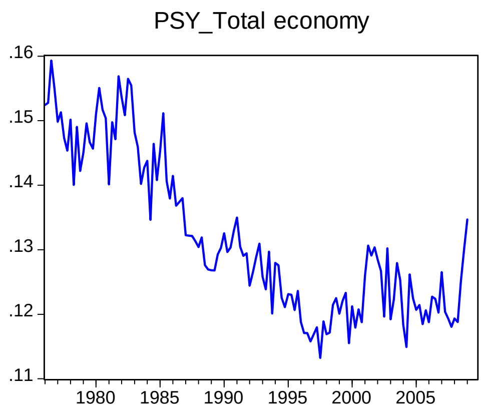


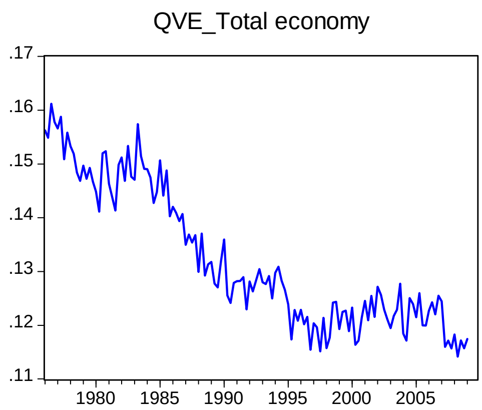

To calculate hiring and separation rates for the whole economy I use the series kindly provided by Ofer Cornfeld. This computation first builds the flows between $E$ (employment), $U$ (unemployment) and $N$ (not-in-the-labor-force) that correspond to the $E, U, N$ stocks published by CPS. The methodology 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 ($\psi$) and the quarterly hiring rate ($h/n$) for the whole economy are defined as follows:

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

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 $\delta_t$. 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, $I_t$:

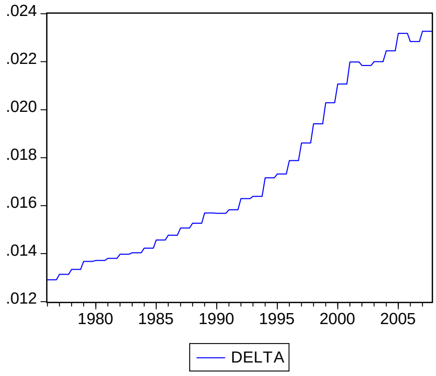
$$I_t = K_t - K_{t-1} + D_t$$

- Calculate implied annual depreciation rate, $\delta_a$:

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

- Calculate implied quarterly depreciation rate for each year, $\delta_{qt}$:

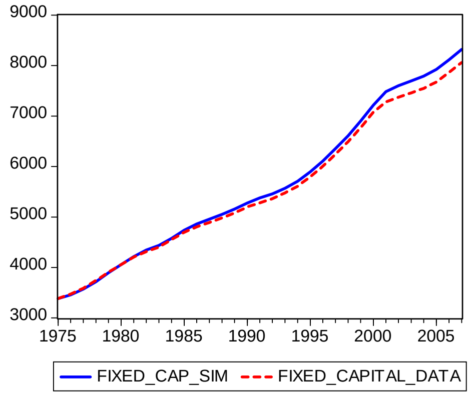
$$\delta_q + (1-\delta_q)\delta_q + (1-\delta_q)^2\delta_q + (1-\delta_q)^3\delta_q = \delta_a$$




quarterly depreciation rate $\delta_q$

- 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 $\delta_{qt}$ 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 $\delta_{qt}$ 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 $\Delta p_t^j$, $j = Inv, Eq, St$. 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 $\omega_t$ 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 $\tau$ denotes the statutory corporate income tax rate as reported by the U.S. Tax Foundation.

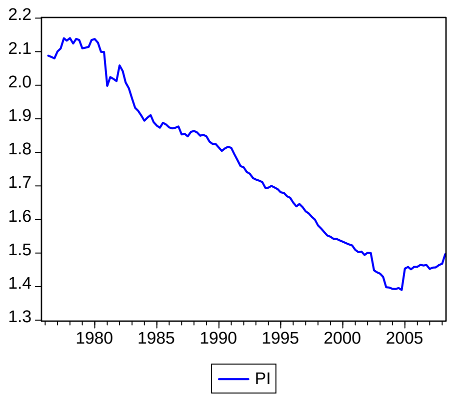
Let $ITC$ denote the investment tax credit on equipment and public utility structures, $ZPDE$ the present discounted value of capital depreciation allowances, and $\chi$ the percentage of the cost of equipment that cannot be depreciated if the firm takes the investment tax credit. Flint Brayton has kindly 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 and BP-filtered

### a. Investment and Hiring Co-Movement $\rho(\frac{i_t}{k_t}, \frac{h_{t-i}}{nt_{-i}})$

**HP filtered** ($\lambda = 1600$)

| lag/lead | -8 | -4 | -1 | 0 | 1 | 4 | 8 |
|---|---|---|---|---|---|---|---|
| | 0.10 | 0.02 | −0.15 | −0.15 | −0.18 | −0.07 | −0.10 |

**BP filtered** (Baxter-King, 6-32)

| lag/lead | -8 | -4 | -1 | 0 | 1 | 4 | 8 |
|---|---|---|---|---|---|---|---|
| | 0.18 | 0.03 | −0.25 | −0.29 | −0.27 | −0.04 | −0.09 |

### b. Hiring Cyclicality $\rho(\frac{h_t}{n_t}, y_{t-i})$

**HP filtered** ($\lambda = 1600$)

| lag/lead | -8 | -4 | -1 | 0 | 1 | 4 | 8 |
|---|---|---|---|---|---|---|---|
| $f$ | −0.10 | −0.12 | −0.27 | −0.20 | −0.16 | 0.00 | 0.08 |
| $\frac{f}{n}$ | −0.07 | 0.00 | −0.08 | −0.03 | −0.07 | 0.00 | 0.02 |
| $\frac{f}{k}$ | −0.12 | −0.13 | −0.25 | −0.17 | −0.13 | 0.02 | 0.10 |

**BP filtered** (Baxter-King, 6-32)

| lag/lead | -8 | -4 | -1 | 0 | 1 | 4 | 8 |
|---|---|---|---|---|---|---|---|
| $f$ | −0.07 | −0.17 | −0.40 | −0.36 | −0.24 | 0.07 | 0.09 |
| $\frac{f}{n}$ | 0.07 | −0.05 | −0.21 | −0.15 | −0.05 | 0.10 | 0.02 |
| $\frac{f}{k}$ | −0.12 | −0.20 | −0.40 | −0.35 | −0.22 | 0.11 | 0.10 |

### c. Investment Cyclicality $\rho(\frac{i_t}{k_t}, y_{t-i})$

**HP filtered** ($\lambda = 1600$)

| lag/lead | -8 | -4 | -1 | 0 | 1 | 4 | 8 |
|---|---|---|---|---|---|---|---|
| $f$ | −0.23 | 0.46 | 0.83 | 0.80 | 0.66 | 0.05 | −0.32 |
| $\frac{f}{n}$ | 0.07 | 0.61 | 0.62 | 0.52 | 0.34 | −0.27 | −0.43 |
| $\frac{f}{k}$ | −0.10 | 0.58 | 0.84 | 0.76 | 0.57 | −0.11 | −0.43 |

**BP filtered** (Baxter-King, 6-32)

| lag/lead | -8 | -4 | -1 | 0 | 1 | 4 | 8 |
|---|---|---|---|---|---|---|---|
| $f$ | −0.28 | 0.40 | 0.84 | 0.79 | 0.61 | −0.03 | −0.30 |
| $\frac{f}{n}$ | 0.01 | 0.58 | 0.67 | 0.51 | 0.28 | −0.33 | −0.39 |
| $\frac{f}{k}$ | −0.14 | 0.54 | 0.85 | 0.75 | 0.52 | −0.20 | −0.41 |

**Table 2**
**Stochastic Behavior of Hiring and Other Labor Market Variables**

**Co-Movement (contemporaneous, logged, HP filtered)**

| | $n_t$ | $\frac{h_t}{n_t}$ | $\frac{h_t}{u_t+o_t}$ | $\frac{\psi}{\frac{h_t}{u_t+o_t}+\psi}$ | $\frac{1}{\frac{n_t}{POP_t}}$ |
|---|---|---|---|---|---|
| with GDP $f$ | 0.82 | $-0.20$ | 0.51 | $-0.67$ | $-0.88$ |
| with $\frac{f}{n}$ | 0.32 | $-0.03$ | 0.35 | $-0.55$ | $-0.48$ |

**Table 3**

**Descriptive Sample Statistics**

| Variable | Mean | Standard Deviation |
|---|---|---|
| $\frac{i}{k}$ | 0.024 | 0.004 |
| $\frac{f}{k}$ | 0.166 | 0.014 |
| $\tau$ | 0.387 | 0.057 |
| $\delta$ | 0.017 | 0.003 |
| $\frac{wn}{f}$ | 0.658 | 0.013 |
| $\frac{h}{n}$ | 0.133 | 0.013 |
| $\frac{v}{u+0}$ | 0.111 | 0.038 |
| $\psi$ | 0.132 | 0.012 |
| $\beta$ | 0.994 | 0.005 |

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

**Table 4a**
**GMM Estimates of the FOC (17) and (18)**

| | specification | $e_1$ | $e_{20}$ | $e_{21}$ | $e_{30}$ | $e_{31}$ | J-Statistic |
|---|---|---|---|---|---|---|---|
| 1 | investment costs only | 134.29 | | | | | 86.26 |
| | | (2.23) | | | | | (0.14) |
| 2 | hiring costs only | | 2.73 | | | | 82.47 |
| | | | (0.12) | | | | (0.21) |
| 3 | both, no interaction | −16.93 | 3.18 | | | | 78.17 |
| | no market tightness | (6.02) | (0.20) | | | | (0.29) |
| 4 | both, no interaction | 4.22 | 3.45 | −11.75 | | | 82.39 |
| | with market tightness | (5.25) | (0.19) | (0.97) | | | (0.17) |
| 5 | both, with interaction | 18.66 | 2.86 | | −1.99 | | 77.81 |
| | no market tightness | (6.80) | (0.21) | | (0.96) | | (0.52) |
| 6 | both, with interaction | 37.66 | 3.10 | −10.63 | −3.10 | 5.85 | 80.44 |
| | with market tightness | (7.45) | (0.27) | (1.78) | (1.04) | (8.78) | (0.16) |

**Notes:**
1. The table reports point estimates with standard errors in parantheses.
2. J-statistic is reported with $p$ value in parantheses.
3. $\eta_1, \eta_2, \eta_3$ are fixed at 2,2,1; $\alpha$ is fixed at 0.68.
4. The instrument set is:.$\frac{i}{k}, \frac{h}{n}, \frac{w}{\frac{f}{n}}, \frac{v}{u}, p^I, \beta$ with 6 lags.

**Table 4b**
**Adjustment Costs Function Implied by the GMM Estimation Results**

| | specification | $g$ | | $g_i$ | | $g_h$ | |
|---|---|---|---|---|---|---|---|
| | | mean | std. | mean | std. | mean | std. |
| 1 | investment costs only | 0.04 | 0.01 | 3.29 | 0.50 | 0 | |
| 2 | hiring costs only | 0.02 | 0.00 | 0 | | 0.36 | 0.03 |
| 3 | both, no interaction no market tightness | 0.02 | 0.01 | −0.42 | 0.06 | 0.41 | 0.04 |
| 4 | both, no interaction with market tightness | 0.02 | 0.00 | 0.10 | 0.01 | 0.28 | 0.05 |
| 5 | both, with interaction no market tightness | 0.02 | 0.00 | 0.20 | 0.09 | 0.33 | 0.04 |
| 6 | both, with interaction with market tightness | 0.02 | 0.00 | 0.60 | 0.15 | 0.19 | 0.04 |

**Notes:**
1. Mean and std. refer to sample statistics.
2. The functions were computed using the point estimates in Table 4a.

**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 | $0.20 - 0.23$ | $0.15 - 0.4$ |
| 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 (30)**

**Investment**

| $T$ | 45 | 75 | 80 |
|---|---|---|---|
| $\rho^T$ | 0.28 | 0.12 | 0.11 |
| $\frac{e}{var(p_t - d_t)}$ | 0.35 | −0.05 | 0.04 |
| $\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1}(d_{t+j+1} - d_{t+j})\right]}{var(p_t - d_t)}$ | 0.40 | 0.40 | 0.34 |
| $\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1} r_{t+j}\right]}{var(p_t - d_t)}$ | −0.25 | −0.65 | −0.62 |

**Hiring**

| $T$ | 45 | 75 | 80 |
|---|---|---|---|
| $\rho^T$ | 0.0003 | $1 * 10^{-6}$ | $5 * 10^{-7}$ |
| $\frac{e}{var P/D}$ | 0.38 | 0.09 | 0.06 |
| $\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1}(d_{t+j+1} - d_{t+j})\right]}{var(p_t - d_t)}$ | 0.68 | 0.91 | 0.93 |
| $\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1} r_{t+j}\right]}{var(p_t - d_t)}$ | 0.05 | 0.00 | −0.01 |

**Notes:**

1. See section 6 for definitions.
2. The table uses the point estimates of row 6 of Table 4a.

**Table 7**
**Scope and Elasticities Implied by GMM Estimation Results**

| | specification | scope | $\frac{\partial i_t}{\partial Q^K}\frac{Q^K}{i_t}$ | $\frac{\partial i_t}{\partial Q^N}\frac{Q^N}{i_t}$ | $\frac{\partial h_t}{\partial Q^k}\frac{Q^K}{h_t}$ | $\frac{\partial h_t}{\partial Q^N}\frac{Q^N}{h_t}$ |
|---|---|---|---|---|---|---|
| 1 | investment costs only | 0 | 4.35 | – | – | – |
| | | | (1.05) | | | |
| 2 | hiring costs only | 0 | – | – | – | 1.00 |
| | | | | | | $(1.31 * 10^{-5})$ |
| 3 | both, no interaction | 0 | −25.61 | 0 | 0 | 1.00 |
| | no market tightness | | (8.29) | | | (0.00) |
| 4 | both, no interaction | 0 | 107.77 | 0 | 0 | 1.00 |
| | with market tightness | | (33.27) | | | (0.00) |
| 5 | both, with interaction | 0.27 | 26.39 | 0.55 | 3.27 | 0.94 |
| | no market tightness | (0.04) | (7.99) | (0.13) | (0.40) | (0.03) |
| 6 | both, with interaction | 0.39 | 13.77 | 0.30 | 3.23 | 0.82 |
| | with market tightness | (0.02) | (4.02) | (0.08) | (0.65) | (0.06) |

**Notes:**
1. All computations are based on the point estimates of Table 4a.
2. The scope statistic is 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. The elasticities are derived in Appendix A.

**Table 8**

**Co-Movement of Series with Business Sector GDP $f$**
logged, HP filtered
$\rho(x_{t-j}, f_t)$

**I Investment costs only**

| $j$ | -8 | -4 | -1 | 0 | 1 | 4 | 8 |
|---|---|---|---|---|---|---|---|
| $\frac{i}{k}$ | $-0.27$ | $-0.01$ | 0.61 | 0.78 | 0.81 | 0.40 | $-0.24$ |
| $\frac{g_i}{f/k}$ | $-0.27$ | $-0.01$ | 0.61 | 0.78 | 0.81 | 0.40 | $-0.24$ |
| $\frac{Q^K}{f/k}$ | $-0.28$ | 0.05 | 0.66 | 0.80 | 0.81 | 0.36 | $-0.18$ |

**II Hiring costs only**

| $j$ | -8 | -4 | -1 | 0 | 1 | 4 | 8 |
|---|---|---|---|---|---|---|---|
| $\frac{h}{n}$ | 0.06 | $-0.01$ | $-0.17$ | $-0.19$ | $-0.25$ | $-0.06$ | $-0.06$ |
| $\frac{g_h}{f/n}$ | 0.06 | $-0.01$ | $-0.17$ | $-0.19$ | $-0.25$ | $-0.06$ | $-0.06$ |
| $Q^N$ | $-0.01$ | 0.10 | 0.00 | $-0.06$ | $-0.14$ | $-0.08$ | 0.05 |

**III Both hiring costs and investment costs**
**no interaction, without market tighness**

| $j$ | -8 | -4 | -1 | 0 | 1 | 4 | 8 |
|---|---|---|---|---|---|---|---|
| $\frac{i}{k}$ | $-0.27$ | $-0.01$ | 0.61 | 0.78 | 0.81 | 0.40 | $-0.24$ |
| $\frac{g_i}{f/k}$ | | | | – | | | |
| $\frac{Q^K}{f/k}$ | | | | – | | | |
| $\frac{h}{n}$ | 0.06 | $-0.01$ | $-0.17$ | $-0.19$ | $-0.25$ | $-0.06$ | $-0.06$ |
| $\frac{g_h}{f/n}$ | 0.06 | $-0.01$ | $-0.17$ | $-0.19$ | $-0.25$ | $-0.06$ | $-0.06$ |
| $Q^N$ | $-0.01$ | 0.10 | 0.00 | $-0.06$ | $-0.14$ | $-0.08$ | 0.05 |

**IV Both hiring costs and investment costs**
**with interaction, without market tighness**

| $j$ | -8 | -4 | -1 | 0 | 1 | 4 | 8 |
|---|---|---|---|---|---|---|---|
| $\frac{i}{k}$ | $-0.24$ | 0.01 | 0.60 | 0.77 | 0.82 | 0.41 | $-0.24$ |
| $\frac{g_i}{f/k}$ | $-0.26$ | $-0.09$ | 0.52 | 0.69 | 0.78 | 0.33 | $-0.25$ |
| $\frac{Q^K}{f/k}$ | $-0.27$ | $-0.06$ | 0.55 | 0.72 | 0.79 | 0.32 | $-0.24$ |
| $\frac{h}{n}$ | 0.03 | $-0.03$ | $-0.14$ | $-0.15$ | $-0.22$ | $-0.05$ | $-0.06$ |
| $\frac{g_h}{f/n}$ | 0.08 | $-0.04$ | $-0.29$ | $-0.34$ | $-0.41$ | $-0.16$ | $-0.01$ |
| $Q^N$ | 0.03 | 0.07 | $-0.13$ | $-0.21$ | $-0.31$ | $-0.17$ | 0.07 |

**V Both hiring costs and investment costs with interaction, with market tighness**

| $j$ | -8 | -4 | -1 | 0 | 1 | 4 | 8 |
|---|---|---|---|---|---|---|---|
| $\frac{i}{k}$ | $-0.27$ | $-0.01$ | 0.61 | 0.78 | 0.81 | 0.40 | $-0.24$ |
| $\frac{g_i}{f/k}$ | $-0.25$ | 0.02 | 0.67 | 0.83 | 0.84 | 0.35 | $-0.25$ |
| $\frac{Q^K}{f/k}$ | $-0.26$ | 0.06 | 0.70 | 0.85 | 0.85 | 0.33 | $-0.23$ |
| | | | | | | | |
| $\frac{h}{n}$ | 0.06 | $-0.01$ | $-0.17$ | $-0.19$ | $-0.25$ | $-0.06$ | $-0.06$ |
| $\frac{g_h}{f/n}$ | 0.02 | $-0.30$ | $-0.80$ | $-0.86$ | $-0.77$ | $-0.20$ | 0.25 |
| $Q^N$ | 0.01 | $-0.28$ | $-0.77$ | $-0.85$ | $-0.77$ | $-0.22$ | 0.28 |

**Notes**:

1. All series are based on the point estimates of Table 4a.
2. $\frac{Q^K}{f/k}$ is net of $p^I$.
3. In III the estimated $e_1$ is negative, so there is no report of marginal costs or $Q^K$.

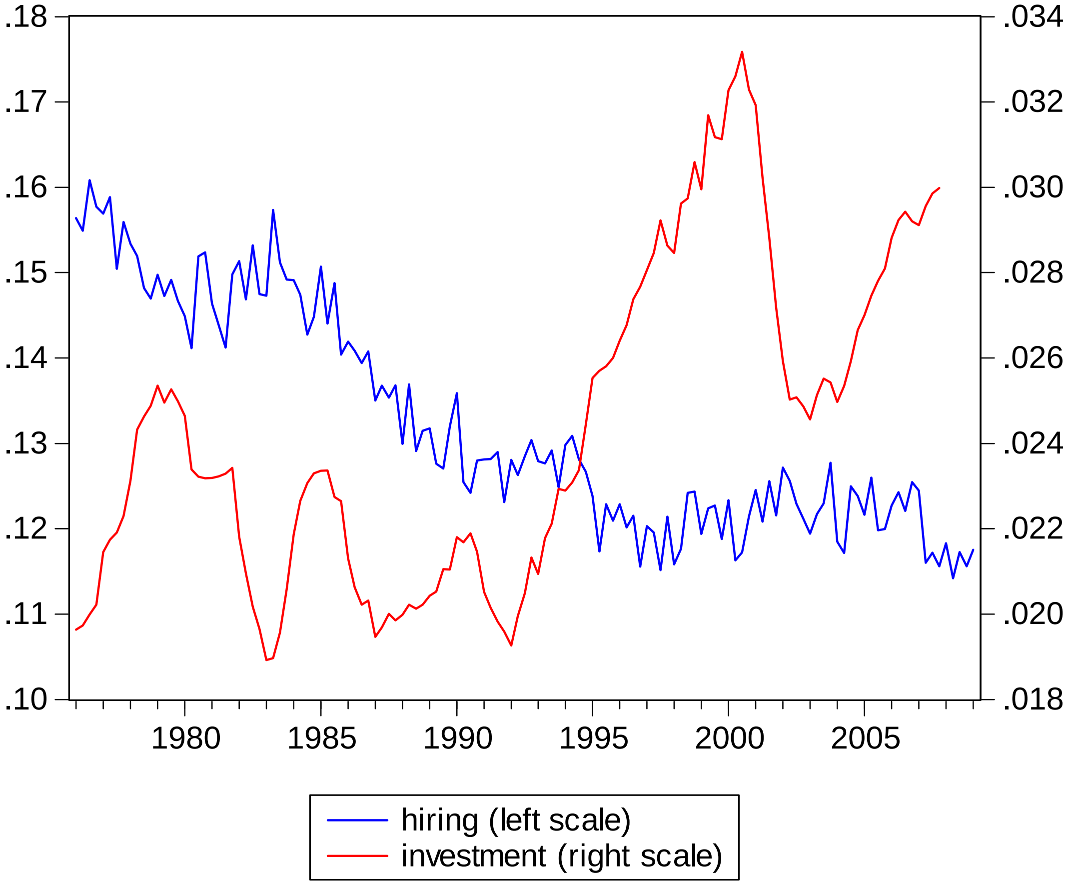



Figure 1a: U.S. hiring $\frac{h}{n}$ and investment $\frac{i}{k}$ rates

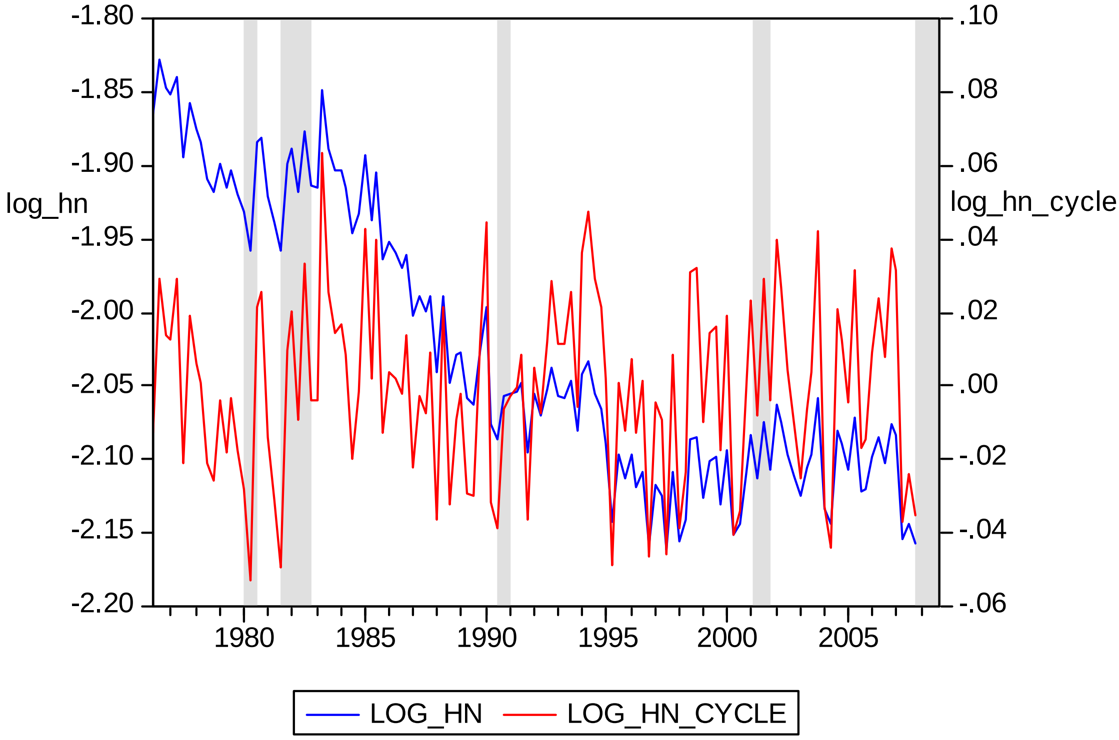



Figure 1b: Log Hiring Rates (levels and HP filtered)

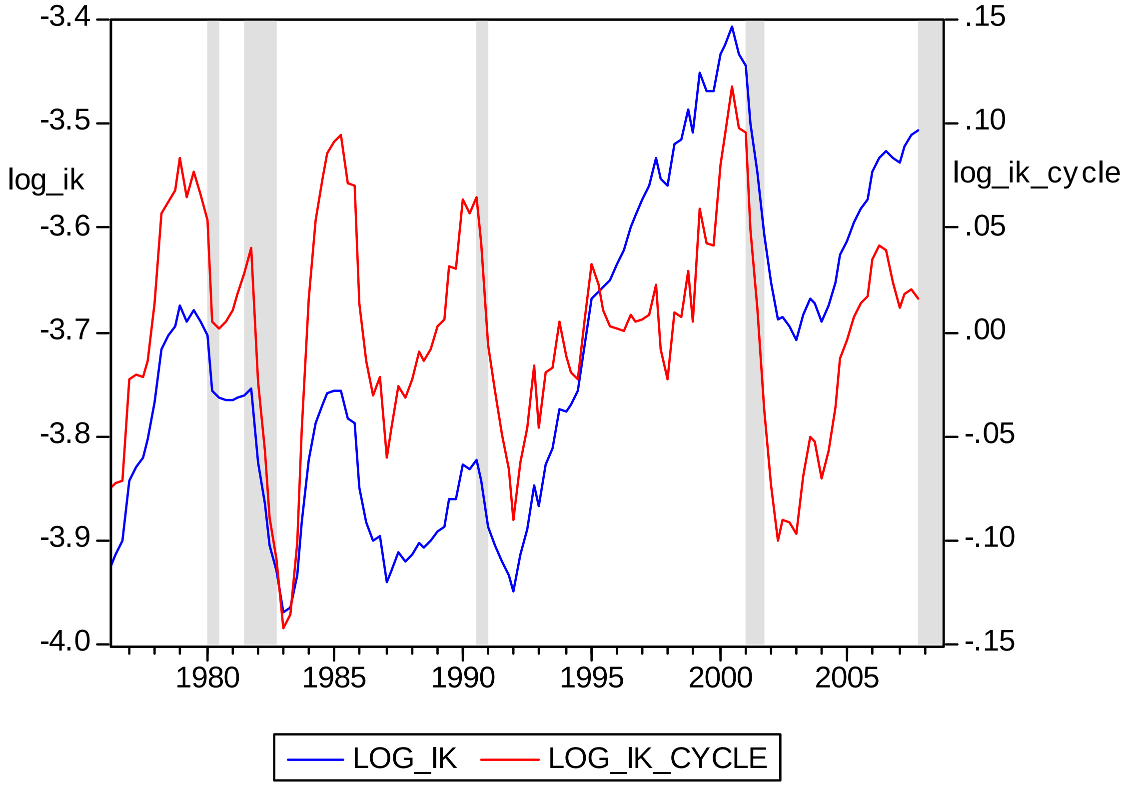



Figure 1c: Log Investment Rates (levels and HP filtered)

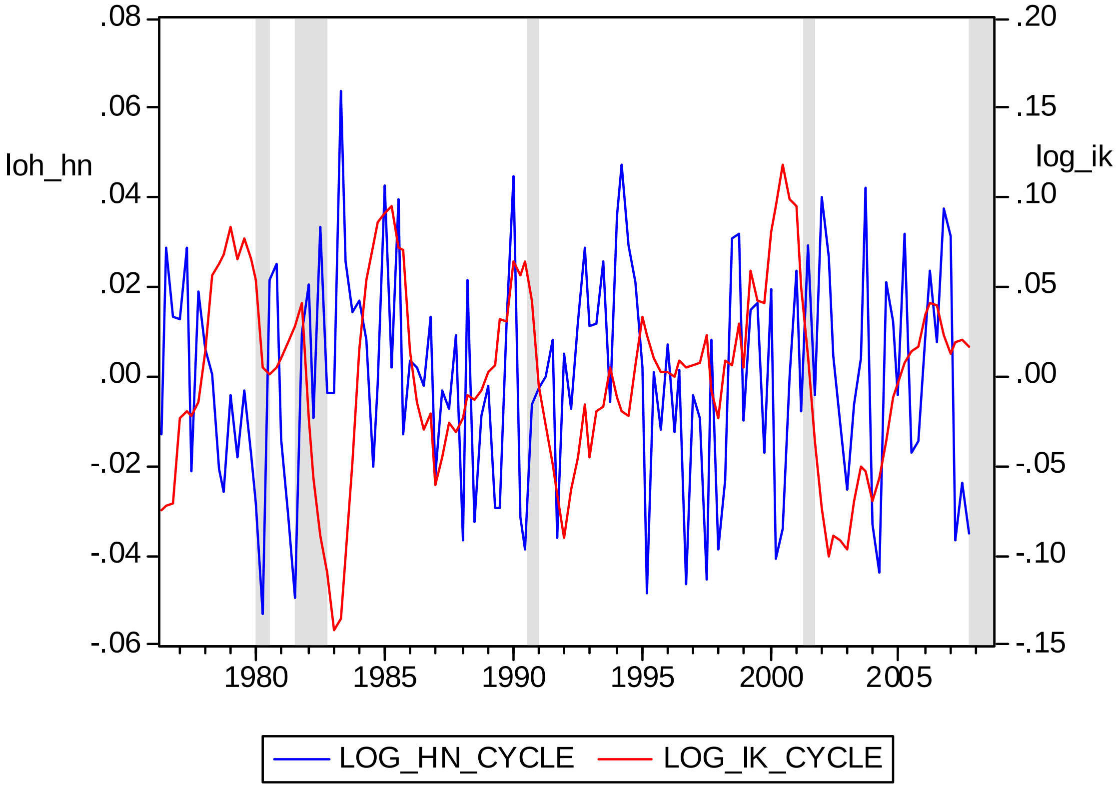



Figure 1d: Hiring and Investment Rates (logged, HP filtered)

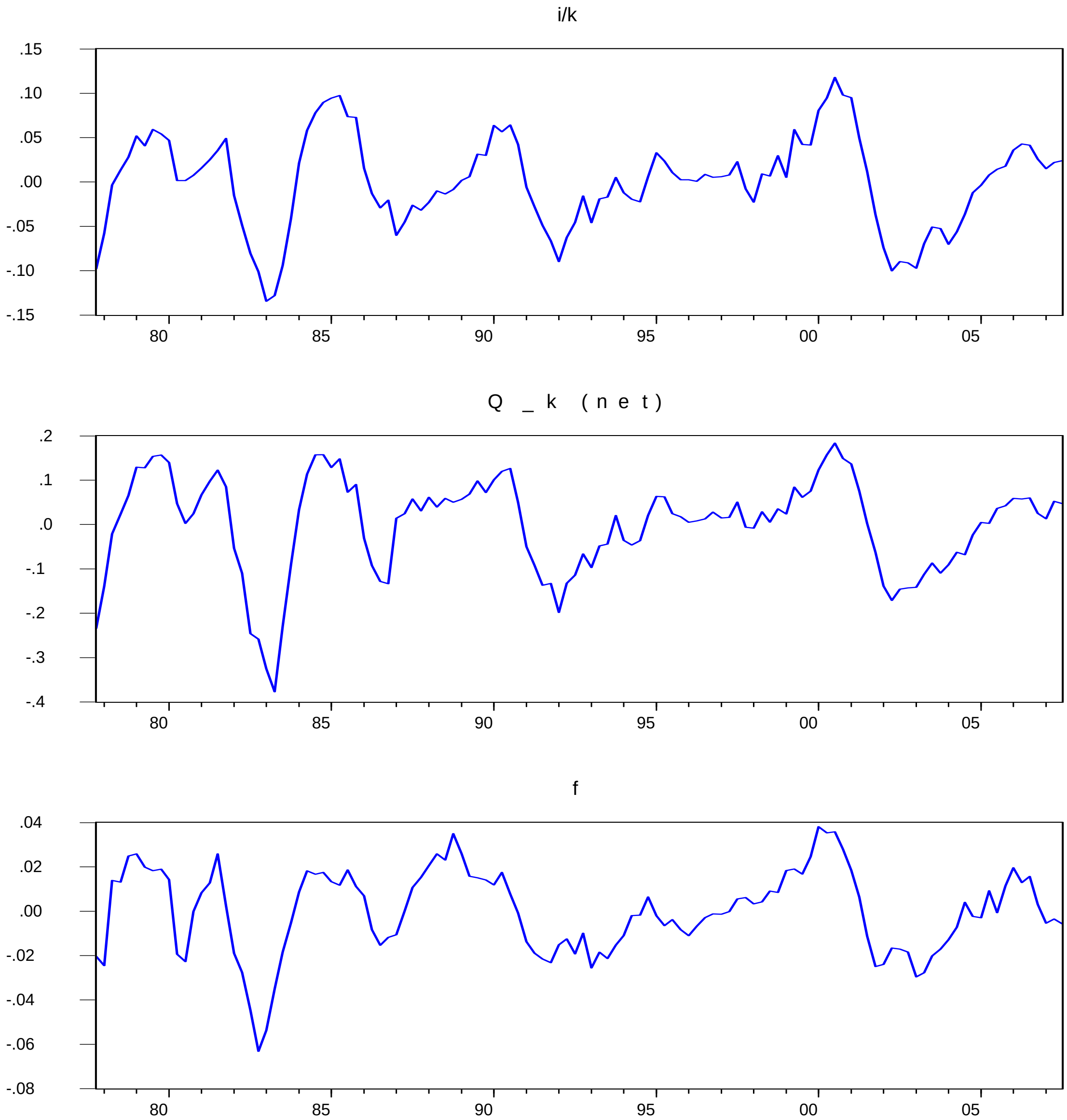



Figure 2a: $\frac{i}{k}, Q^K, f$ logged and HP filtered

correlations

| | $\frac{i}{k}$ | $Q^K$ | $f$ |
|---|---|---|---|
| $\frac{i}{k}$ | 1 | | |
| $Q^K$ | 0.92 | 1 | |
| $f$ | 0.78 | 0.85 | 1 |

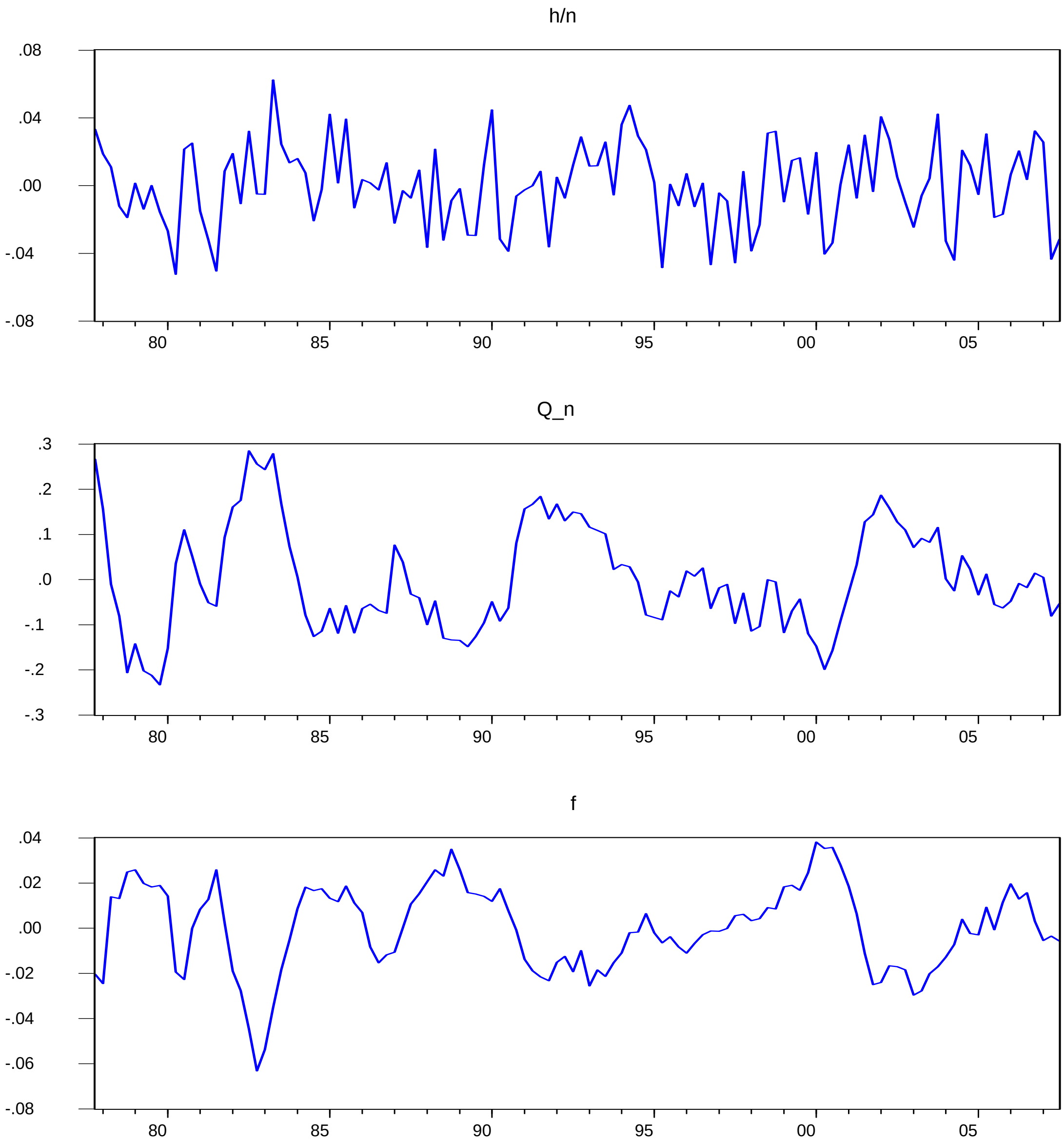



Figure 2b: $\frac{h}{n}$, $Q^N$, $f$ logged, HP filtered

correlations

| | $\frac{h}{n}$ | $Q^N$ | $f$ |
|---|---|---|---|
| $\frac{h}{h}$ | 1 | | |
| $Q^N$ | 0.43 | 1 | |
| $f$ | $-0.19$ | $-0.85$ | 1 |