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THE FORWARD LOOKING BEHAVIOR OF HIRING AND INVESTMENT

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Abstract

The decisions of firms on investment and hiring play a crucial role in business cycle fluctuations. This paper explores their dynamics in the presence of frictions. It does so within a unified framework, stressing their mutual dependence and placing the emphasis on their joint, forward-looking behavior.

Using estimation of aggregate, private sector U.S. data, it shows that the model with frictions is able to fit the data. A key element is the interaction of hiring costs and investment costs. It is significant and negatively signed, implying complementarity between investment and hiring. The estimated costs are of modest size.

The results are used to explain important business cycle facts, including the rise in unemployment in the Great Recession, the recent phenomenon of jobless recoveries, the negative co-movement of gross investment and gross hiring, and the role of discount rates.

Key Words: gross investment, gross hiring, unemployment, frictions, business cycles, present values of hiring and investment, forward-looking behavior, discount rates, the Great Recession, jobless recoveries, complementarities.

JEL Classification: E22, E24, E32

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The Forward Looking Behavior of Hiring and Investment[1]

1 Introduction

This paper studies the joint behavior of hiring and investment in the presence of frictions, using private sector U.S. data. The importance of these decisions by firms for aggregate activity cannot be overstated. The evolution of employment and of the capital stock are essential for the understanding of macroeconomic fluctuations. It has been shown that gross hiring is a key factor for understanding employment and unemployment dynamics.[2] Hiring frictions were shown to play a key role in determining the business cycle properties of labor productivity[3] and in accounting for dynamic environments in which wage dispersion exists and evolves in response to shocks.[4] Investment is key for the understanding of the evolution of the capital stock and consequently of firm market value.[5]

Hiring and investment are modelled in the literature as the outcomes of a dynamic, intertemporal optimization problem of the firm. The intertemporal dimension rests on the existence of frictions, whereby the firm incurs costs and time lags to turn capital and labor into active factors of production. But while the firm evidently decides on both hiring and investment, the treatment in the literature has typically focused on the behavior of one and not the other, or has posited costs pertaining to one but not the other. Additionally, part of the literature has been concerned with the narrower concept of adjustment costs, which usually relate to net hiring rather than gross hiring (hugely different variables) or which do not cater for job-worker matching processes. Thus, the search and matching literature focuses on job vacancy costs and posits either no capital or costless investment in capital. Investment costs models follow the same route with respect to capital, usually disregarding labor. Even DSGE models,[6] usually specify frictions with respect to only one factor – capital or labor. Moreover, all too often,

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[2] See, for example, Hall (2007) and Rogerson and Shimer (2011).

[3] Gali and van Rens (2010) show that a lower degree of hiring frictions may lower the cyclicality of labor productivity in ways which are consistent with actual U.S. aggregate data dynamics.

[4] See Coles and Mortensen (2012).

[5] See Erickson and Whited (2000), Bond and van Reenen (2007), Liu, Whited and Zhang (2009) and Cochrane (2011).

[6] Such as those by Christiano, Eichenbaum and Evans (2005), Smets and Wouters (2007), or Gali (2008, 2010).

the empirical macroeconomic work that has estimated costs, especially investment costs, has reported weak results. This weakness was manifested in a lack of fit or the need to postulate implausibly large costs to explain the data.

This paper explores the dynamic behavior of investment and hiring within a unified framework, stressing their mutual dependence and placing the emphasis on their joint, forward-looking behavior. Using estimation of aggregate, private sector U.S. data, it shows that the model with frictions is able to fit the data. A key element is the interaction of hiring costs and investment costs. It is significant and negatively signed, implying complementarity between investment and hiring. The estimated hiring and investment costs are of modest size only.

The results are used to explain important business cycle facts, including the rise in unemployment in the Great Recession, the recent phenomenon of jobless recoveries, the negative co-movement of gross investment and gross hiring, and the role of discount rates. These findings have implications for business cycle modelling, such as the advantages of incorporating joint investment and hiring costs, complete with the cited interaction, into DSGE models.

A major implication of the findings is that hiring and investment can be treated as forward-looking variables, reflecting the expectations of future discounted profits from employing labor and capital.[7]Using the results of estimation, it employs a number of techniques used in the asset pricing literature (forecasting regressions, restricted VAR analyses and variance decompositions) to study this forward-looking aspect. The analysis suggests that investment and hiring are differentially related to their expected, future determinants. Investment is linked more to movements in future returns than to changes in the marginal product of capital. Hiring is linked more to changes in labor profitability (the marginal product less the wage) and less to the movements in future returns.

The paper proceeds as follows: Section 2 briefly discusses the relevant related strands of literature. Section 3 presents the firm's optimization problem and the resulting optimality conditions. Section 4 presents and discusses the empirical strategy, implemented in the following sections: Section 5 discusses estimation issues and presents the results. Section 6 uses the results to look at the implied magnitude of frictions and to gauge the plausibility of

[7]This naturally links up with stock prices that are also forward-looking and relate to the same expected discounted future profits. Indeed, in previous work, Monika Merz and I (Merz and Yashiv (2007)) have shown that this set-up allows one to define asset values for hiring and for investment and that these values can be used to explain the time variation of equity values of firms in the U.S. economy. Building on Merz and Yashiv (2007), Bazdresch, Belo and Lin (2012) have further shown that hiring and investment predict stock returns in a cross-section of U.S. publicly traded firms. The current paper retains the focus on forward-looking behavior but does not make use of stock market data or tries to explain them.

the estimates. Section 7 discusses hiring and investment as driven by their present values. Section 8 uses Finance techniques to estimate and approximate the present value relationships embodied in the model and decompose them. Section 9 looks at the ability of the results to explain the recent jobless recoveries and the high unemployment of the Great Recession. Section 10 sums up the mechanism and concludes. Technical matters and data issues are treated in the appendices.

2 Background Literature

The current paper relates to two major strands in the macroeconomic literature and provides a missing link between them. It then makes use of a third strand, in Finance, which has examined the relation between present value variables and their future determinants. I examine each in turn.

The first is the literature on search and matching models, which feature dynamic, optimal hiring decisions by firms in the face of frictions (see Pissarides (2000), Rogerson, Shimer,and Wright (2005), Yashiv (2007) and Rogerson and Shimer (2011) for overviews and surveys). Hiring costs and time lags are the expression of frictions in these models, which differ from the neo-classical model mainly by the emphasis placed on the existence of such frictions in the labor market. The first order condition for optimal hiring is a key ingredient and this is one of the two estimating equations examined here. Most of this literature, however, does not include capital as a factor of production, and when it does, it is typically assumed not to be the subject of any friction. Many papers posit very simple hiring costs, usually a linear function of the number of job vacancies. Thus, it usually states that marginal vacancy costs are constant. The finding in this literature, as indicated above, is that gross hiring, subject to these frictions, is key in accounting for employment and unemployment dynamics. The model here features a generalization of the hiring problem and a wider concept of costs relative to what has been considered by these models.

It should also be noted that models which feature costs of adjusting labor have been studied for about half a century (Hamermesh (1993) provides a useful discussion). But most of these studies typically relate to net employment changes as distinct from gross changes of the type examined here, and have ignored any interaction with capital. The distinction between net and gross flows is critically important, as hiring costs are incurred with respect to the gross flow of incoming workers and the stochastic properties of these various flows are substantially different (see Hamermesh and Pfann (1996), in particular pp. 1266-67).

The second strand of literature includes investment models, mostly following the seminal contributions of Lucas (1967) and Lucas and Prescott

(1971) and of Tobin (1969) and Brainard and Tobin (1968).[8] These models have been studied extensively for over four decades. Chirinko (1993) is an earlier survey and Erickson and Whited (2000) and Bond and van Reenen (2007) are more recent discussions. The idea in these models is that costs are key to the understanding of investment behavior. As in the hiring case, they endow the investment problem with its dynamic optimization aspect and are geared to capture the real world feature of gradual adjustment of the capital stock. These models have encountered a lot of empirical difficulties and have engendered much debate (see Chirinko (1993) and Bond and van Reenen (2007)). Like search and matching models, much of this literature does not feature the other factor of production, namely labor. In the current paper I present results both from the "traditional" formulation of the investment costs model and from a formulation which allows for the interaction of investment costs and hiring costs. Hence, when presenting the results I provide a comparison with the results of nine key studies in this literature. The approach here is akin to the Euler equation approach in the investment literature proposed by Abel (1980), with the important distinction that it incorporates hiring and the interaction of costs between hiring and investment. When discussing results I note the difference between aggregate and micro-based studies. Note, too, that in what follows I do not use stock market or firm value data as investment Q models do. As mentioned, the linkages with such data were explored by Merz and Yashiv (2007).

It should also be noted that models of the business cycle (evidently) feature optimal hiring and investment decisions. Many of them do not feature frictions, though a large part of the RBC literature assumes 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), surveyed by Christiano, Trabandt and Walentin (2010), do posit costs for investment but no frictions in hiring. Note, too, that in business cycle models there is no explicit interaction between hiring costs and investment costs.

A key issue in the current paper is the mutual dependence of hiring and investment and the interaction of their costs. This is not a new issue. Mortensen (1973) has examined the interrelation of costs in a theoretical model and over the years some empirical work was attempted; prominent examples include Nadiri and Rosen (1969), Shapiro (1986), and Hall (2004). These studies point to the potential importance of including costs on both

[8] The Lucas (1967) paper formulates adjustment costs and dynamic firm behavior. Lucas and Prescott (1971) analyze investment under uncertainty in the presence of convex costs of adjustment. The Tobin (1969) paper deals, among many other issues, with the relation of investment to stock market value and has little to say on the relevant dynamics. The link between convex costs of adjustment and the Tobin's Q theory of investment was made explicit by Mussa (1977) and by by Abel (1983).

capital and labor. However key differences with the current study are that these papers do not model at least one of two elements, which the empirical work below finds to be of crucial importance: (i) an interaction term between the two costs; and (ii) gross, as opposed to net, and aggregate, as opposed to micro-level, hiring flows. Hence most of their findings are quite different from what is reported here.

This paper stresses the forward-looking aspect of hiring and investment. Consequently an important issue is the future determinants of current behavior. This issue is studied, for the case of stock prices, by a sizeable strand of literature in Finance, launched by the work of Campbell and Shiller (1988). A key concern in this literature has been the question of what is the relative importance of dividend growth and of future returns for stock price volatility. I make use of the methodologies developed in this literature, surveyed by Cochrane (2005, 2011), Lettau and Ludvigson (2009), and Koijen and Van Nieuwerburgh (2010), to determine the relative importance of the future determinants of current hiring and current investment. Recently Hall (2013) has taken up this issue, albeit using a different empirical methodology.

3 The Model

I delineate a partial equilibrium model which serves as the basis for estimation.[9] There are identical workers and identical firms, who live forever and have rational expectations. All variables are expressed in terms of the output price level. Firms make gross investment (i) and gross hiring (h) decisions[10]. 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 subject to frictions and hence are costly activities. Frictions may pertain to many dimensions: search processes, organizational structure, technological innovation, production disruptions, financial frictions, implementation and installations lags, etc. Hiring costs may include search costs for worker attributes (such as talent), costs for advertising, screening and testing, matching frictions, training costs and more. Investment involves implementation costs, financial premia on certain projects, capital installation costs, learning the use of new equipment, etc. Both activities may involve, in addition to production disruption, also the

[9] 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).

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

implementation of new organizational structures within the firm and new production practices. All of these costs reduce the firm's profits. I represent these costs by a 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, allowing hiring costs and investment costs to interact. I specify and justify the functional form of g and discuss its properties 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 separation rate is time-varying. Equations (2) and (3) feature a time lag of one period in the activation of capital and labor.

Firms' profits before tax, π, equal the difference between revenues net of investment and hiring 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:

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

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 $t + j$.

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

The 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:

$$\begin{aligned}
Q^K_t &= E_t \left\{\beta_{t+1}\left[(1-\tau_{t+1})\left(f_{k_{t+1}} - g_{k_{t+1}}\right) + (1-\delta_{t+1})\, Q^K_{t+1}\right]\right\} && (7)\\
Q^K_t &= (1-\tau_t)\left(g_{i_t} + p^I_t\right) && (8)\\
Q^N_t &= E_t \left\{\beta_{t+1}\left[(1-\tau_{t+1})\left(f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1}\right) + \left(1-\psi_{t+1}\right) Q^N_{t+1}\right]\right\} && (9)\\
Q^N_t &= (1-\tau_t)\, g_{h_t} && (10)
\end{aligned}$$

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

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

Dynamic optimality requires the following two transversality conditions to be fulfilled

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

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

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

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

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

It is straightforward to show that in the special case of time-invariant discount factors, no 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 The Empirical Strategy

The model posits certain relationships which describe optimal hiring and investment behavior as forward-looking, costly activities. The structure of these relationships resembles asset pricing relations, such as stock price equations. These relationships include observables and unobservables. Unlike stock prices, the equivalents in terms of this model are not observed in the markets. Thus, costs are unobserved directly and need to be inferred by estimating the cost function (g). The estimation of this function allows not only to infer current marginal costs (i.e., the LHS of (13) and (14)), but also the present value expected when the firm is following optimal policy (i.e., the RHS of these equations, or, equivalently Q^K and Q^N). The route to be taken in estimation and the study of its implications consists of the following:

Structural estimation of equations (13) and (14), which generates estimated series for marginal costs (g_{h_t}, g_{i_t}), and, equivalently, the present values of hiring and investment (Q_t^N, Q_t^K). This estimation requires the examination of alternative specifications, including ones that are standard in the literature. It allows to see whether the interaction between hiring costs and investment costs is important and what kind of relationship between hiring and investment it implies. It evidently also allows the determination of the model fit of the data. This is done in Section 5, generating a specification which fits the data and which is taken from this point onward to study the full implications of the model.

I then *compare the resulting estimates to the findings in the relevant literatures*, gauging their plausibility. This is done in Section 6. Past estimates in some studies yielded unreasonably large cost estimates. There is no point in using such estimates. The results show that this is not the case here and that the estimated costs are moderate or even small.

Then two sets of results are examined:

In one I *relate investment and hiring rates to both present value terms (Q^K and Q^N).* I use the afore-going estimates to study the relationships of hiring and investment rates $(\frac{h_t}{n_t}, \frac{i_t}{k_t})$ and their present values (Q_t^N, Q_t^K). I explore the implications for the co-movement and simultaneity of investment and hiring and quantify the relevant elasticities. This is done in Section 7.

In the second I *decompose the two present value terms into their components.* I link current values with expected future values, drawing upon a restricted VAR and approximation methodologies used in the asset pricing literature in Finance. This quantifies the various asset values involved here and their relationships over time. It then allows for a variance decomposition of the future determinants of current hiring and investment. This is done in Section 8.

Finally, Section 9 looks at the explanation offered by the model to the recent phenomenon of *"jobless" recoveries,* including the Great Recession period and the associated high unemployment. Section 10 *sums up the mechanism* emerging from these various empirical tests and concludes.

5 Estimation

I estimate alternative versions of the model. The alternatives pertain to the degree of convexity of the costs function, the existence of linear terms in this function, the examination of standard specifications, and the set of instruments used. I estimate equations (13) and (14), using structural estimation. In what follows I present the parameterization of this function (as well as of the production function), the econometric methodology, the data and estimation results.

5.1 Methodology

5.1.1 Parameterization

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

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

The *costs function* g, capturing the different frictions in the hiring and investment processes, is at the focus of the estimation work and merits discussion. It is meant to capture all the frictions involved, and not, say, just capital adjustment costs or vacancy costs. One should keep in mind that it is formulated as the costs function of the representative firm within a macroeconomic model, and not one of a single firm in a heterogenous firms micro set-up.

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

$$g(\cdot) = \begin{bmatrix} f_1 \frac{i_t}{k_t} + f_2 \frac{h_t}{n_t} \\ + \frac{e_1}{\eta_1} (\frac{i_t}{k_t})^{\eta_1} \\ + \left[\frac{e_2}{\eta_2}\right] (\frac{h_t}{n_t})^{\eta_2} \\ + \left[\frac{e_3}{\eta_3}\right] \left(\frac{i_t}{k_t} \frac{h_t}{n_t}\right)^{\eta_3} \end{bmatrix} f(z_t, n_t, k_t). \quad (18)$$

This function is linearly homogenous in its arguments i, k, h, n. The parameters e_l, $l = 1, 2, 3$ express scale, and the parameters η_1, η_2, η_3 express the elasticity of costs with respect to the different arguments. I rationalize the use of this form in what follows.

Arguments of the function. This specification captures the idea that frictions or costs increase with the extent of the activity in question, hiring or investment. The latter needs to be modelled relative to the size of the firm. The intuition is that hiring 10 workers, for example, means different levels of activity for firms with 100 workers or firms with 10,000 workers. Hence firm size, as measured by its physical capital stock or its level of employment, is taken into account and the costs function is increasing in the investment and hiring rates, $\frac{i}{k}$ and $\frac{h}{n}$. The function used postulates that costs are proportional to output, i.e., the results can be stated in terms of lost output.

More specifically, the terms in the function presented above may be justified as follows (drawing on Garibaldi and Moen (2009)): suppose each worker i makes a recruiting and training effort h_i; as this is to be modelled as 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 one gets $c\left(\frac{h}{n}\right)\frac{f}{n}$; as n workers do it then the aggregate cost function is given by $c\left(\frac{h}{n}\right) f$.

Convexity. I use a convex function, allowing for free estimation of the degree of convexity. The use of such a function may be questioned at the micro-level, as non-convexities were found to be significant at that level (plant, establishment, or firm). But a number of papers have given empirical support to the use of a convex function in the aggregate, showing that a convex formulation is appropriate at the macroeconomic level. [11]

[11] Cooper and Haltiwanger (2006) use an indirect inference procedure to estimate the structural parameters of a rich specification of capital adjustment costs. While finding that non-convexities matter at the plant-level, they note that "...the aggregate moments...seem to be much closer to the prediction of a quadratic cost of adjustment model" (page 628). They state that "a model with only convex adjustment costs fits the aggregate data created by our estimated model reasonably well ...we find that the non-convexities are less important at the aggregate relative to the plant level" (page 613). Kahn and Thomas (2008, see in particular their discussion on pages 417-421) study a dynamic, stochastic, general equilibrium model with nonconvex capital adjustment costs. One key idea which emerges from their analysis is that there are smoothing effects that result from equilibrium price changes. They find that "...movements in relative prices ...eliminate the implications of plant-level nonconvexities for aggregate dynamics (page 429)." Favilukis and Lin (2011)

Interaction.. The term $\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3}$ expresses the interaction of investment and hiring costs. This term, usually absent in many studies, has important implications for the complementarity of investment and hiring. It, too, is estimated without constraints.

Relation to Known Cases. The function encompasses widely-used cases as special cases. For example, the quadratic case has $\eta_1 = \eta_2 = 2$; a standard Tobin's Q model of investment has $e_2 = e_3 = 0$ and $\eta_1 = 2$; a Pissarides-type matching model would have $e_1 = e_3 = 0, \eta_2 = 1$.

Alternative specifications. In estimation, I explore a number of alternative specifications:

1) The degree of convexity of the g function. I examine free and restricted estimation of the power parameters η_1, η_2 and $\eta_{3.}$

2) Existence of linear terms in the g function, i.e. whether f_1, f_2 are needed.

3) Standard specifications. I set $e_2 = e_3 = 0$ and look at investment costs only and then I set $e_1 = e_3 = 0$ and look at hiring costs only. I also examine the case of both investment and hiring costs but no interaction $e_3 = 0$.

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

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 (13) and (14).

5.1.2 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:

use data on asset prices as additional restrictions when examining firm investment behavior and find that "...within such a model, non-convex frictions are unnecessary to match important features of aggregate investment...a model with convex costs alone does nearly as good of a job at matching firm level micro data as our preferred model with both convex and non-convex costs" (page 26).

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

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

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.

5.2 The Data

The data are quarterly, pertain to the private sector of the U.S. economy, and cover the period 1976-2011.[12] This sample period covers five NBER-dated recessions, including the Great Recession of 2007-2009 and its aftermath. The data include NIPA data on GDP and its deflator, capital, investment, the price of investment goods and depreciation, BLS CPS 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.

(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 1 presents key sample statistics.

Table 1

5.3 Results

Table 2 reports the results of estimation. The table reports the estimates and their standard errors, Hansen's (1982) J-statistic and its p-value.

Table 2a,b

[12] The start date of 1976 is due to the lack of availability of credible monthly CPS data from which the gross hiring flow series is derived.

While typically one assumes a particular convex function, say a quadratic, I begin by looking at unrestricted estimates, in row 1 of panel a. In this specification all nine parameters are freely estimated, including α of the production function (17), and the scale $(f_1, f_2, e_1, e_2, e_3)$ and power parameters (η_1, η_2 and η_3) of the costs function (18). The results suggest that α is around the conventional estimate of 0.67, that the degree of convexity is around the cubic for the investment rate term, quadratic for the hiring rate term and linear for the interaction term ($\eta_3 = 1$). While there are low standard errors for these four power parameters, the five scale parameters are imprecisely estimated. Holding α fixed at 0.67 and the linear terms at zero ($f_1 = f_2 = 0$), as reported in row 2, yields similar results for the powers and precise estimates for the scale parameters (e_1, e_2, e_3). But both rows have low p-values for the J statistic, that imply rejection of the null hypothesis.

Following these results, rows 3 and 4 of panel (a) restrict the convexity to be either cubic-quadratic with linear interaction ($\eta_1 = 3, \eta_2 = 2$ and $\eta_3 = 1$) or quadratic with linear interaction ($\eta_1 = \eta_2 = 2$ and $\eta_3 = 1$). In these cases the scale parameters are precisely estimated and the p-value indicates that the model is not rejected. When verifying that the resulting costs function satisfies first and second order conditions for convexity, only row 4 yields a convex costs function throughout.

Figure 1 compares the marginal costs implied by the latter two specifications (of rows 3 and 4): the cubic-quadratic with linear interaction ($\eta_1 = 3, \eta_2 = 2$ and $\eta_3 = 1$) and the quadratic with linear interaction ($\eta_1 = \eta_2 = 2, \eta_3 = 1$). Panel (a) shows $\frac{g_i}{f/k}$ evaluated over the sample range values of the investment rate $\frac{i}{k}$, holding the hiring rate $\frac{h}{n}$at its average value. Panel (b) shows $\frac{g_h}{f/n}$ evaluated over the sample range values of the the hiring rate $\frac{h}{n}$, holding the investment rate $\frac{i}{k}$ at its average value.

Figure 1

Over the relevant ranges both specifications appear linear in these first derivatives of the costs function (i.e., marginal costs). The specification of row 4 is positive throughout, somewhat higher for the investment case and somewhat lower for the hiring case. This implies that the specification of row 4 – quadratic with linear interaction – is the one to be preferred, and is, in any case, quite close to the cubic-quadratic specification of row 3.

Appendix C reports variations on these specifications, mostly in terms of the instrument set, as a check for robustness. The results there are in line with those of panel (a) of Table 2.

Panel (b) of Table 2 looks at standard specifications in the literature. Column 1 sets $\eta_1 = 2, e_2 = e_3 = 0$, i.e., quadratic investment costs, with no role for hiring, as is typical in the Tobin's Q/investment literature. Column 2 sets $\eta_2 = 1, e_1 = e_3 = 0$, i.e., linear hiring costs with no role for investment, as used in the search and matching literature. Column 3 uses a quadratic function for both hiring and investment costs but no interaction ($\eta_1 = \eta_2 = 2, e_3 = 0$). The panel reports precise estimates and reasonable p-values for the J statistic. However, the reasons not to prefer these standard specifications become clear below, when studying the various implications of the estimates.

The conclusions thus far are as follows, taking into account the alternative specifications discussed in Appendix C: quadratic costs and linear interaction of investment and hiring costs generate a good fit of the data; the interaction is significant and is negatively signed, implying complementarity between investment and hiring (to be discussed below). In what follows I shall refer to the results of row 4 in panel a as the preferred specification.

In order to explore the implications of these estimates and characterize the joint behavior of investment and hiring, I use them in several ways as delineated above, in Section 4. I start by looking at the magnitude of costs, comparing them to the findings in the literature.

6 Gauging the Estimates: the Degree of Frictions

The results of Table 2 merit inspection for plausibility and the derivation of the frictions they imply. This is done by constructing the time series for total and marginal costs implied by the point estimates of the parameters of the g function and relating them to what is known on these issues.

6.1 The Estimated Frictions

The estimated costs are interesting and important by themselves, as many models rely on their existence. Their key moments are presented in Tables 4c and 4d.

Table 2c,d

Essentially total costs are about 1.4% of GDP on average, with a standard deviation of 0.2%. Marginal investment costs add about 6% on average to the price p_t^I of a unit of capital (see below). Marginal hiring costs are on average the equivalent of 1.6 weeks of wages. To gain a better grasp of the implications of these moments, the following comparisons place them in context.

6.2 Comparisons to the Literature

How do these compare to the literature?

Total costs as a fraction of GDP (i.e., $\frac{g}{f}$) are around 1.4% of output according to the preferred specification (row 4 of Table 2c), a reasonable estimate, as will be discussed below.

Marginal costs of hiring in terms of average output per worker ($\frac{g_h}{\frac{f}{n}}$) have a sample mean of 0.08 in row 4 of Table 2c, the preferred specification. This is roughly equivalent to 12% of quarterly wages.[13] In other words, firms pay the equivalent of about 1. 6 weeks of wages to hire the **marginal** worker.

How does one evaluate this estimate? There is little empirical evidence on these costs in the literature. The literature has some estimates of **average** hiring costs, which typically relate only to vacancy costs.[14] Note that the results here do not refer only to vacancy costs and pertain to the marginal hire with convex costs. It turns out that the current results are consistent with the literature estimates of average vacancy costs.

Older, micro evidence relates mostly to labor adjustment costs, which is a narrower concept than the one discussed here. These latter costs may exclude vacancy costs or matching costs, and typically they pertain to costs of net employment changes ($n_t - n_{t-1}$), as distinct from gross hiring (h_t). As noted above, net and gross flows are hugely different, in terms of all moments of their distributions. The literature suggests a very wide range of estimates (see Hamermesh (1993, pp. 207-209)) and 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 0.75 in row 4 of Table 2c.[15] To give another, more intuitive, perspective on these numbers, consider how much one needs to add to the price of one unit of the investment good p^I in **marginal** costs: it implies 5.6% on average. By contrast, the estimate of row 1 of Table 2d with only quadratic investment costs has a sample mean of 2.33 in terms of average output per unit of capital ($\frac{f}{k}$) or 17% to be added to the price of the investment good, an implausible result.

How reasonable are these estimates? The most natural place to look for comparisons is the Q-literature. Table 3 presents nine estimates of the investment equation from this literature. The equation links the investment-

[13] Wages are 66% of output per worker on average, see Table 3.

[14] 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, which is equivalent to 1.4 weeks of wages. 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.

[15] The units of measurement – in terms of output per unit of capital $\frac{f}{k}$ – were chosen so as to facilitate comparison with existing studies, as discussed below.

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 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 3 cannot give more than a rough idea as to the "neighborhood" of costs estimates.

Table 3

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: high 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; moderate 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; low costs, as in the rest of the studies, namely 4, 6a, 7, 8, and 9. 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. The studies finding these latter magnitudes are micro studies, using cross-sectional or panel data.

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 3 is the one reported in row 1 of Tables 2b and 2d. This is the specification positing a quadratic function and ignoring labor. The implied total costs are 3% of output (as in studies of the moderate costs set) and the implied marginal costs are 2.3 of average output per unit of capital (as in the high costs set). As indicated above, this is 17% of the price of a unit of investment good p^I. These implausible results are a major reason to reject these particular estimates here.

(ii) The preferred specifications – the GMM results of the full model, row 4 of Tables 2a and 2c – cannot be directly compared to the results of Table 3, 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 3 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 0.75, the findings of Table 2c correspond to the third set, i.e., to low costs. Note that the estimation here uses aggregate time series, while the cited papers of the third set use microeconomic cross-sectional or panel data.

Overall, then, the frictions implied by the estimates are not high and are very reasonable in comparison to what is known from the literature.

7 Hiring, Investment and Their Present Values

This section examines the implications of the estimates for the co-movement of hiring and investment and their present values in the context of cyclical behavior. It begins with a discussion of the implications of the model for this co-movement and shows how the two present values (Q^K, Q^N) affect both hiring and investment (7.1). This facilitates the ensuing discussion of the implications of the finding of negative interaction (7.2), the sensitivity of investment and hiring to their present values (7.3), and a co-movement and cyclical analysis presented and discussed in terms of the second moments related to (7.4). Following the next section, which discusses the decomposition of the present values, a summing-up of the mechanism is offered.

7.1 Hiring and Investment Rates as Functions of the Present Values

Taking equations (8)-(10), using the definitions of the derivatives of the g function spelled out in Appendix A, and the results of Table 2 whereby $\eta_1 = \eta_2 = 2, \eta_3 = 1$, and $e_1 e_2 - e_3^2 > 0$, the following relations are derived:

$$\frac{h_t}{n_t} = \frac{1}{(1-\tau_t)(e_1 e_2 - e_3^2)} \left(e_1 \frac{Q_t^N}{\frac{f_t}{n_t}} - e_3 \frac{Q_t^K}{\frac{f_t}{k_t}} + e_3 (1-\tau_t) \frac{p_t^I}{\frac{f_t}{k_t}} \right) \tag{21}$$

$$\frac{i_t}{k_t} = \frac{1}{(1-\tau_t)(e_1 e_2 - e_3^2)} \left(-e_3 \frac{Q_t^N}{\frac{f_t}{n_t}} + e_2 \frac{Q_t^K}{\frac{f_t}{k_t}} - e_2 (1-\tau_t) \frac{p_t^I}{\frac{f_t}{k_t}} \right) \tag{22}$$

The implications of these relations are the following:

a. As $e_1, e_2 > 0, e_3 < 0$ in Table 2, $\frac{h_t}{n_t}$ and $\frac{i_t}{k_t}$ are positive linear functions of both Q_t^N and Q_t^K,and negative functions of p_t^I, all corrected for taxes and cast in terms of the relevant average output.

b. The co-variation of the pairs within the set of four variables $\{\frac{h_t}{n_t}, \frac{i_t}{k_t}, \frac{Q_t^N}{(1-\tau_t)\frac{f_t}{n_t}}, \frac{Q_t^K}{(1-\tau_t)\frac{f_t}{k_t}}\}$ may be derived from (21) and (22).

In fact these points can be easily derived and quantified from re-writing (21) and (22) as the following linear equations:

$$\frac{h_t}{n_t} = a\frac{g_{h_t}}{\frac{f_t}{n_t}} - c\frac{g_{i_t}}{\frac{f_t}{k_t}} \tag{23}$$

$$\frac{i_t}{k_t} = -c\frac{g_{h_t}}{\frac{f_t}{n_t}} + b\frac{g_{i_t}}{\frac{f_t}{k_t}} \tag{24}$$

$$a = \frac{e_1}{e_1e_2 - e_3^2}; b = \frac{e_2}{e_1e_2 - e_3^2}; c = \frac{e_3}{e_1e_2 - e_3^2} \tag{25}$$

It is therefore apparent that models which ignore the present value of the other factor are incorrect as long as $e_3 \neq 0$ (and so $c \neq 0$).

Table 4 shows the first and second moments of the RHS of (23) and (24), using these decompositions.

Table 4

In the table note that the different terms are not just the variables that appear, but also their coefficients (a, b, c), which are given above, in (25).

Of the mean hiring rate, 58% is due to the present value of hiring term $(\frac{g_{h_t}}{\frac{f_t}{n_t}})$ and the remaining 42% are due to the investment term $(\frac{g_{i_t}}{\frac{f_t}{k_t}})$. The variance of of the hiring rate (std of 1%) is decomposed in rows 2 and 3, which sum up to 1. The investment term plays a substantial role – its variance is half of that of the hiring term and the co-variance of the two terms is substantial. Overall, these results imply that the present value of investment $\frac{g_{i_t}}{\frac{f_t}{k_t}}$ plays a substantial role in the determination of hiring rates.

The mean investment rate of 2% is due to the present value of hiring term (32%) and the investment term (68%). The variance of the investment rate (std of 0.3%) is decomposed into a small part due to the hiring term and the big part played by the variance of the investment term $(\frac{g_{i_t}}{\frac{f_t}{k_t}})$ and the large co-variation with hiring.

It ensues that the cross effects are asymmetric: the investment terms play a bigger role in hiring than the hiring term in investment.

7.2 Negative Interaction Engenders Simultaneity

Across all specifications of Table 2a, 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, as can be seen in equations (21)-(22), a positive sign for $\partial(\frac{h_t}{n_t})/\partial Q^K$ and for $\partial(\frac{i_t}{k_t})/\partial Q^N$ (for the full derivations of these derivatives, as well as the relevant elasticities, see Appendix A.) Note that $\partial(\frac{i_t}{k_t})/\partial Q^K$ and $\partial(\frac{h_t}{n_t})/\partial Q^N$ 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 of complementarity between investment and hiring is to be expected as it implies that they should be simultaneous. 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 5.

Table 5

The scope is 0 by construction in all specifications without a cost interaction. For the preferred specification, it is on average a multiple 1.4 of total costs, with a standard deviation of 0.08. Basically, the cost of doing investment and hiring sequentially $(g(0,\frac{h}{n})+g(\frac{i}{k},0))$ sums up to about 3.3% of GDP; the cost of doing them simultaneously sums up to about 1.4% of GDP, i.e., it is 1.9% of GDP cheaper. This is a multiple 1.4 of costs $(\frac{1.9\%}{1.4\%}=1.4)$. It means that there are substantial savings of costs when investing and hiring at the same time. Hence the preferred estimates of row 4 in Table 2a imply that there is meaningful inter-relation between hiring and investment costs. The decision by the firm on one factor is strongly dependent on the other.

7.3 The Elasticities of Hiring and Investment w.r.t Present Values

Table 5 further quantifies the relations between hiring and investment and their present values. It presents 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 investment is very highly elastic with respect to the present value of investing Q^K; hiring has much lower elasticity, lower than unitary, with respect to its present value Q^N. The cross elasticities are low for investment w.r.t Q^N and high for hiring w.r.t Q^K. These results are of course consistent with those of sub-section 7.1 reported above, which implied a great sensitivity of hiring to Q^K and much less sensitivity of investment to Q^N. The more standard formulation of Table 4b row 3, which leaves out the interaction, implies an investment elasticity that is somewhat lower relative to the preferred case (which does have an interaction term) and a unitary elasticity for hiring which is almost double that implied by the preferred specification. By construction, this specification does not admit cross-elasticities.

The following distinction, however, is important. The preceding sub-section has shown that optimal behavior includes 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, for example, Q^K rises while Q^N declines. 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. The elasticity estimates of Table 5 imply that the Q^K movements and the Q^N movements engender different responses. Therefore it is possible that investment will rise with the rise in Q^K while hiring falls with the fall in Q^N. This is indeed what is found in this sample, as discussed in the following sub-section.

7.4 Co-Movement and Cyclical Analysis

The analysis focuses on the gross hiring rate $\frac{h}{n}$ and the gross investment rate $\frac{i}{k}$ of the aggregate U.S. economy. In what follows I examine their cyclical behavior and their co-movement, over the data sample 1976-2011, which includes the Great Recession period.

7.4.1 The Data Facts

Figure 2a plots *the raw series* and Table 6a reports their key moments.

Figure 2a and Table 6a

The figure and the table indicate that the rate of investment has higher volatility (in terms of the coefficient of variation) and somewhat higher persistence. While the rate of investment has gone up in the early 1990s and has stayed up (albeit with a lot of fluctuations), the hiring rate has gradually declined and has stayed down since the mid 1990s. The correlation between them is negative.

Figure 2b and Table 6b look at *the cyclical behavior* of the two series. The graphs relate to the logged series in levels and using the Hodrick-Prescott

(HP) and Baxter-King band pass (BK) filter and displays NBER-dated recessions. The table presents co-movement with three cyclical measures – real business sector GDP f, labor productivity $\frac{f}{n}$ and capital productivity $\frac{f}{k}$.

Figure 2b and Table 6b

While the investment rate is clearly pro-cyclical, the hiring rate is counter-cyclical. Both contemporaneously and dynamically, hiring is counter-cyclical with respect to the three cyclical variables. These correlations are stronger when using the BK filter, relative to the HP filter. 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. Note that in recessions the rate of hiring rises while the rate of investment falls. Two years ahead of the recession investment rises and hiring falls; closer to the recession they switch signs. Judging by the strength of the correlation measures, investment rates are stronger leading indicators of the cycle.

Figure 2c and Table 6c show *the co-movement* of the two series over the cycle, referring again to logged, HP-filtered and BP-filtered series of investment and hiring with NBER-dated recessions. The table reports their dynamic correlations.

Figure 2c and Table 6c

The investment and hiring rates series do not move together, consistently with their markedly different cyclical behavior. They exhibit negative correlation, contemporaneously and at most leads and lags.

7.4.2 Examining the Counter-Cyclicality of Hiring

The counter-cyclicality of gross hiring may appear counter-intuitive. To put this behavior in further perspective and show how it relates to other labor market facts, I look at labor market variables which are often discussed in the literature. First, note several relations that hold true in steady state:

Hiring to employment h equals separations from employment s:

$$h = s \tag{26}$$

Non-employment in the steady state, i.e., unemployment u plus the pool out of the labor force o, satisfies:

$$\frac{u+o}{pop} = \frac{\psi}{\frac{h}{u+o} + \psi} \tag{27}$$

where pop is the working age population and ψ is the separation rate from employment n ($s= \psi\ n$).

In steady state the hiring rate is the product of the job finding rate, steady state non-employment and the inverse of the employment rate:

$$\frac{h}{n} = \frac{h}{u+o} \times \frac{u+o}{pop} \times \frac{pop}{n} \tag{28}$$

Using the above formulation of steady-state non-employment:

$$\underbrace{\frac{h}{n}}_{\text{hiring rate}} = \underbrace{\frac{h}{u+o}}_{\text{job finding}} \times \underbrace{\frac{\psi}{\frac{h}{u+o}+\psi}}_{\text{ss non-emp}} \times \underbrace{\frac{1}{\frac{n}{pop}}}_{\text{inv emp ratio}} \tag{29}$$

Table 7 shows the co-movement statistics for these variables.

Table 7

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. Steady state non-employment $\frac{\psi}{\frac{h}{u+o}+\psi}$ and the inverse of the employment ratio $\frac{1}{\frac{n}{pop}}$ are counter-cyclical, as widely known too. The hiring rate is counter-cyclical as the counter-cyclicality of the last two variables dominates the pro-cylicality of the job-finding rate. 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 obvious. 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. Moreover, their relationship with the cycle is different and switches sign as discussed above.

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 the 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.

7.4.3 The Cyclicality of the Present Values

This sub-section will document the cyclical behavior of the estimated Q^K (net of p^I) and of the estimated Q^N in relation to the afore-cited business cycle facts.

8 Decomposing The Present Value of Investment and Hiring

I have derived – through structural estimation – the costs function (g) which defines the present value of hiring (Q^N) and of investment (Q^K). How are these values related to their expected future determinants, given that both hiring and investment are forward-looking variables? In other words, what in the future drives hiring and investment today? In this section, I follow the empirical methodology of the asset pricing literature in Finance and examine the present value relationships governing hiring and investment. This involves the study of the determinants of hiring and investment, using forecasting regressions, VARs and approximated relations. The analysis is based on the framework proposed by Campbell and Shiller (1988) and its more recent elaboration by Cochrane (2005, 2011), whose notation I follow. This model is often referred to as the dynamic, dividend-growth model.[16] Note that I do not consider stock prices here; I simply apply the empirical framework developed in the cited Finance literature to the current context. As mentioned above, the connections between the current framework and stock prices were explored in Merz and Yashiv (2007).[17] The results in the Finance literature do, however, provide a natural benchmark against which to compare the current results.

8.1 An Asset Pricing Model

The model begins from the following two-period representation for the stock price (P) and dividends (D):

$$\begin{aligned} P_t &= E_t\left(R_{t+1}^{-1}[D_{t+1}+P_{t+1}]\right) \\ \frac{P_t}{D_t} &= E_t\left(R_{t+1}^{-1}[\frac{D_{t+1}}{D_t}+\frac{D_{t+1}}{D_t}\frac{P_{t+1}}{D_{t+1}}]\right) \end{aligned} \tag{30}$$

where R is the gross return. Iterated forward this yields:

$$\frac{P_t}{D_t}=E_t\left(\sum_{j=0}^{\infty}\left(\prod_{k=1}^{j+1}R_{t+k}^{-1}\frac{D_{t+k}}{D_{t+k-1}}\right)\right) \tag{31}$$

These relationships hold true also ex-post if one defines returns as:

$$R_t=\frac{D_{t+1}+P_{t+1}}{P_t} \tag{32}$$

[16] Lettau and Ludvigson (2009), Koijen and Van Nieuwerburgh (2010) and Cochrane (2011) provide surveys of these empirical studies and a discussion of their implications for asset pricing.

[17] See also Jermann (1998).

Using logs, this asset pricing relationship can be approximated as:

$$p_t - d_t = k + E_t\left(d_{t+1} - d_t - r_{t+1} + \rho(p_{t+1} - d_{t+1})\right) \tag{33}$$

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.

Equation (33) is an ex-ante formulation using conditional expectations. The following ex-post equation holds true as well, when using (32):

$$p_t - d_t = k + \left(d_{t+1} - d_t - r_{t+1} + \rho(p_{t+1} - d_{t+1})\right) \tag{34}$$

Based on (34), the following ex-post relations in levels and in variance hold true in approximation:

$$p_t - d_t \simeq \sum_{j=1}^{\infty} \rho^{j-1} k + \left(\sum_{j=0}^{\infty} \rho^j \left(d_{t+j+1} - d_{t+j} - r_{t+j+1}\right) \right) \tag{35}$$

$$\begin{aligned} var(p_t - d_t) \quad &\simeq \quad cov\left[p_t - d_t, \sum_{j=0}^{\infty} \rho^j \left(d_{t+j+1} - d_{t+j}\right)\right] \\ &\quad - cov\left[p_t - d_t, \sum_{j=0}^{\infty} \rho^j r_{t+j+1}\right] \end{aligned} \tag{36}$$

The current price dividend ratio ($p_t - d_t$)) is related to future dividend growth ($d_{t+j+1} - d_{t+j}$) and to future returns (r_{t+j+1}), with the relevant discounting (using ρ^j). The price-dividend ratio will be higher when future dividend growth is higher and/or when future returns are lower.

8.2 Empirical Methodology

These relationships have been examined in the Finance literature in a number of ways.

Forecasting Regressions. One way is to estimate forecasting regressions of the type:

$$
\begin{aligned}
(p_{t+1} - d_{t+1}) &= a + \phi(p_t - d_t) + e_{p,t} \\
d_{t+1} - d_t &= c + b_d(p_t - d_t) + e_{d,t} \\
r_{t+1} &= d + b_r(p_t - d_t) + e_{r,t}
\end{aligned} \tag{37}
$$

The log price dividend ratio $(p_t - d_t)$ is expected to forecast future dividend growth $(d_{t+1} - d_t)$ and/or future returns (r_{t+1}). These equations are examined as separate regressions or within a system. The last two regressions have been estimated also using a longer horizons, so on the LHS may appear longer horizon dividend growth $(d_{t+H} - d_t)$ or compounded returns $(r_{s,t+H} = r_{s,t+1} + r_{t+1,t+2} + ... + r_{t+H-1,t+H})$, where H is the forecast horizon. Using equation (34), the coefficients in this system should obey the restriction:

$$
b_d - b_r = 1 - \rho\phi \tag{38}
$$

VAR Estimation. A second, more general formulation, encompassing (37) as a special case, is to estimate a restricted VAR on the de-meaned variables:

$$
\begin{pmatrix} p_{t+1} - d_{t+1} \\ d_{t+1} - d_t \\ r_{t+1} \end{pmatrix} = B \begin{pmatrix} p_t - d_t \\ d_t - d_{t-1} \\ r_t \end{pmatrix} + \begin{pmatrix} \varepsilon_{1_t} \\ \varepsilon_{2_t} \\ \varepsilon_{3_t} \end{pmatrix} \tag{39}
$$

Defining:

$z_t = \begin{pmatrix} p_t - d_t \\ d_t - d_{t-1} \\ r_t \end{pmatrix}$, with the variables de-meaned
$e_1 = (1, 0, 0)$
$e_2 = (0, 1, 0)$
$e_3 = (0, 0, 1)$
$\underline{\varepsilon}_t = \begin{pmatrix} \varepsilon_{1_t} \\ \varepsilon_{2_t} \\ \varepsilon_{3_t} \end{pmatrix}$
This VAR can be written as:

$$
z_{t+1} = Bz_t + \underline{\varepsilon} \tag{40}
$$

Equations (34) and (35) can be written in the same terms as:

$$
\begin{aligned}
e_1 z_t &= k + e_2 z_{t+1} - e_3 z_{t+1} + \rho e_1 z_{t+1} \quad (41)\\
&= k + e_2 z_{t+1} - e_3 z_{t+1} + \rho(k + e_2 z_{t+2} - e_3 z_{t+2} + \rho e_1 z_{t+2})\\
&= \sum_{j=1}^{\infty} \rho^{j-1} k + \sum_{j=0}^{\infty} \rho^{j} \left(e_2 - e_3\right) B^{j+1} z_t
\end{aligned}
$$

Hence the restrictions for this VAR are (allowing for de-meaning, hence dropping the first term on the RHS):

$$
e_1 z_t = \sum_{j=0}^{\infty} \rho^{j} \left(e_2 - e_3\right) B^{j+1} z_t \quad (42)
$$

which gives:

$$
e_1 (I - \rho B) - \left(e_2 - e_3\right) B = 0 \quad (43)
$$

Note that restriction (38) is a special case of the last set of restrictions (43).

Variance Decomposition. A third way used by this empirical literature is to truncate the RHS of the variance decomposition (36) at date T and compute its components.

Links. To connect the first and third ways, note the following (see Cochrane (2011, pp. 2-4)). First, divide (38) by $1 - \rho\phi$ to get:

$$
\frac{b_d}{1 - \rho\phi} - \frac{b_r}{1 - \rho\phi} = 1
$$

Define:

$$
\begin{aligned}
b_d^{lr} &= \frac{b_d}{1 - \rho\phi}\\
b_r^{lr} &= \frac{b_r}{1 - \rho\phi}
\end{aligned}
$$

to be the long run regression coefficients of log dividend growth on the log price -dividend ratio and of log returns on the log price -dividend ratio (i.e., coefficients of the regressions of $\sum_{j=0}^{\infty} \rho^{j-1} \left(d_{t+j+1} - d_{t+j}\right)$ on $p_t - d_t$ and of $\sum_{j=0}^{\infty} \rho^{j-1} r_{t+j+1}$ on $p_t - d_t$).

This means:

$$
b_d^{lr} - b_r^{lr} = 1
$$

From the third type of computation, divide (36) throughout by $var(p_t - d_t)$ to get:

.

$$
\begin{aligned}
1 &\simeq cov\left[p_t - d_t, \sum_{j=0}^{\infty} \rho^j \left(d_{t+j+1} - d_{t+j}\right)\right] \\
&\quad -cov\left[p_t - d_t, \sum_{j=0}^{\infty} \rho^j r_{t+j+1}\right]
\end{aligned}
$$

This too yields:

$$b_d^{lr} - b_r^{lr} \simeq 1$$

Employing the first way, one gets estimates of b_d^{lr} and b_r^{lr} by running regressions using the whole sample. Employing the third way, one gets estimates of b_d^{lr} and b_r^{lr} by computing the truncated (T periods) co-variance terms.

8.3 Implementing the Forecasting Model for Hiring and Investment

I cast the estimated model of hiring and investment into this asset pricing framework by defining P and D 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 marginal Q for capital investment (Q^K) and marginal Q for labor hiring (Q^N), each divided by the relevant productivity; the "dividend" D is the flow of net income from capital or from labor.

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

$$\frac{(1-\tau_t)\left(g_{i_t} + p_t^I\right)}{\frac{f_t}{k_t}} = \left\{ \frac{\frac{f_{t+1}}{k_{t+1}}}{\frac{f_t}{k_t}} \frac{\beta_{t+1}\left(1-\tau_{t+1}\right)}{\frac{f_{t+1}}{k_{t+1}}} \left[f_{k_{t+1}} - g_{k_{t+1}} + (1-\delta_{t+1})(g_{i_{t+1}} + p_{t+1}^I)\right] \right\} \tag{44}$$

I define the following asset pricing terms:

$$
\begin{aligned}
P_{t+k}^1 &= \frac{(1-\tau_{t+k})\left(g_{i_{t+k}} + p_{t+k}^I\right)}{\frac{f_{t+k}}{k_{t+k}}} \equiv \frac{Q_{t+k}^K}{\frac{f_{t+k}}{k_{t+k}}} \qquad (45) \\
D_{t+k}^1 &\equiv \frac{(1-\tau_{t+k})\frac{\left(f_{k_{t+k}} - g_{k_{t+k}}\right)}{\frac{f_{t+k}}{k_{t+k}}}}{(1-\delta_t)}
\end{aligned}
$$

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

$$\frac{(1-\tau_t)\,g_{h_t}}{\frac{f_t}{n_t}} = \left\{ \frac{\frac{f_{t+1}}{n_{t+1}}}{\frac{f_t}{n_t}} \frac{\beta_{t+1}\,(1-\tau_{t+1})}{\frac{f_{t+1}}{n_{t+1}}} \left[f_{n_{t+1}} - g_{n_{t+1}} - w_{t+1} + (1-\psi_{t+1}) g_{h_{t+1}}\right] \right\} \tag{46}$$

I define:

$$P^2_{t+k} \equiv \frac{(1-\tau_{t+k})\,g_{h_{t+k}}}{\frac{f_{t+k}}{n_{t+k}}} \equiv \frac{Q^N_{t+k}}{\frac{f_{t+k}}{n_{t+k}}} \tag{47}$$

$$D^2_{t+k} = \frac{(1-\tau_{t+k})\left(\frac{f_{n_{t+k}} - g_{n_{t+k}} - w_{t+k}}{\frac{f_{t+k}}{n_{t+k}}}\right)}{1-\psi_t}$$

These prices and "dividends" are not observed on the market, as in the Finance literature. Rather, they represent what the firm actually gets from its use of capital and labor in production. Thus, the "dividend" in the investment case is the net marginal productivity of capital; in the hiring case it is net labor profitability, i.e., the net marginal product of labor less the wage. These "dividends" do not depend on institutional or financial considerations of firms as dividends do in the Finance context. Note that a version of equation (44) was used by Cochrane (1991, 1996) and by Liu, Whited and Zhang (2009) for production-based asset pricing, exploring it empirically in a cross-section of firms. As noted, the results in Finance provide for a natural benchmark, as in both cases the issue is future discounted flows accruing to the firm being related to current values through the asset pricing relationship.

8.4 Results

Table 8 presents the different tests discussed above, separately for the two equations – investment and hiring.[18]

Table 8

There are a number of results which stand out:

Forecasting Regressions

(i) In the single variable forecasting regressions, most coefficients are significant. This implies that capital productivity growth, labor profitability

[18] When presenting the approximated variance decomposition, I report the error of the approximated variance equation (36) 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 (36) that this can be positive or negative. This error comes from estimation and approximation errors and from the sample truncation.

growth, and returns are forecastable or predictable by the "price-dividend" ratio.

(ii) In the case of hiring, the single variable forecasting regressions adjusted R-squared ($\overline{R}^2$) increases with the forecast horizon for labor profitability growth, reaching high levels of almost 0.80 at 16 and 20 quarters. The forecasted growth is the change in log labor profitability, i.e., after-tax labor productivity less wages. For the return forecast these adjusted R-squared decrease with the forecast horizon to around 0. At four quarters, the $\overline{R}^2$ is around 0.30. This means that labor profitability growth is highly forecastable and returns are much less so.

(iii) In the case of investment, the single variable forecasting regressions $\overline{R}^2$ increase with the forecast horizon for capital productivity growth and for the return forecast. At 20 quarters they reach about 0.20 for capital productivity growth and almost 0.40 for the return forecast.

Points (i)-(iii) indicate results which are markedly different from those typically obtained in the Finance literature (albeit, there, relating to stock market variables). Here there is far better forecasting power for the hiring equation, especially with respect to labor profitability growth.[19] In the Finance literature, the values of the $\overline{R}^2$ coefficients noted above are seldom higher than 0.10 for one-period forecasts and are at most 0.30 for long horizon forecasts in terms of future returns. They are around 0 for future dividend growth. Likewise, dividend growth coefficients are typically not statistically significant in that literature. The results for the investment equation here are somewhat more similar to those obtained in this Finance literature and so is also the pattern of a rise in explanatory power with the forecast horizon.

VAR Estimation

(iv) The analysis for hiring indicates that the hiring "price-dividend" ratio is persistent (ϕ and b_{pp} are estimated to be above 0.9), that a simple restricted system produces estimates similar to the single-variable regressions, and that the complete, restricted VAR analysis indicates a stronger predictive effect for labor profitability growth ($b_{dp} > b_d$) and a weaker one for returns ($|b_{rp}| < |b_r|$), relative to the single-variable regressions. All estimated coefficients are significant.

(v) The analysis for investment indicates that the investment "price-divided" ratio is extremely persistent (ϕ and b_{pp} are estimated to be around 0.99), a finding that is similar to many Finance studies for stock-price to dividend ratios. The simple restricted system produces estimates similar to the single-variable regressions. The complete, restricted VAR analysis indicates a stronger predictive effect for capital productivity growth ($b_{dp} >$

[19] Compare, for example, the results here to those discussed by Lettau and Ludvigson (2009), Koijen and Van Nieuwerburgh (2010) and Cochrane (2011).

b_d) and a weaker one for returns ($|b_{rp}| < |b_r|$), relative to the single-variable regressions. But the $\overline{R}^2$ in some of the investment VAR equations is low or even negative and the estimate of b_d is insignificant.

Points (iv) and (v) basically show that the single regressions, systems, and VARs yield similar results, but that the complete, restricted VARs assign different strength to the predictor variable.

Variance Decomposition

(vi) In the hiring case, the variance decomposition yields approximated values that have a relatively small error (see last row of panel c). There is also a close correspondence between the variance decomposition results and the estimates of long run coefficients. It indicates that hiring values co-move more with future labor profitability growth (around 60% to 80% of the variance of "price-dividend" ratios) than with future returns (the complementary 40% to 20%, in absolute value). Even a small number of periods ($T = 10$) suffices to get this result in the approximated relationship.

(vii) In the investment case, the variance decomposition yields approximated values that have a relatively small error only at long horizons (i.e., at a high value of T). It indicates that investment values co-move more with future returns (around 50% to 80% of the variance of price-dividend ratios in absolute value) than with future capital productivity growth (the complementary 50% to 20%).

Points (vi) and (vii) imply that hiring and investment relate differentially to their future determinants, with hiring dependent on future changes in labor profitability, while investment is dependent on future returns.

Overall Findings

Taken together, the results indicate that the connection between "price-dividend" ratios with future variables is significant and seems stronger or tighter for hiring than for investment. Both are stronger or much stronger than the typical findings in the Finance literature for stock price-dividend ratios. Hiring values are linked more to future changes in labor profitability, while investment values are linked more to changes in future returns.

The findings for hiring are consistent with the cyclical behavior of labor profitability. The key element in profitability here is $\frac{f_{n_t} - w_t}{\frac{f_t}{n_t}} = \alpha - \frac{w_t}{\frac{f_t}{n_t}}$. Real unit labor costs (or the labor share in income), $\frac{w_t}{\frac{f_t}{n_t}}$, are counter-cyclical contemporaneously, displaying a correlation of -0.38 with HP-filtered log GDP, so labor profitability falls in recessions. Without forward-looking behavior, one would expect hiring to fall and thus be pro-cyclical. But the dynamic cross-correlation $\rho(f_t, \frac{w_{t+l}}{\frac{f_{t+l}}{n_{t+l}}})$ turns positive within a 2 quarters lead, and remains so up to 19 quarters ahead. In other words, unit labor costs fall following recessions. In fact, the correlation with HP-filtered log GDP is

+0.40 between 4 and 10 quarters ahead, i.e., costs go down and profitability rises going forward after a recession.[20] Hence forward-looking hiring is counter-cyclical and rises in recessions.

9 Explaining Jobless Recoveries

Figures 3a and 3b show the employment to labor force and employment to population ratios. NBER-dated recessions are shown in grey shading,

Figures 3a and 3b

The two ratios exhibit similar patterns. Following the 1980 and 1981-2 recessions, recovery of the ratios was sharp and quick. Following the 2001 and 2007-2009, the ratios continued to decline for some quarters and stayed relatively low. The latter phenomenon has been labeled "jobless" recoveries. The 1990-1991 case is intermediate, with some delay in the recovery.

In what follows I attempt to explain this phenomenon using the current results. The idea is to use estimation results to explain the changing behavior of **net** employment growth.

I start off with the dynamic equation for net hiring:

$$\frac{n_{t+1}-n_t}{n_t} = \frac{h_t}{n_t} - \psi_t \tag{48}$$

Define the relationship between hiring and separations as follows:

$$\psi_t \equiv \lambda_t \frac{h_t}{n_t} \tag{49}$$

where λ_t is time-varying.

Recall from equation (21) that:

$$\frac{h_t}{n_t} = \frac{1}{(1-\tau_t)(e_1e_2-e_3^2)}\left(e_1\frac{Q_t^N}{\frac{f_t}{n_t}} - e_3\frac{Q_t^K}{\frac{f_t}{k_t}} + e_3(1-\tau_t)\frac{p_t^I}{\frac{f_t}{k_t}}\right) \tag{50}$$

Hence:

$$\begin{aligned}\frac{n_{t+1}-n_t}{n_t} &= (1-\lambda_t)\frac{1}{(1-\tau_t)(e_1e_2-e_3^2)}\left(e_1\frac{Q_t^N}{\frac{f_t}{n_t}} - e_3\frac{Q_t^K}{\frac{f_t}{k_t}} + e_3(1-\tau_t)\frac{p_t^I}{\frac{f_t}{k_t}}\right)\\ &= (1-\lambda_t)A\left(e_1\frac{Q_t^N}{(1-\tau_t)\frac{f_t}{n_t}} - e_3\frac{Q_t^K}{(1-\tau_t)\frac{f_t}{k_t}} + e_3\frac{p_t^I}{\frac{f_t}{k_t}}\right)\end{aligned}$$

where:

[20] This cyclicality pattern of the labor share over time is documented and analyzed by Rios-Rull and Santaeulalia-Llopis (2010).

$$A \equiv \frac{1}{e_1 e_2 - e_3^2}$$

Using the definitions of the present values Q_t^K and Q_t^N:

$$\begin{aligned} Q_t^K &= (1-\tau_t)\left(g_{i_t} + p_t^I\right) \\ Q_t^N &= (1-\tau_t)\, g_{h_t} \end{aligned}$$

I get:

$$\frac{n_{t+1} - n_t}{n_t} = (1-\lambda_t) A \left(e_1 \frac{g_{h_t}}{\frac{f_t}{n_t}} - e_3 \frac{g_{i_t}}{\frac{f_t}{k_t}} \right) \tag{51}$$

The net hiring rate is therefore a function of the parameter estimates ($e_{1,}e_2, e_3$, and the ensuing A), the estimated marginal costs ($\frac{g_{h_t}}{\frac{f_t}{n_t}}, \frac{g_{i_t}}{\frac{f_t}{k_t}}$), and the time-varying parameter λ_t, which is solved out of equation (49).

Figure 3c presents a plot of net employment growth (LHS of equation (51)) and the two components of the RHS, namely $(1-\lambda_t)Ae_1 \frac{g_{h_t}}{\frac{f_t}{n_t}}$ and $-(1-\lambda_t)Ae_3 \frac{g_{i_t}}{\frac{f_t}{k_t}}$:

Figure3c

It can be seen that from 1976 to 1995, the hiring-cost based component ($(1-\lambda_t)Ae_1 \frac{g_{h_t}}{\frac{f_t}{n_t}}$) tracks net employment growth closely; since then it is the investment-cost based component ($-(1-\lambda_t)Ae_3 \frac{g_{i_t}}{\frac{f_t}{k_t}}$) that plays this role. This change in the relative importance of each component is further confirmed by the following decomposition of the first two moments, presented in Table 9.

Table 9

Both moments indicate that the importance of the investment-cost based component was relatively high after 1995, after being relatively low in the 1976-1995 period. The mean and the variance of this term relative to the hiring-cost based component rise substantially while the co-variation between them does not change much.

The economic mechanism in operation here may be understood by considering the following implications of Figure 4 and Table 9:

(i) Over the sample period the marginal cost of investment $\frac{g_{i_t}}{\frac{f_t}{k_t}}$ has risen relative to the marginal costs of hiring $\frac{g_{h_t}}{\frac{f_t}{n_t}}$, as shown in Figure 3d (with NBER-dated recessions shaded):

Figure 3d

This is so as the expected, discounted future marginal productivity of capital rose, while the expected, discounted future marginal profits from labor fell (see equations (13) and (14)).

(ii) Using equation (51), point (i) above implies that the investment marginal cost $\frac{g_{i_t}}{\frac{f_t}{k_t}}$ has gained in importance in the determination of net employment growth relative to marginal hiring costs $\frac{g_{h_t}}{\frac{f_t}{n_t}}$, noting that the term $(1-\lambda_t)A$ multiplies both marginal costs. This is indeed what is seen in Figure 4c.

(iii) Figure 4d also shows that $\frac{g_{i_t}}{\frac{f_t}{k_t}}$ falls sharply during recessions and for some time thereafter, while $\frac{g_{h_t}}{\frac{f_t}{n_t}}$ rises in recessions.

(iv) The rise of the rate of non-employment may also be explained using this decline in the hiring rate. The non-employment rate is defined as unemployment (U) plus those of of the labor force (OLF) divided by working age population ($\dot{POP}$). In steady state this should satisfy the following equation:

$$\frac{U+OLF}{POP}=\frac{\psi}{\psi+\frac{\frac{h}{n}}{\frac{u}{n}}} \tag{52}$$

Hence when $\frac{h}{n}$ declines, the RHS rises. Figure 4e shows that in the data the two sides of equation (**??**) are close.

Figure 3e

(v) Combining these points, it emerges that recent recessions exhibit lower net employment growth coming out of the recession than previous ones, i.e., "jobless" recoveries. The intuition is that the dependence of hiring on investment behavior has risen, with the rise in the expected present value of investment; investment falls sharply in recessions and in their immediate aftermath; thus the rise in hiring after recessions has slowed, being mitigated by the effects of the fall in investment.

10 Summary of the Mechanism and Conclusions

The paper has shown that a model of aggregate investment and hiring with costs capturing frictions is a consistent and reasonable model, which fits U.S. data. It was shown that it is important to examine investment and hiring together and to allow for the interaction between their costs. It is difficult to capture hiring behavior and investment behavior without considering the other factor. The model fits the data even though costs are estimated to be moderate or small. 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 with the differential relations of investment and hiring with the relevant components of these present values.

The key notion in this paper is the forward-looking aspect of investment and hiring. The results indicate two sets of key implications of the estimated variables: one shows that the hiring rate is heavily influenced by the present value of investment, while the rate of investment is less influenced by the present value of hiring. Another set shows that investment is driven mostly by expected future returns while hiring depends mostly on changes in future labor profitability.

The results imply the following cyclical patterns: in a boom investment rates rise while hiring rates decline. This is so because the rates move together with their present values. Specifically, in the U.S. data sample examined here, the present value of investment was pro-cyclical while that of hiring was counter-cyclical. As the marginal productivity of capital rises in booms and in subsequent quarters, Q^K rises and with it the investment rate. By contrast, the hiring rate falls with the decrease in the present value of hiring, Q^N, as future labor profitability falls. The latter falls due to the fact that while the labor share first falls in a boom (thereby increasing profitability), it subsequently rises for a substantial period of time. In recessionary times, firms, looking into the future, expect higher profitability from employing labor. Hence, they increase the rate at which they hired workers.

The set-up examined in this paper and the mechanism emerging from the empirical estimates emphasize intertemporal aspects. Hence it is not enough to consider just current productivity changes; the concurrent change in future variables is no less important. These results are consistent with the observations and claims of two recent contributions dealing with the cyclical behavior of the labor market, each highlighting intertemporal issues that previously were not given much attention:

Hall (2009) models workers' compensation, and consequently the firms' share of the match surplus, as the present value of wage payments over the duration of the job as an hypothetical up-front payment that the worker pays the employer at the beginning of the job, essentially funding hiring costs. Hall thinks of actual compensation arrangements as annuitizing this payment over the duration of the job. Hence in his set-up, as is the case here, there is a distinction between current hiring costs and future profits from labor, which depend on future wage payments.

As noted above, Rios-Rull and Santaeulalia-Llopis (2010) study the behavior of the labor share over time and its cyclical implications. They remark that in RBC models the assumption is that the factor distribution of income is constant at all frequencies. Their findings challenge this premise – there is an overshooting pattern in the U.S. labor share in response to a productivity innovation. They state that "... a productivity innovation produces a reduction in the labor share at impact, making it countercyclical, but it also subsequently produces a long-lasting increase of the labor share that overshoots its long-run average after five quarters and peaks above mean five years later at a level larger in absolute terms than the initial drop, after which it slowly returns to average" (page 931). This behavior is in line with the movement of labor profitability which determines Q^N, as discussed above.

This paper, purposefully, did not specify a full DSGE model. This was done in order to focus on firms' investment and hiring decisions and not let the analysis be affected by possible mis-specifications or problematics in other parts of the macroeconomy. To account for firm investment and hiring behavior, one does not need to get into issues such as optimal intertemporal consumption and labor choices of the individual, with all the associated empirical difficulties. Future research may, nonetheless, take up such a model in an attempt to map the linkages between the structural shocks to the economy and the differential evolution of the relevant present values.

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Appendix A
The Cost Function and Its Key Derivatives and Elasticities

The Cost Function

$$g(\cdot) = \left[\frac{e_1}{\eta_1}(\frac{i_t}{k_t})^{\eta_1} + \frac{e_2}{\eta_2}(\frac{h_t}{n_t})^{\eta_2} + \frac{e_3}{\eta_3}\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3}\right] f(z_t, n_t, k_t). \tag{53}$$

First Derivatives

$$g_{i_t} = \left[e_1(\frac{i_t}{k_t})^{\eta_1 - 1} + e_3\left(\frac{h_t}{n_t}\right)^{\eta_3}\frac{i_t}{k_t}^{\eta_3 - 1}\right]\frac{f_t}{k_t} \tag{54}$$

$$g_{h_t} = \left[e_2(\frac{h_t}{n_t})^{\eta_{2-1}} + e_3\left(\frac{i_t}{k_t}\right)^{\eta_3}\frac{h_t}{n_t}^{\eta_3 - 1}\right]\frac{f_t}{n_t} \tag{55}$$

$$\begin{aligned} g_{k_t} &= -\left[e_1(\frac{i_t}{k_t})^{\eta_1} + e_3\left(\frac{h_t}{n_t}\frac{i_t}{k_t}\right)^{\eta_3}\right]\frac{f_t}{k_t} \\ &\quad +(1-\alpha)\left[\frac{e_1}{\eta_1}(\frac{i_t}{k_t})^{\eta_1} + \frac{e_2}{\eta_2}(\frac{h_t}{n_t})^{\eta_2} + \frac{e_3}{\eta_3}\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3}\right]\frac{f_t}{k_t} \end{aligned} \tag{56}$$

$$\begin{aligned} g_{n_t} &= -\left[e_2(\frac{h_t}{n_t})^{\eta_2} + e_3\left(\frac{h_t}{n_t}\frac{i_t}{k_t}\right)^{\eta_3}\right]\frac{f_t}{n_t} \\ &\quad +\alpha\left[\frac{e_1}{\eta_1}(\frac{i_t}{k_t})^{\eta_1} + \frac{e_2}{\eta_2}(\frac{h_t}{n_t})^{\eta_2} + \frac{e_3}{\eta_3}\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3}\right]\frac{f_t}{n_t} \end{aligned} \tag{57}$$

Second Derivatives

$$g_{ii_t} = \underbrace{\left[\begin{array}{c} e_1(\eta_1 - 1)\left(\frac{i_t}{k_t}\right)^{\eta_1 - 2} \\ +e_3(\eta_3 - 1)\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3 - 2}\left(\frac{h_t}{n_t}\right)^2 \end{array}\right]}_{\widetilde{g}_{ii}}\frac{f(z_z, n_t, k_t)}{k_t^2} \tag{58}$$

$$g_{hh_t} = \underbrace{\left[\begin{array}{c} e_2(\eta_2 - 1)\left(\frac{h_t}{n_t}\right)^{\eta_2 - 2} \\ +e_3(\eta_3 - 1)\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3 - 2}\left(\frac{i_t}{k_t}\right)^2 \end{array}\right]}_{\widetilde{g}_{hh}}\frac{f(z_z, n_t, k_t)}{n_t^2} \tag{59}$$

$$g_{ih_t} = g_{hi_t} = \underbrace{\left[e_3\eta_3\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3-1}\right]}_{\widetilde{g}_{ih}}\frac{f(z_z,n_t,k_t)}{k_t n_t} \tag{60}$$

Elasticities
Starting from the F.O.C and differentiating the following is obtained:[21]

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

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

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

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

[21] The complete derivation is avaialble upon request.

Appendix B: The Data

variable	**symbol**	**definition**
GDP	f	gross value added of NFCB
GDP deflator	p^f	price per unit of gross value added of NFCB
wage share	$\frac{wn}{f}$	numerator: compensation of employees in NFCB
discount rate 1	r	the rate of consumption growth minus 1
discount rate 2	r	the weighted average cost of capital – see note 1
employment	n	employment in nonfinancial corporate business sector
hiring	h	gross hires
separation rate	ψ	gross separations divided by employment
vacancies	v	adjusted Help Wanted Index
investment	i	gross investment in NFCB sector
capital stock	k	stock of private nonresidential fixed assets in NFCB sector
depreciation	δ	depreciation of the capital stock
price of capital goods	p^I	real price of new capital goods

variable	**symbol**	**source**
GDP	f	NIPA accounts, table 1.14, line 40
GDP deflator	p^f	NIPA table 1.15, line 1
wage share	$\frac{wn}{f}$	NIPA table 1.14, lines 17 and 20
discount rate 1	r	COMPLETE
discount rate 2	r	Fed; see note 1
employment	n	CPS; see note 2
hiring	h	CPS; see note 2
separation rate	ψ	CPS; see note 2
vacancies	v	Conference Board; see note 3
investment	i	BEA and Fed Flow of Funds; see note 4
capital stock	k	BEA and Fed Flow of Funds; see note 4
depreciation	δ	BEA and Fed Flow of Funds; see note 4
price of capital goods	p^I	NIPA and U.S. tax foundation; see note 5

Notes:

1. *The discount rate and the discount factor*

The discount rate is based on a DSGE-type model with logarithmic utility $U(c_t) = \ln c_t$.

Then in general equilibrium:

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

Hence:

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

where c is non-durable consumption.

2. *Employment, hiring 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).

3. *Vacancies and Market Tightness*

In order to compute $\frac{v}{n+o}$ I use:

(i) The vacancies series based on the Conference Board Composite Help-Wanted Index that takes into account both printed and web job advertisements, as computed by Barnichon (2010), available at
http://sites.google.com/site/regisbarnichon/research.

This index was multiplied by a constant to adjust its mean to the mean of the JOLTS vacancies series over the overlapping sample period (2001Q1–2007Q4).

(ii)The unemployment and the out of labor force series are the BLS CPS data.

4. *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).

- Construct annual fixed-cost depreciation of private nonresidential fixed assets in NFCB sector, D_t . 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}:

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

- 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. The resulting quarterly series, i_t_unadj, is thus in real terms.

- Perform Denton's 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:

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

5. *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. 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:

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

where

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

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. 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. 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

$$\begin{aligned} p^{Eq} &= \widetilde{p}^{Eq} (1 - \tau_{Eq}) \\ p^{St} &= \widetilde{p}^{St} (1 - \tau_{St}), \end{aligned}$$

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

Appendix C
Alternative Specifications

The following tables report variations on the specifications reported in Tables 2a and 2b.

Table C-1
GMM estimates

	specification	e_1	e_2	e_3	η_1	η_2	η_3	f_1	f_2	α
1	all free	85,018	8.6	−41.8	3.88	2.20	1.06	2.74	0.02	0.68
		(234,098)	(9.2)	(12.2)	(0.34)	(0.52)	(0.01)	(6.60)	(0.25)	(0.009)
2	constrained	113,317	6.9	−33.0	3.98	2.08	1.02	3.56	−0.02	0.67
		(191,649)	(1.7)	(5.6)	(0.09)	(0.19)	(0.01)	(3.50)	(0.36)	–
3	constrained	62,637	8.4	−52.1	3.36	1.87	1.01	0	0	0.67
		(45,384)	(2.3)	(8.1)	(0.11)	(0.21)	(0.01)	–	–	–
4	constrained	30,378	7.1	−43.4	3.22	1.96	1.02	0	0	0.67
		(48,639)	(3.6)	(19.8)	(0.38)	(0.37)	(0.07)	–	–	–
5	3, 2, 1	1436	1.9	−2.5	3	2	1	0	0	0.67
		(355)	(0.4)	(1.3)	–	–	–	–	–	–
6	3, 2, 1	−469	0.6	7.6	3	2	1	0	0	0.67
		(327)	(0.3)	(1.5)	–	–	–	–	–	–
7	2, 2, 1	76	1.5	−4.8	2	2	1	0	0	0.67
		(12)	(0.4)	(1.5)	–	–	–	–	–	–
8	2, 2, 1	58	1.4	−4.2	2	2	1	0	0	0.67
		(10)	(0.3)	(1.5)	–	–	–	–	–	–

	specification	J-Statistic	instrument set
1	all free	68.7	$\frac{h}{n}, \frac{i}{k}, \frac{f}{k}$
		(0.07)	
2	partially constrained	72.9	$\frac{h}{n}, \frac{i}{k}, \frac{f}{k}$
		(0.04)	
3	partially constrained	82.9	$\frac{h}{n}, \frac{i}{k}, \frac{f}{k}$
		(0.01)	
4	partially constrained	85.9	$\frac{h}{n}, \frac{i}{k}, p^I$
		(0.01)	
5	3, 2, 1	73.5	$\frac{h}{n}, \frac{i}{k}, \frac{f}{k}$
		(0.10)	
6	3, 2, 1	71.6	$\frac{h}{n}, \frac{i}{k}, p^I$
		(0.13)	
7	2, 2, 1	71.7	$\frac{h}{n}, \frac{i}{k}, \frac{f}{k}$
		(0.12)	
8	2, 2, 1	77.1	$\frac{h}{n}, \frac{i}{k}, p^I$
		(0.06)	

Notes:

1. The table reports point estimates with standard errors in parantheses.
2. The J-statistic is reported with p value in parantheses.

Table C-2

Adjustment Costs Implied by the GMM Estimation Results

	specification	$\frac{g}{f}$		$\frac{g_i}{\frac{f}{k}}$		$\frac{g_h}{\frac{f}{n}}$	
1	all free	0.050	0.003	0.39	0.87	0.13	0.16
2	partially constrained	0.034	0.004	1.10	0.83	0.11	0.15
3	partially constrained	0.015	0.008	1.29	3.19	0.35	0.24
4	partially constrained	0.007	0.007	1.37	2.44	0.18	0.18
5	$\eta_1 = 3, \eta_{\mathbf{2}} = 2, \eta_3 = 1$	0.014	0.001	0.37	0.23	0.19	0.03
6	$\eta_1 = 3, \eta_{\mathbf{2}} = 2, \eta_3 = 1$	0.025	0.002	0.77	0.13	0.24	0.02
7	$\eta_1 = \eta_{\mathbf{2}} = 2, \eta_3 = 1$	0.018	0.003	1.01	0.29	0.09	0.03
8	$\eta_1 = \eta_{\mathbf{2}} = 2, \eta_3 = 1$	0.015	0.002	0.72	0.22	0.09	0.03

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

The first four specifications, with no or few restrictions, have low p-values and imprecise estimates of the scale parameters, very much like those of rows 1 and 2 in Table 2a. As in the latter table, they seem to point to a power specification of $\eta_1 = 3, \eta_{\mathbf{2}} = 2, \eta_3 = 1$. The remaining four specifications, more restricted, have precise estimates and higher p-values. They imply cost functions that are similar to those of rows 3 and 4 in Table 2a.

Table 1

Descriptive Sample Statistics
Quarterly, U.S. data 1976-2011

Variable	Mean	Standard Deviation
$\frac{f}{k}$	0.153	0.013
τ	0.380	0.053
$\frac{i}{k}$	0.022	0.003
δ	0.015	0.003
$\frac{wn}{f}$	0.652	0.017
$\frac{h}{n}$	0.132	0.012
ψ	0.131	0.012
β	0.994	0.004

Note: The sample size contains 143 quarterly observations from 1976:2 to 2011:4. For data definitions see Appendix B.

Table 2a

GMM estimates

	η_s	$e_\mathbf{1}$	$e_\mathbf{2}$	$e_\mathbf{3}$	η_1	$\eta_\mathbf{2}$	η_3	$f_\mathbf{1}$	$f_\mathbf{2}$	α	J
1	free	$57,166$	20.5	-98.6	3.16	1.93	1.00	-0.98	0.005	0.67	80.
		$(94,598)$	(18.2)	(57.7)	(0.34)	(0.54)	(0.05)	(22.8)	(0.15)	(0.05)	(0.00
2	constr.	$54,299$	7.9	-73.5	3.25	1.71	1.00	0	0	0.67	88.
		$(36,173)$	(1.7)	(9.2)	(0.11)	(0.16)	(0.01)	–	–	–	(0.00
3	$3,2,1$	1585	2.0	-3.9	3	2	1	0	0	0.67	75.
		(328)	(0.3)	(1.3)	–	–	–	–	–	–	(0.0
4	$2,2,1$	76	1.8	-6.9	2	2	1	0	0	0.67	75.
		(12)	(0.3)	(1.4)	–	–	–	–	–	–	(0.0

Notes:
1. The table reports point estimates with standard errors in parantheses.
2. The J-statistic is reported with p value in parantheses.
3. The instrument set is $\frac{h}{n}, \frac{w}{n/f}, \frac{i}{k}$ with 10 lags

Table 2b

GMM estimates, Standard Specifications

	$\mathbf{e_1}$	$\mathbf{e_2}$	$\mathbf{e_3}$	**J-Statistic**	**fixed parameters**
1	107	0	0	77.4	$\eta_1 = 2$
	(4)	–	–	(0.08)	
2	0	0.16	0	75.7	$\eta_2 = 1$
	–	(0.01)	–	(0.10)	
3	64	0.84	0	76.3	$\eta_1 = 2, \eta_2 = 2$
	(10)	(0.26)	–	(0.08)	

Notes:
1. The table reports point estimates with standard errors in parantheses.
2. The J-statistic is reported with p value in parantheses.
3. The instrument set is $\frac{h}{n}, \frac{w}{n/f}, \frac{i}{k}$ with 10 lags.
4. α is set at 0.67.

Table 2c

Adjustment Costs Implied by the GMM Estimation Results

	specification	$\frac{g}{f}$		$\frac{g_i}{\frac{f}{k}}$		$\frac{g_h}{\frac{f}{n}}$	
1	all free	0.026	0.015	1.05	5.67	0.97	0.50
2	partially constrained	0.011	0.009	0.67	4.07	0.29	0.32
3	$\boldsymbol{\eta}_1 = 3, \boldsymbol{\eta_2} = 2, \boldsymbol{\eta}_3 = 1$	0.012	0.002	0.25	0.27	0.18	0.03
4	$\boldsymbol{\eta}_1 = \boldsymbol{\eta_2} = 2, \boldsymbol{\eta}_3 = 1$	0.014	0.002	0.75	0.30	0.08	0.04

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

Table 2d

Adjustment Costs Implied by the GMM Estimation Results

	specification	$\frac{g}{f}$		$\frac{g_i}{\frac{f}{k}}$		$\frac{g_h}{\frac{f}{n}}$	
1	$\eta_1 = 2, e_2 = e_3 = 0$	0.03	0.008	2.33	0.36	–	
2	$e_1 = e_3 = 0$	0.02	0.002	–	–	0.16	–
3	$e_3 = 0$	0.02	0.004	1.39	0.21	0.11	0.01

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

Table 3

Estimates of the Marginal Adjustment Costs for Capital
Summary of Key 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, 1953-1976	0.14	3.2
3	Shapiro (1986)	Manufacturing, 1955-1980	0.08	1.33
4	Hubbard et al (1995)	Compustat, 1976-1987	$0.20 - 0.23$	$0.15 - 0.45$
5	Gilchrist and Himmelberg (1995)	Compustat, 1985-1989	$0.17 - 0.18$	$0.50 - 0.98$
6a	Gilchrist and Himmelberg (1998)	Compustat, 1980-1993	0.23	$0.15 - 0.21$
6b		Split Sample		$0.13 - 1.1$
7	Hall (2004)	Industry panel, 1958-1999	0.10	0.10
8	Cooper and Haltiwanger (2006)	LRD panel, 1972-1988	0.12	$0.04, 0.26$
9	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 Tables 2c and 2d.

Table 4
Decomposition of the Hiring Rate and Investment Rate Equations
First Two Moments

a. Hiring Equation

$$\frac{h_t}{n_t} = \frac{1}{(e_1 e_2 - e_3^2)} \left(e_1 \frac{g_{h_t}}{\frac{f_t}{n_t}} - e_3 \frac{g_{i_t}}{\frac{f_t}{k_t}} \right) \tag{61}$$

		$\frac{h_t}{n_t}$		1 $\left(\frac{e_1}{e_1 e_2 - e_3^2}\right) \frac{g_{h_t}}{\frac{f_t}{n_t}}$	2 $\left(\frac{-e_3}{e_1 e_2 - e_3^2}\right) \frac{g_{i_t}}{\frac{f_t}{k_t}}$
1	mean	0.13	relative mean	0.58	0.42
2	std	0.01	relative var	7.9	3.9
3			relative cova	−5.38	

b. Investment Equation

$$\frac{i_t}{k_t} = \frac{1}{(e_1 e_2 - e_3^2)} \left(-e_3 \frac{g_{h_t}}{\frac{f_t}{n_t}} + e_2 \frac{g_{i_t}}{\frac{f_t}{k_t}} \right) \tag{62}$$

		$\frac{i_t}{k_t}$		1 $\left(\frac{-e_3}{e_1 e_2 - e_3^2}\right) \frac{g_{h_t}}{\frac{f_t}{n_t}}$	2 $\left(\frac{e_2}{e_1 e_2 - e_3^2}\right) \frac{g_{i_t}}{\frac{f_t}{k_t}}$
1	mean	0.02	relative mean	0.32	0.68
2	std	0.003	relative var	0.85	3.50
3			relative cova	−1.67	

Notes:

1. The equations include the following terms:

$$\frac{g_{h_t}}{\frac{f_t}{n_t}} = \left[e_2 (\frac{h_t}{n_t})^{\eta_{2-1}} + e_3 \left(\frac{i_t}{k_t} \right)^{\eta_3} \frac{h_t}{n_t}^{\eta_3 - 1} \right]$$

$$\frac{g_{i_t}}{\frac{f_t}{k_t}} = \left[e_1 (\frac{i_t}{k_t})^{\eta_1 - 1} + e_3 \left(\frac{h_t}{n_t} \right)^{\eta_3} \frac{i_t}{k_t}^{\eta_3 - 1} \right]$$

2. Row 1 reports the mean hiring or investment rate and the relative means of the two decomposition terms indicated in columns 1 and 2.

3. Row 2 reports the std. of the hiring or investment rate and the relative variances of the two decomposition terms indicated in columns 1 and 2.

4. Row 3 reports the relative co-variance of the two decomposition terms indicated in columns 1 and 2.

5. All results are based on the point estimates of row 4 in Table 2a.

Table 5
Scope and Elasticities Implied by The GMM Estimation Results

	specification	**scope**	$\frac{\partial i_t}{\partial Q^K}\frac{Q^K}{i_t}$	$\frac{\partial i_t}{\partial Q^N}\frac{Q^N}{i_t}$	$\frac{\partial h_t}{\partial Q^k}\frac{Q^K}{h_t}$	$\frac{\partial h_t}{\partial Q^N}\frac{Q^N}{h_t}$
Table 4b row 3	both, no interaction	0	11.1	–	–	1
			(2.6)			–
Table 4a row 4	preferred	1.36	13.7	0.35	8.32	0.56
		(0.08)	(3.2)	(0.18)	(0.51)	(0.21)

Notes:

1. All computations are based on the point estimates of Table 2a and 2b.
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 6

Stochastic Behavior of Hiring and Investment

a. The Raw Series – Data Moments

	$\frac{i}{k}$	$\frac{h}{n}$
mean	0.02	0.13
median	0.02	0.13
std.	0.003	0.010
coefficient of variation	0.15	0.08
auto-correlation	0.98	0.93
correlation	-0.58	

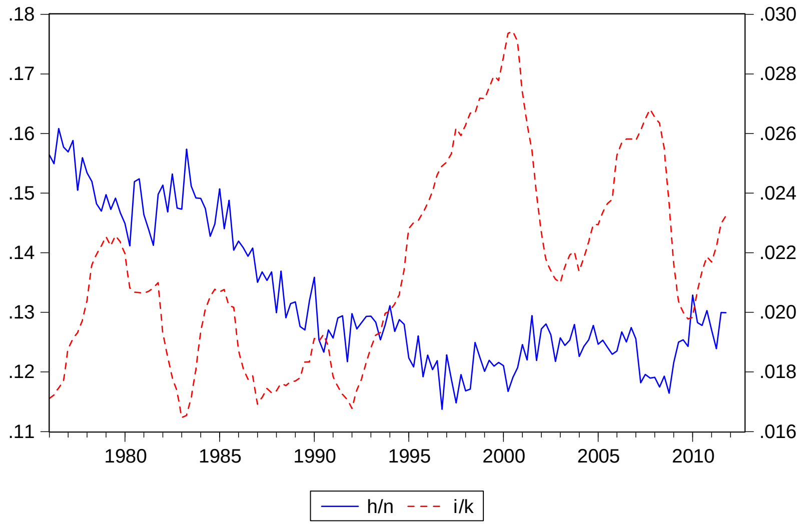


Figure 2a: Hiring $\frac{h}{n}$ (left axis) and investment $\frac{i}{k}$ (right axis), raw data

b. Cyclicality

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

HP filtered ($\lambda = 1600$)

lag/lead	-8	-4	-1	0	1	4	8
f	-0.15	-0.30	-0.34	-0.25	-0.12	0.17	0.20
$\frac{f}{n}$	-0.13	-0.20	-0.11	-0.04	0.05	0.21	0.09
$\frac{f}{k}$	-0.18	-0.31	-0.30	-0.19	-0.07	0.22	0.19

BK filtered (Baxter-King, 6-32)

lag/lead	-8	-4	-1	0	1	4	8
f	-0.23	-0.34	-0.45	-0.36	-0.24	0.11	0.13
$\frac{f}{n}$	-0.09	-0.19	-0.20	-0.08	0.01	0.17	0.03
$\frac{f}{k}$	-0.29	-0.35	-0.40	-0.29	-0.17	0.17	0.13

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

HP filtered ($\lambda = 1600$)

lag/lead	-8	-4	-1	0	1	4	8
f	0.10	0.50	0.84	0.79	0.63	-0.03	-0.40
$\frac{f}{n}$	0.10	0.62	0.63	0.50	0.29	-0.34	-0.44
$\frac{f}{k}$	-0.06	0.60	0.84	0.75	0.55	-0.17	-0.49

BK filtered (Baxter-King, 6-32)

lag/lead	-8	-4	-1	0	1	4	8
f	-0.12	0.51	0.84	0.79	0.62	0.00	-0.27
$\frac{f}{n}$	0.12	0.49	0.63	0.49	0.27	-0.28	-0.37
$\frac{f}{k}$	0.01	0.62	0.84	0.73	0.51	-0.16	-0.39

Notes:

1. The variable y denotes the cyclical indicator which is f (NFCB GDP), or $\frac{f}{n}$ (labor productivity), or $\frac{f}{k}$ (capital productivity).

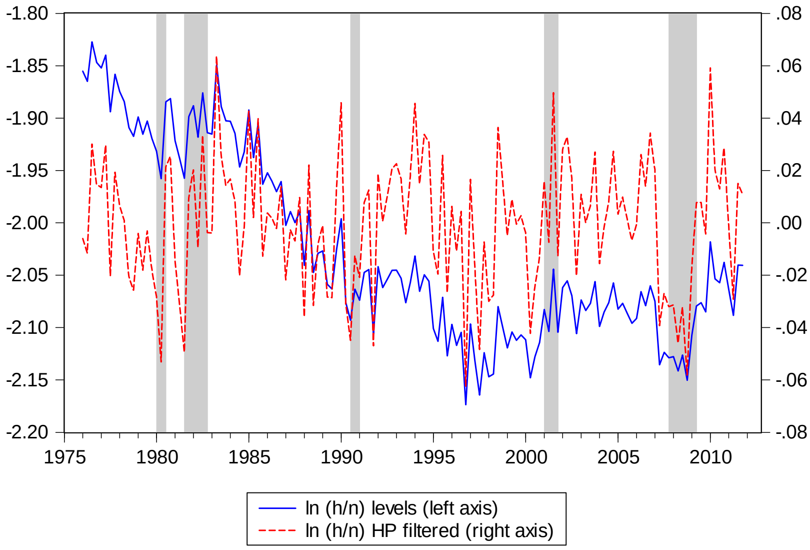


Figure 2b, Panel A: Log Hiring Rates (levels and HP filtered).

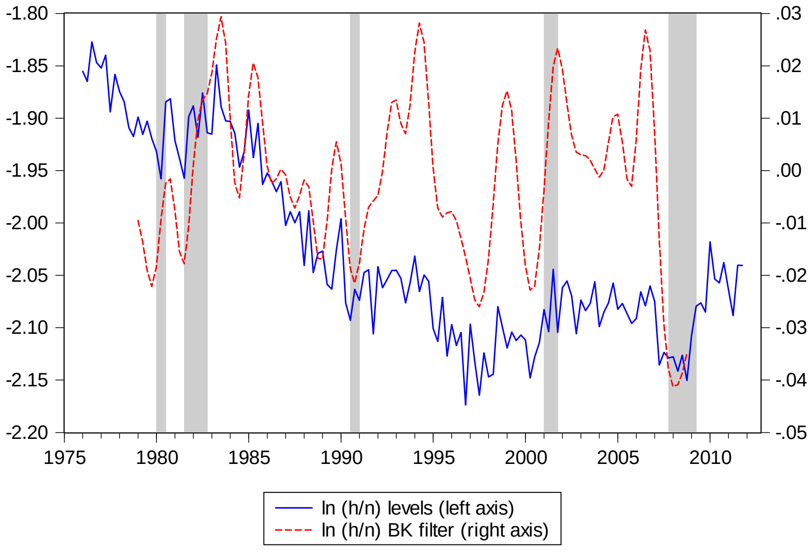


Figure 2b, Panel B: Log Hiring Rates (levels and BK filtered).

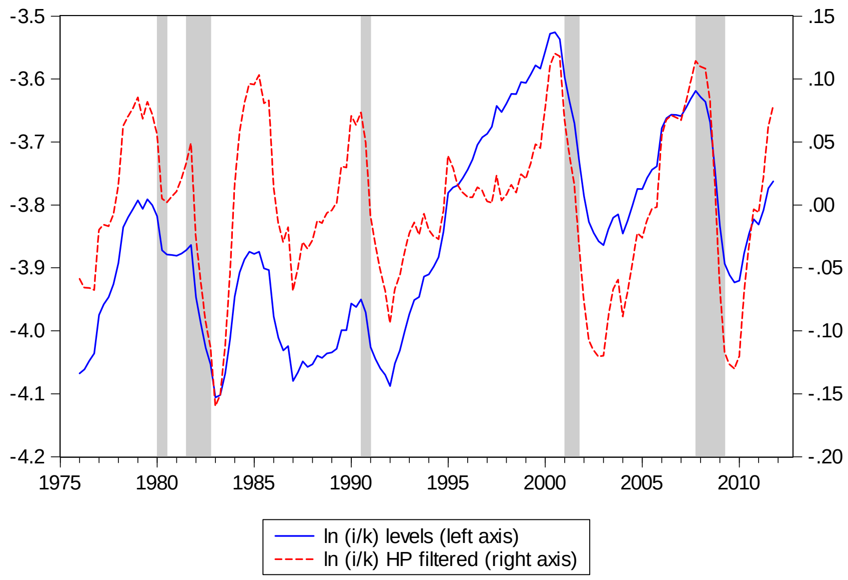


Figure 2b, Panel C: Log Investment Rates (levels and HP filtered).

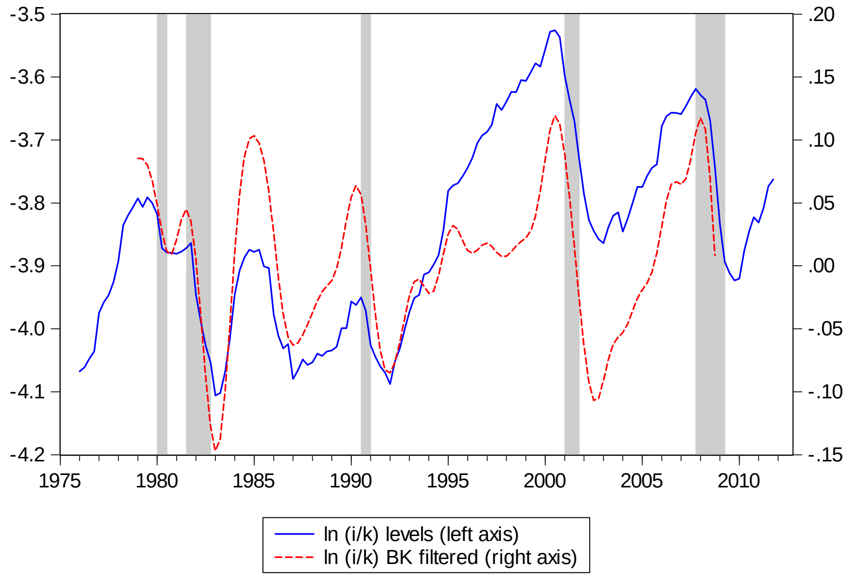


Figure 2b, Panel D: Log Investment Rates (levels and BK filtered).

c Investment and Hiring Co-Movement $\rho(\ln \frac{h_t}{n_t}, \ln \frac{i_{t+i}}{k_{t+i}})$

HP filtered ($\lambda = 1600$)

lag/lead	**-8**	**-4**	**-1**	**0**	**1**	**4**	**8**
	-0.08	-0.24	-0.35	-0.30	-0.22	0.10	0.21

BP filtered (Baxter-King, 6-32)

lag/lead	**-8**	**-4**	**-1**	**0**	**1**	**4**	**8**
	-0.20	-0.26	-0.44	-0.42	-0.35	0.02	0.19

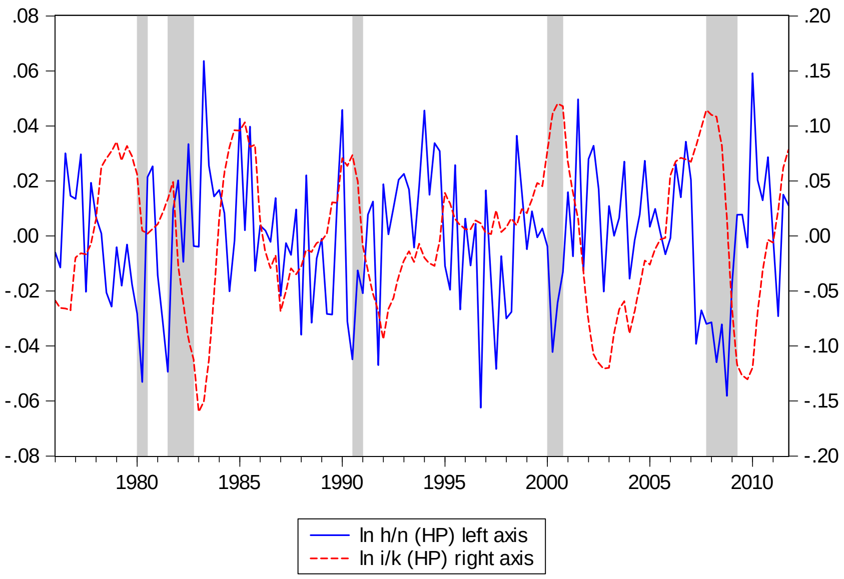


Figure 2c, Panel A: Hiring $\frac{h}{n}$ and investment $\frac{i}{k}$ rates (logged, HP filtered).

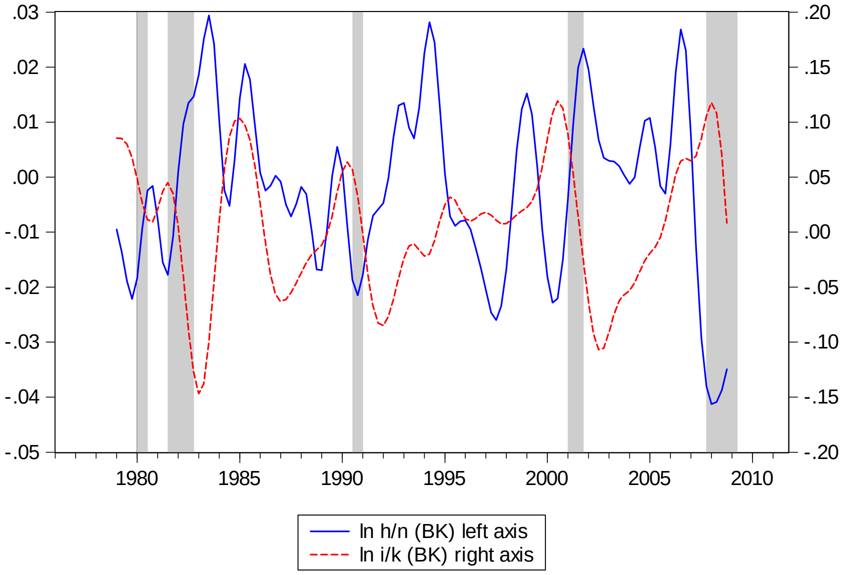


Figure 2c, Panel B: Hiring $\frac{h}{n}$ and investment $\frac{i}{k}$ rates (logged, BK filtered).

Table 7
Stochastic Behavior of Gross Hiring and Other Labor Market Variables

Co-Movement (contemporaneous) with Cyclical Indicators

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	**0.81**	**−0.25**	**0.53**	**−0.72**	**−0.82**
with labor productivity $\frac{f}{n}$	**0.42**	**−0.04**	**0.38**	**−0.62**	**−0.46**

logged, BK 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	0.83	**−0.36**	0.69	−0.80	−0.88
with labor productivity $\frac{f}{n}$	0.36	**−0.08**	0.44	−0.72	−0.50

Table 8
Asset Pricing Tests

Hiring

a. Single Forecasting Regressions Results

		coefficient	standard error	$\overline{R}^2$
dividend growth forecasting[1]	b	0.11	0.03	0.08
4 quarter ahead [1]	b	0.48	0.07	0.28
8 quarter ahead [1]	b	1.01	0.09	0.50
12 quarter ahead [1]	b	1.42	0.09	0.66
16 quarter ahead [1]	b	1.62	0.08	0.78
20 quarter ahead [1]	b	1.58	0.09	0.76
return forecasting[1]	b	−0.06	0.01	0.17
4 quarter ahead[1]	b	−0.22	0.03	0.28
8 quarter ahead[1]	b	−0.30	0.06	0.17
12 quarter ahead[1]	b	−0.24	0.08	0.06
16 quarter ahead[1]	b	−0.10	0.10	0.0003
20 quarter ahead[1]	b	0.09	0.10	−0.002

b. VARs

		coefficient	standard error	$\overline{R}^2$
restricted, forecasting system[2]	ϕ	0.95	0.02	0.87
	b_d	0.12	0.02	0.08
	b_r	−0.07	0.02	0.16
restricted, complete VAR[3]	b_{pp}	0.90	0.02	0.87
	b_{dd}	0.08	0.04	0.27
	b_{rr}	0.45	0.11	0.11
	b_{dp}	0.19	0.02	0.27
	b_{rp}	−0.04	0.02	0.11

c. Variance Decomopsition and Long Run Coefficients[4]

T	**10**	**20**	**30**	**40**
$\frac{b_d}{1-\rho\phi} = b_d^{lr}$		0.62(0.09)		
$\frac{b_r}{1-\rho\phi} = b_r^{lr}$		−0.37(0.09)		
$\frac{b_{dp}}{1-\rho b_{pp}} = b_d^{lr}$		0.82(0.07)		
$\frac{b_{rp}}{1-\rho b_{pp}} = b_r^{lr}$		−0.17(0.07)		
$\frac{cov\left[p_t - d_t, \sum_{j=0}^{T} \rho^{j-1}(d_{t+j+1} - d_{t+j})\right]}{var(p_t - d_t)}$	0.71	0.75	0.77	0.78
$\frac{cov\left[p_t - d_t, \sum_{j=0}^{T} \rho^{j-1} r_{t+j+1}\right]}{var(p_t - d_t)}$	−0.21	−0.18	−0.19	−0.18
$\frac{e_t}{var(p_t - d_t)}$	0.08	0.07	0.04	0.04

Investment

a. Single Forecasting Regressions Results

		coefficient	standard error	$\overline{R}^2$
dividend growth forecasting[1]	b	0.01	0.01	−0.002
4 quarter ahead[1]	b	0.03	0.02	0.02
8 quarter ahead[1]	b	0.07	0.03	0.04
12 quarter ahead[1]	b	0.10	0.03	0.07
16 quarter ahead [1]	b	0.15	0.04	0.11
20 quarter ahead [1]	b	0.23	0.04	0.21
return forecasting[1]	b	−0.02	0.01	0.05
4 quarter ahead[1]	b	−0.10	0.02	0.16
8 quarter ahead[1]	b	−0.18	0.03	0.24
12 quarter ahead[1]	b	−0.26	0.04	0.30
16 quarter ahead[1]	b	−0.31	0.04	0.32
20 quarter ahead[1]	b	−0.35	0.05	0.36

b. VARs

		coefficient	standard error	$\overline{R}^2$
restricted, forecasting system[2]	ϕ	0.998	0.006	0.995
	b_d	0.007	0.006	−0.002
	b_r	−0.024	0.006	0.045
restricted, complete VAR[3]	b_{pp}	0.997	0.005	0.994
	b_{dd}	0.060	0.047	0.438
	b_{rr}	0.343	0.043	−0.071
	b_{dp}	0.015	0.004	0.438
	b_{rp}	−0.016	0.005	−0.071

c. Variance Decompsition and Long Run Coefficients[4]

T	60	65	70	75
$\frac{b_d}{1-\rho\phi} = b_d^{lr}$		0.23(0.17)		
$\frac{b_r}{1-\rho\phi} = b_r^{lr}$		−0.78(0.17)		
$\frac{b_{dp}}{1-\rho b_{pp}} = b_d^{lr}$		0.47(0.13)		
$\frac{b_{rp}}{1-\rho b_{pp}} = b_r^{lr}$		−0.50(0.13)		
$\frac{cov\left[p_t-d_t, \sum_{j=0}^{T} \rho^{j-1}(d_{t+j+1}-d_{t+j})\right]}{var(p_t-d_t)}$	0.45	0.44	0.38	0.22
$\frac{cov\left[p_t-d_t, \sum_{j=0}^{T} \rho^{j-1} r_{t+j+1}\right]}{var(p_t-d_t)}$	−0.35	−0.40	−0.50	−0.66
$\frac{e_t}{var(p_t-d_t)}$	0.20	0.16	0.12	0.12

Notes:

1. **Forecasting regressions:**
Dividend growth forecasting

$$d_{t+H} - d_t = a + b(p_t - d_t) + e_t$$

Return forecasting

$$r_{t+H} = a + b(p_t - d_t) + e_t$$

where:

$$r_{t+H} = r_{t+1} + r_{t+2} + ... + r_{t+H}$$

The table reports results for $H = 1, 4, 8, 12, 16, 20$.
2. **Restricted, forecasting system** given by:

$$\begin{aligned} (p_{t+1} - d_{t+1}) &= a + \phi(p_t - d_t) + e_{p,t} \\ d_{t+1} - d_t &= c + b_d(p_t - d_t) + e_{d,t} \\ r_{t+1} &= d + b_r(p_t - d_t) + e_{r,t} \end{aligned}$$

The restriction is:

$$b_d - b_r = 1 - \rho\phi$$

where

$$\rho = \frac{\frac{P}{D}}{1 + \frac{P}{D}}$$

and P, D are sample average values.
3. **Restricted, complete VAR**:
Using $z_t = \begin{pmatrix} p_t - d_t \\ d_t - d_{t-1} \\ r_t \end{pmatrix}$, with the variables de-meaned
$e_1 = (1, 0, 0)$
$e_2 = (0, 1, 0)$
$e_3 = (0, 0, 1)$
$\underline{\varepsilon}_t = \begin{pmatrix} \varepsilon_{1_t} \\ \varepsilon_{2_t} \\ \varepsilon_{3_t} \end{pmatrix}$
The VAR is:

$$z_{t+1} = Bz_t + \underline{\varepsilon}$$

where:

$$B = \begin{pmatrix} b_{pp} & b_{pd} & b_{pr} \\ b_{dp} & b_{dd} & b_{dr} \\ b_{rp} & b_{rd} & b_{rr} \end{pmatrix}$$

The restrictions are:

$$e_1(I - \rho B) - (e_2 - e_3)\, B = 0$$

4. Variance Decomposition and Long Run Coefficients

a. b_d, b_r, ϕ , b_{dp}, b_{rp}, b_{pp} taken from panel b. Standard errors are computed using the delta method.

b. T varies according to the values indicated in the top row.

Table 9
Net Hiring Growth Decomposed

$$\frac{n_{t+1}-n_t}{n_t} = (1-\lambda_t)A\left(e_1\frac{g_{h_t}}{\frac{f_t}{n_t}} - e_3\frac{g_{i_t}}{\frac{f_t}{k_t}}\right)$$

Full Sample

		$\frac{n_{t+1}-n_t}{n_t}$		1 $(1-\lambda_t)Ae_1\frac{g_{h_t}}{\frac{f_t}{n_t}}$	2 $-(1-\lambda_t)Ae_3\frac{g_{i_t}}{\frac{f_t}{k_t}}$
1	mean	0.001	relative mean	0.72	0.28
2	std	0.005	relative var	0.41	0.19
3			relative cova	0.20	

First Sub-Period
1976 – 1995

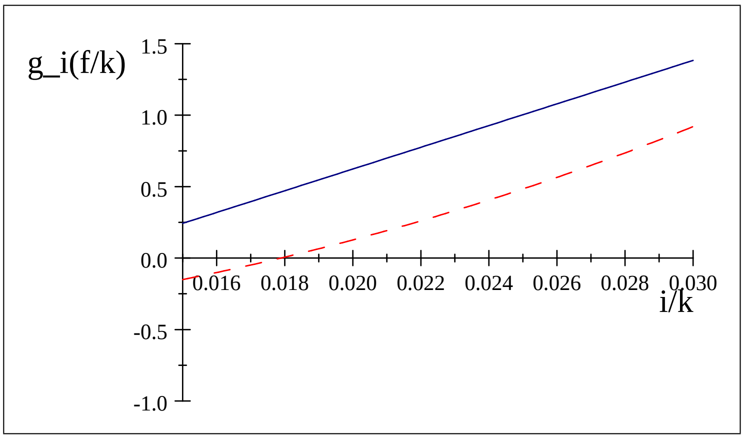
		$\frac{n_{t+1}-n_t}{n_t}$		1 $(1-\lambda_t)Ae_1\frac{g_{h_t}}{\frac{f_t}{n_t}}$	2 $-(1-\lambda_t)Ae_3\frac{g_{i_t}}{\frac{f_t}{k_t}}$
1	mean	0.002	relative mean	0.81	0.19
2	std	0.005	relative var	0.54	0.08
3			relative cova	0.19	

Second Sub-Period
1996 – 2011

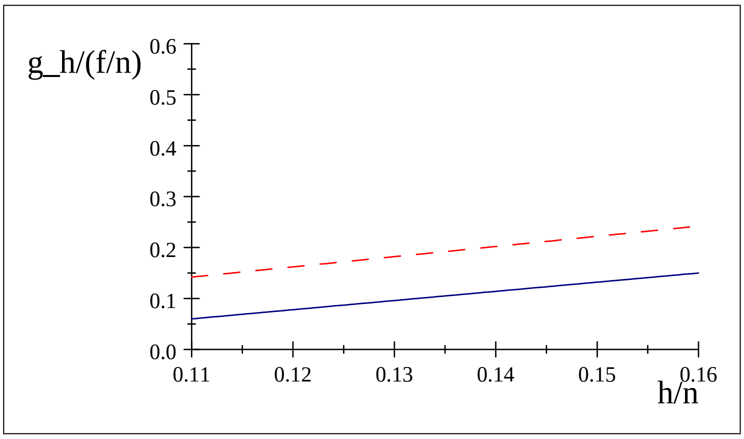
		$\frac{n_{t+1}-n_t}{n_t}$		1 $(1-\lambda_t)Ae_1\frac{g_{h_t}}{\frac{f_t}{n_t}}$	2 $-(1-\lambda_t)Ae_3\frac{g_{i_t}}{\frac{f_t}{k_t}}$
1	mean	0.0004	relative mean	0.26	0.74
2	std	0.005	relative var	0.20	0.34
3			relative cova	0.23	

Figure 1
The Estimated Marginal Costs Functions

a. marginal investment costs $\frac{g_i}{f/k}$



b.marginal hiring costs $\frac{g_h}{f/n}$



Notes:

1. The graphs uses the point estimates of Rows 3 and 4 in Table 4a to plot $\frac{g_{i_t}}{\frac{f_t}{k_t}}$ as a function of $\frac{i_t}{k_t}$ and $\frac{g_{h_t}}{\frac{f_t}{n_t}}$ as a function of $\frac{h_t}{n_t}$.

2. The red line (dashed) uses row 3 estimates and the blue line uses row 4 estimates.

3. In (a) average sample values are used for $\frac{h_t}{n_t}$ and in (b) average sample values are used for $\frac{i_t}{k_t}$.

Figures 2 appear within Table 6 above

Figure 3
Job Less Recoveries

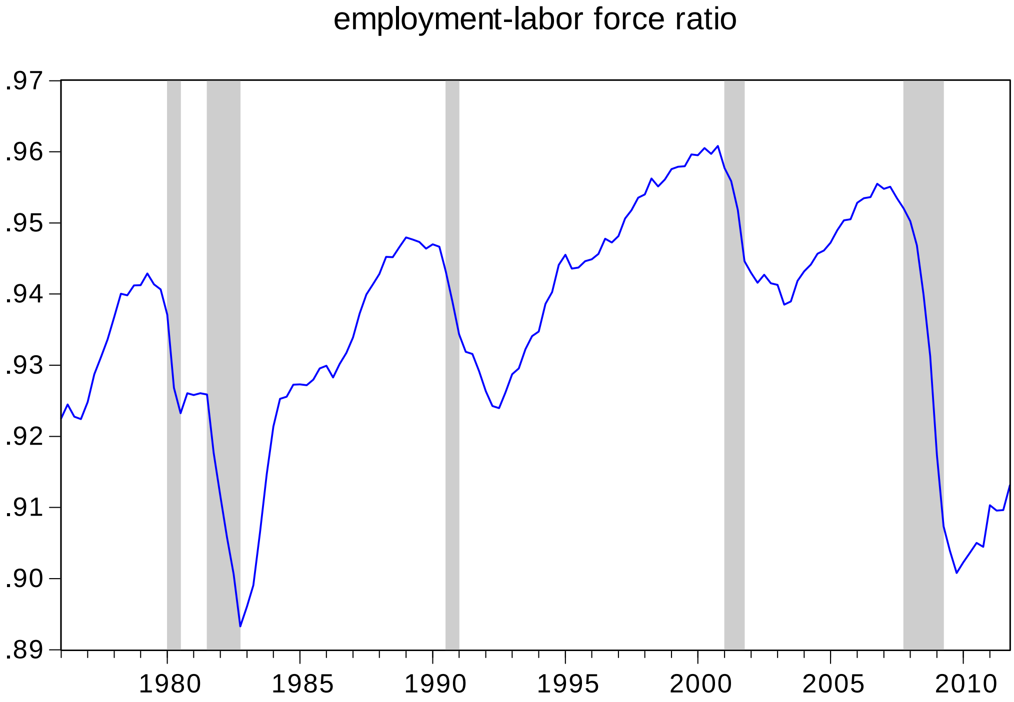


Figure 3a: $\frac{n}{n+u}$**ratio**

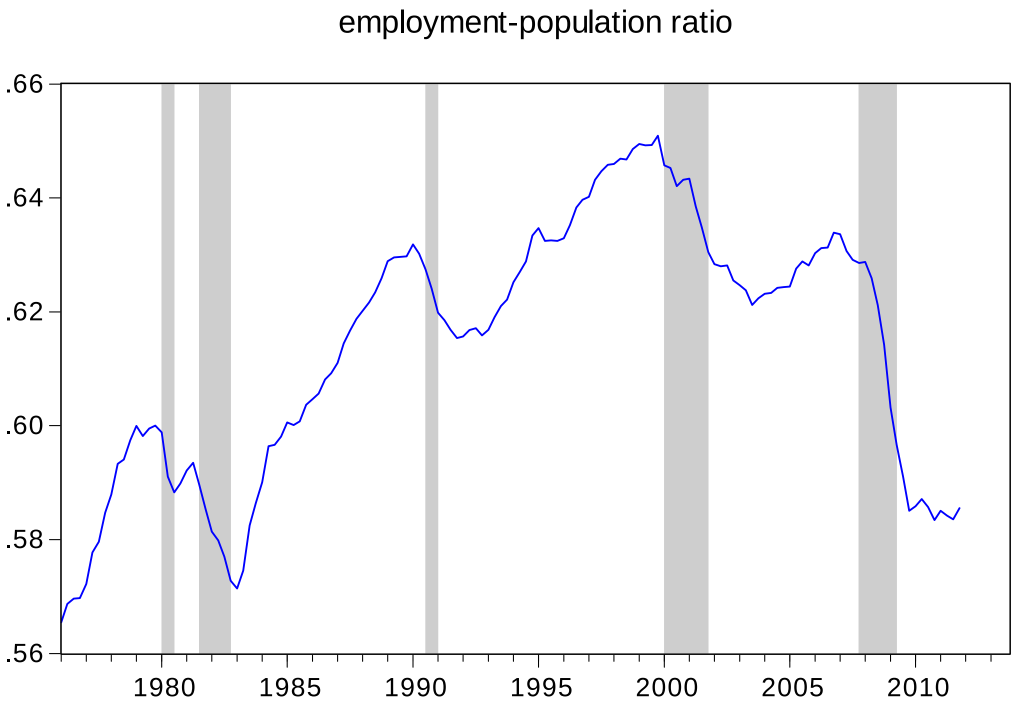


Figure 3b: $\frac{n}{POP}$ **ratio**

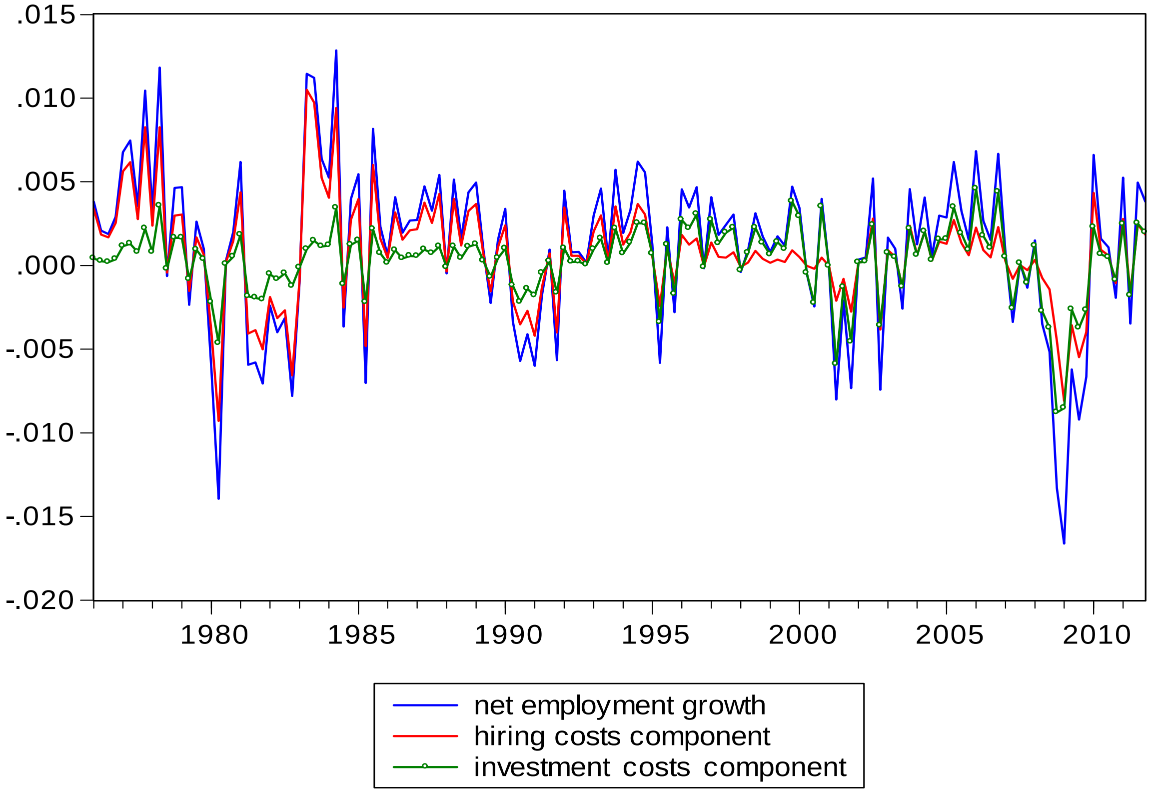


Figure 3c: Net employment growth decomposed

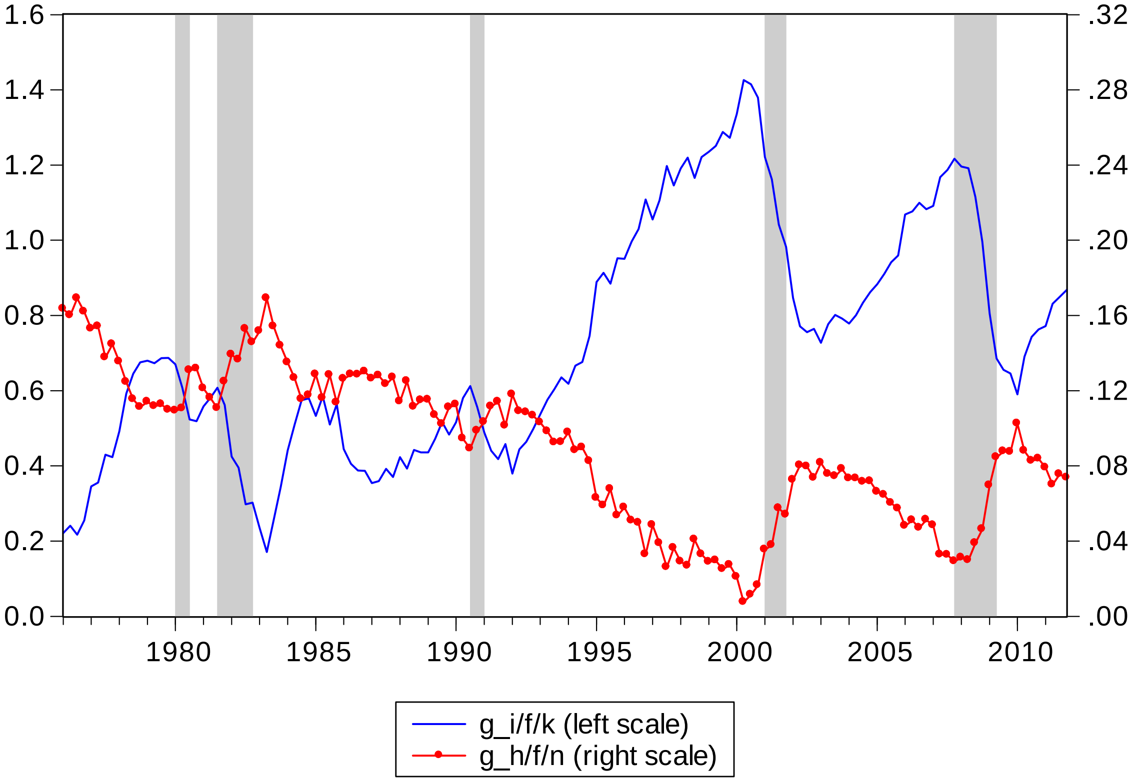


Figure 3d: Marginal costs of investment and hiring

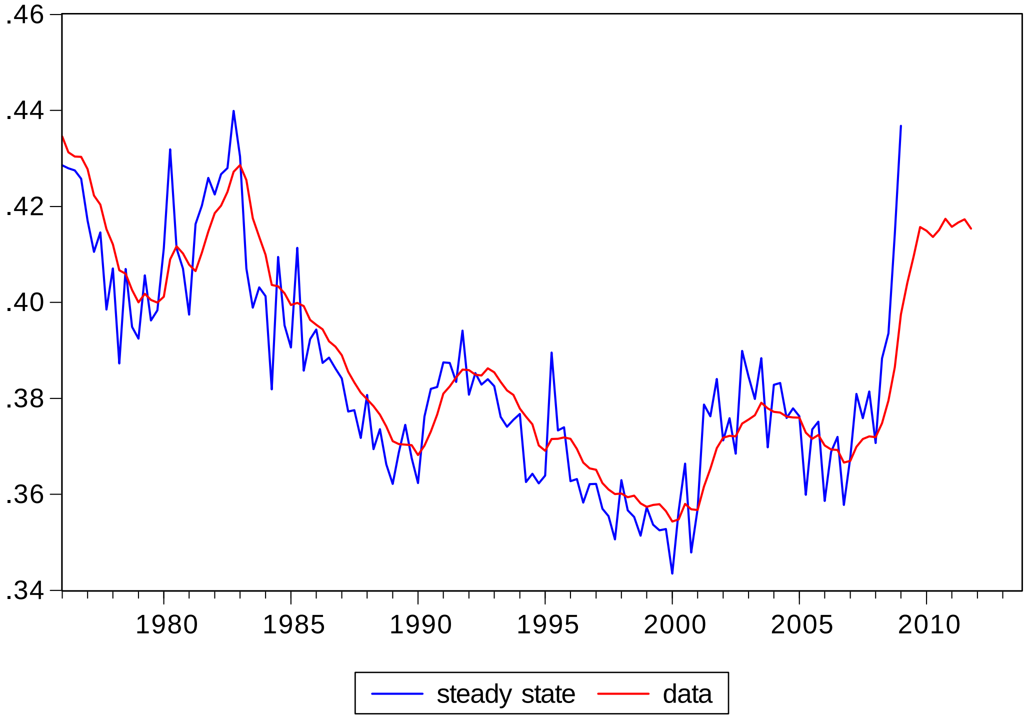


Figure 3e: Non Employment Rate