On The Joint Behavior of Hiring and Investment

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- Costs of adjustment – important for NK models; future real marginal costs drive inflation in the NKPC.
- Hiring costs – a crucial ingredient in search and matching models; search costs for firms.
- Investment costs – Tobin's Q approach, important for capital investment and financial markets.

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- Examples: search and matching models with no capital; Q models with no labor.
- Even business cycle models (CEE, JPE 2005; SW, AER 2007) feature adj. costs of K only.
- All too often empirical work has reported weak results.

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- Explicit modelling of the interaction of adjustment costs on K and N
- In previous work (Merz and Yashiv, AER 2007) it was shown useful for explaining asset (stock) prices

Structure of the Presentation

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- Conclusions

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- Investment seems to be driven mostly by variables that serve to discount future streams.
- Hiring depends mostly on labor profitability.
- Costs crucially depend on the interaction between the two activities and are convex in their rates.

Business Cycle Facts

- Graphs with NBER recession dates

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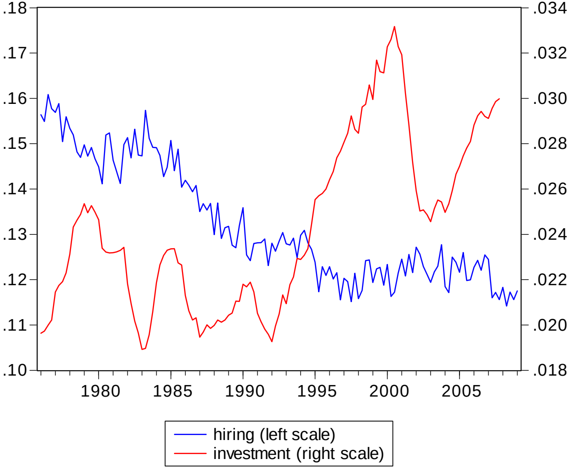
- Second moments (logged, HP filtered)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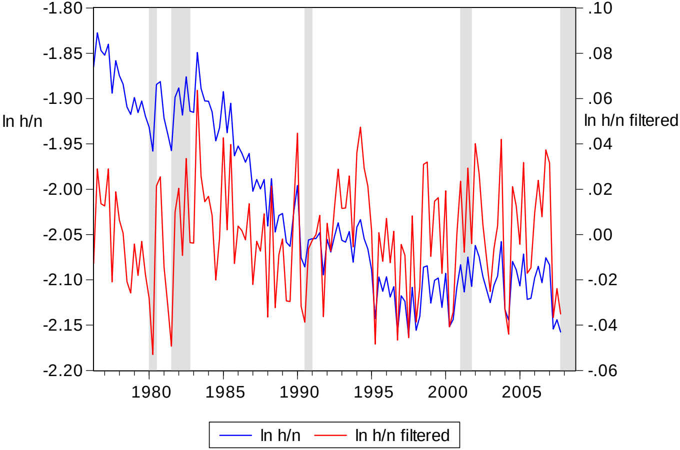
hiring (left scale)
investment (right scale)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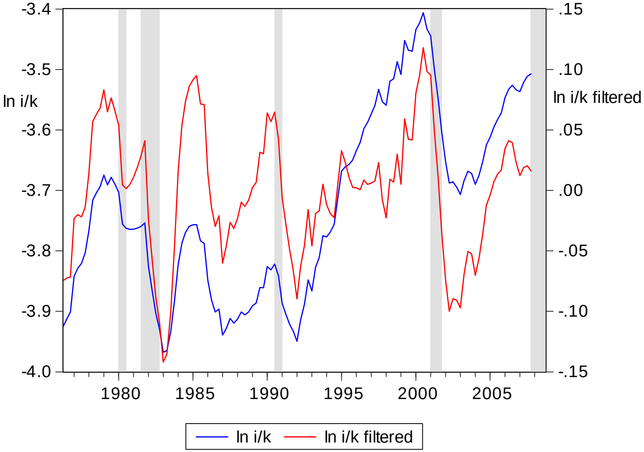
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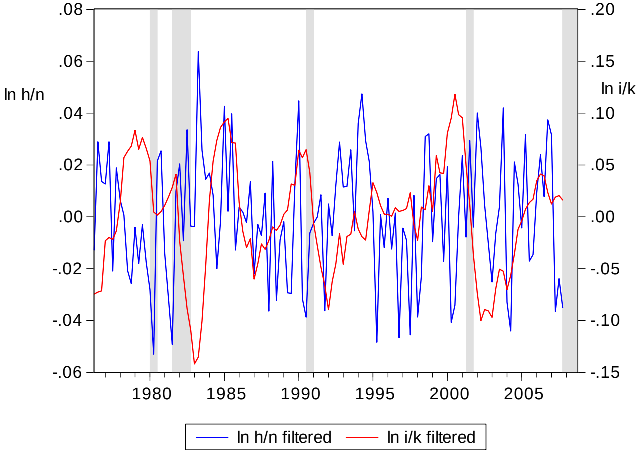
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- levels h, i and rates $\frac{h}{n}, \frac{i}{k}$
- three cyclical measures: GDP f, labor productivity $\frac{f}{n}$, capital productivity $\frac{f}{k}$

a. Volatility and Relative Volatility

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

b. Persistence

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

c. Co-Movement

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

-12	-8	-4	-1	0	1	4	8	12
-0.03	0.10	0.02	-0.15	-0.15	-0.18	-0.07	-0.10	-0.0

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

	-12	-8	-4	-1	0
f	-0.13	-0.10	-0.12	-0.27	-0.20
$\frac{f}{n}$	-0.14	-0.07	0.00	-0.08	-0.03
$\frac{f}{k}$	-0.15	-0.12	-0.13	-0.25	-0.17

	0	1	4	8	12
f	-0.20	-0.16	0.00	0.08	0.03
$\frac{f}{n}$	-0.03	-0.07	0.00	0.02	-0.05
$\frac{f}{k}$	-0.17	-0.13	0.02	0.10	0.03

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

	-12	-8	-4	-1	0
f	-0.40	-0.23	0.46	0.83	0.80
$\frac{f}{n}$	-0.32	0.07	0.61	0.62	0.52
$\frac{f}{k}$	-0.36	-0.10	0.58	0.84	0.76

	0	1	4	8	12
f	0.80	0.66	0.05	-0.32	-0.25
$\frac{f}{n}$	0.52	0.34	-0.27	-0.43	-0.08
$\frac{f}{k}$	0.76	0.57	-0.11	-0.43	-0.27

But note difference between hiring rates and other labor market variables

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

moment	n_t	h_t	$\frac{h_t}{n_t}$	$\frac{h_t}{u_t+o_t}$
std	0.0126	0.0238	0.0244	0.0290
relative std to GDP f	0.62	1.18	1.21	1.44
relative std to $\frac{f}{n}$	1. 03	1.94	1.99	2. 37

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

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

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- $$y_t = f(z_t, n_t, k_t), \tag{1}$$
- $$k_{t+1} = (1 - \delta_t)k_t + i_t, \quad 0 \leq \delta_t \leq 1. \tag{2}$$
  $$n_{t+1} = (1 - \psi_t)n_t + h_t, \quad 0 \leq \psi_t \leq 1. \tag{3}$$

- $$\pi_t = [f(z_{t,} n_t, k_t) - g(i_t, k_t, h_t, n_t)] - w_t n_t \,. \tag{4}$$
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- $$\max_{\{i_{t+j}, h_{t+j}\}} E_t \left\{ \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} \beta_{t+i} \right) cf_{t+j} \right\} \qquad (6)$$

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- The firm takes the variables w, p^I, δ, ψ, and β as given.

- F.O.C.

$$(1-\tau_t)\left(g_{i_t}+p_t^I\right) = E_t\left\{\begin{array}{c}\beta_{t+1}(1-\tau_{t+1}) \\ \left[\begin{array}{c} f_{k_{t+1}}-g_{k_{t+1}} \\ +(1-\delta_{t+1})(g_{i_{t+1}}+p_{t+1}^I)\end{array}\right]\end{array}\right\} \quad (7)$$

$$(1-\tau_t)\,g_{h_t} = E_t\left\{\begin{array}{c}\beta_{t+1}(1-\tau_{t+1}) \\ \left[\begin{array}{c} f_{n_{t+1}}-g_{n_{t+1}}-w_{t+1} \\ +(1-\psi_{t+1})g_{h_{t+1}}\end{array}\right]\end{array}\right\}. \quad (8)$$

Present values

- $$Q_t^K = E_t \left\{ \begin{array}{c} \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} \beta_{t+1+i} \right) \left(\prod_{i=0}^{j} (1-\delta_{t+1+i}) \right) \\ (1-\tau_{t+1+j}) \left(f_{k_{t+1+j}} - g_{k_{t+1+j}} \right) \end{array} \right\}. \quad (9)$$

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- $$Q_t^N = E_t \left\{ \begin{array}{c} \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} \beta_{t+1+i} \right) \left(\prod_{i=0}^{j} \left(1 - \psi_{t+1+i}\right) \right) \\ \left(1 - \tau_{t+1+j}\right) \left(f_{n_{t+1+j}} - g_{n_{t+1+j}} - w_{t+1+j} \right) \end{array} \right\}. \tag{10}$$

Estimation

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- $$g(\cdot) = \left[\begin{array}{c} \frac{e_1}{\eta_1}\left(\frac{i_t}{k_t}\right)^{\eta_1} \\ +\frac{e_2}{\eta_2}\left(\frac{h_t}{n_t}\right)^{\eta_2} \\ +\frac{e_3}{\eta_3}\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3} \end{array} \right] f(z_t, n_t, k_t). \qquad (12)$$

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- In addition to the purchase costs, **investment** involves capital installation costs, learning the use of new equipment, etc.
- Adjusting labor or capital involves disruptions to production.
- Potentially also the implementation of new organizational structure within the firm and new production practices.

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3. Allows for interaction $\frac{e_3}{\eta_3}\left(\frac{i_t}{k_t}\frac{h_t}{n_t}\right)^{\eta_3}$
4. Special cases: Pissarides model $e_2 h_t \frac{f_t}{n_t}$

   Tobin's Q models $\frac{e_1}{2}\frac{i_t^2}{k_t}\frac{f_t}{k_t}$

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- Formulating the costs as a function of these efforts and putting them in terms of output per worker: $c\left(\frac{h}{n}\right)\frac{f}{n}$
- As n workers do it then the aggregate adjustment cost function is $c\left(\frac{h}{n}\right) f$.

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- They include $f, k, n, i, h, \beta, w, \delta, \psi, p^I, \tau$

- These data have the following features:

(i) They pertain to the U.S. private sector, thus not confounding the analysis with government hiring and investment.
(ii) Both hiring h and investment i refer to **gross** flows.
Likewise, separation of workers ψ and depreciation for capital δ are gross measures.
(iii) The estimating equations take into account taxes and rules regarding depreciation.

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- Points (ii) and (iii) require a substantial amount of computation, which is explained in the data appendix.

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4. derive the implications for the joint behavior of hiring and investment, including cyclical behavior

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3. Interaction between costs

- Table 4, panel a, fixed powers, including standard specifications
- Table 4, panel b, free powers to be estimated

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- Column 2 takes the standard case of the investment literature, only quadratic costs for adjusting capital ($e_2 = e_3 = 0; \eta_1 = 2$);
- Column 3 takes the standard case of the search and matching literature – linear hiring costs ($e_1 = e_3 = 0; \eta_2 = 1$);

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- Columns 2-4 consider standard specifications
- Column 2 takes the standard case of the investment literature, only quadratic costs for adjusting capital $(e_2 = e_3 = 0; \eta_1 = 2)$;
- Column 3 takes the standard case of the search and matching literature – linear hiring costs $(e_1 = e_3 = 0; \eta_2 = 1)$;
- Column 4 allows both types of costs but no interaction term $(\eta_1 = \eta_2 = 2; e_3 = 0)$.

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- Column (2) yields costs that are twice as high as those reported in column (1), for both total and marginal costs.
- The J-statistic test rejects the specification of column (3).
- Column (4) yields negative marginal investment costs.

- Table 4, panel b, free powers (with or without restrictions).

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- In what follows, I use the no parameter restrictions case (column 9) as the second benchmark specification.

The Joint Behavior of Hiring and Investment

Implications of the estimates:

1. Value of adjustment costs

The Joint Behavior of Hiring and Investment

Implications of the estimates:

1. Value of adjustment costs
2. Present value decomposition

The Joint Behavior of Hiring and Investment

Implications of the estimates:

1. Value of adjustment costs
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3. Co-movement analysis

The Joint Behavior of Hiring and Investment

Implications of the estimates:

1. Value of adjustment costs
2. Present value decomposition
3. Co-movement analysis
4. Business cycle analysis

The Value of Adjustment Costs

- *Total costs* as a fraction of GDP (i.e. $\frac{g}{f}$) are around 2% of output

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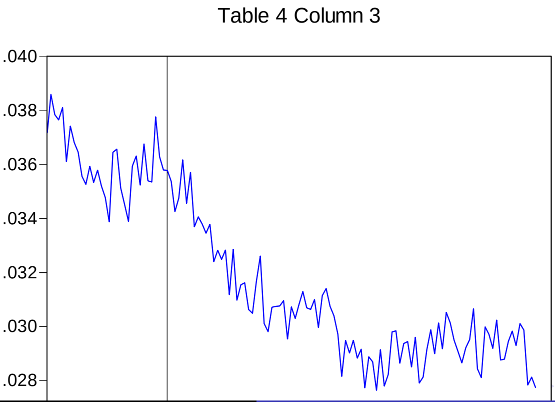
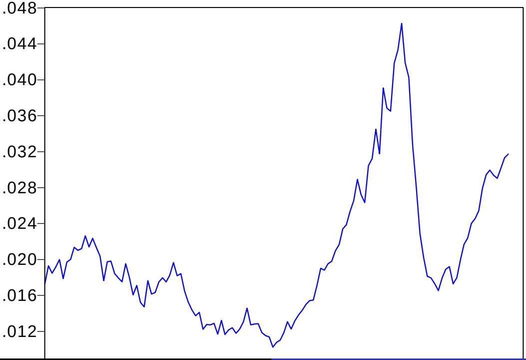


- Bad news

Table 4 Column 9



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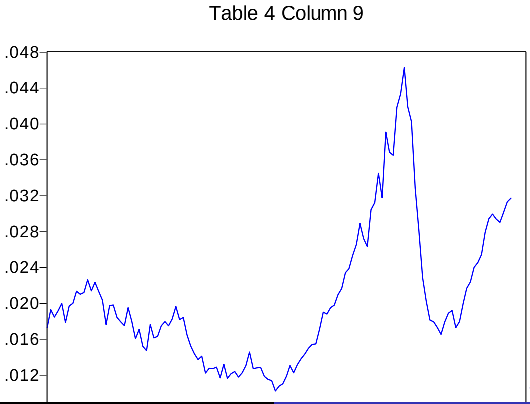

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- In other words, firms pay on the margin the equivalent of about **4 weeks of wages** to hire the worker.

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- The widely-cited Shimer (AER 2005) paper calibrates these costs at 0.213, **3 weeks of wages**
- Hagedorn and Manovskii (AER 2008): 0.057 to 0.067 in current terms or **1.1 to 1.3 weeks of wages.**

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- The results of column (9) somewhat higher (0.14 vs 0.07) than those suggested by Mortensen and Nagypal (2006) or Hagedorn and Manovskii (AER 2008).

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- The most natural place to look for comparisons is the Q-literature.
- The equation links the investment-to-capital ratio to a measure of Tobin's Q.
- These studies differ from each other and from the current study on many dimensions: the data sample used, the functional form assumed for marginal adjustment costs, additional variables included in the cost function, treatment of tax issues, and reduced form vs. structural estimation.

Nine key studies:

- (i) *High adjustment costs.* 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.

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- Shapiro 1986, Gilchrist and Himmelberg 1995, 1998.

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- Hubbard et al 1995, Barnett and Sakellaris 1999, Hall 2004, Cooper and Haltiwanger 2006, Cooper, Haltiwanger and Willis 2010.

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- This is the specification positing a quadratic function and ignoring labor.
- The implied total costs are 4.2% of output (as in studies of the moderate adjustment costs set).
- The implied marginal costs are 3.36 of average output per unit of capital (as in the high adjustment costs set).

- (ii) The GMM results of the full model cannot be directly compared to the results of Table 5.

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- Nevertheless, the findings of the benchmark run: total adjustment costs $(\frac{g}{f})$, estimated at 2%; marginal costs $(\frac{g_i}{\frac{f}{k}})$, estimated at a mean of 1.2 or 2
- corresponds to the second set, i.e., moderate adjustment costs.

Decomposition of the Present Values of Investment and Hiring

- Asset pricing approach – Campbell, Shiller, Cochrane

$$\begin{aligned} P_t &= E_t\left(R_{t+1}^{-1}[D_{t+1}+P_{t+1}]\right) \\ \frac{P_t}{D_t} &= E_t\left(R_{t+1}^{-1}[\frac{D_{t+1}}{D_t}+\frac{D_{t+1}}{D_t}\frac{P_{t+1}}{D_{t+1}}]\right) \end{aligned} \tag{13}$$

- Log-linear approximation:

$$p_t - d_t = k + E_t \left(d_{t+1} - d_t - r_{t+1} + \rho (p_{t+1} - d_{t+1}) \right) \qquad (14)$$

- Iterating forward:

$$p_t - d_t \simeq \sum_{j=1}^{\infty} \rho^{j-1} k + E_t \left[\sum_{j=1}^{\infty} \rho^{j-1} \left(d_{t+j+1} - d_{t+j} - r_{t+j} \right) \right] \tag{15}$$

- In variance terms (ex-post):

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

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

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

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

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

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- $\rho = \frac{\frac{P}{D}}{1+\frac{P}{D}}$ acts as a discount factor
- e_t due to approximation and truncation

T	20	30	40	50
n	105	95	85	75
investment				
ρ^T	0.56	0.41	0.31	0.23
$\frac{e}{var(p_t - d_t)}$	0.67	0.50	0.12	-0.04

T	20	30	40	50
$\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1}(d_{t+j+1} - d_{t+j})\right]}{var(p_t - d_t)}$	0.19	0.23	0.20	0.19
$\frac{cov\left[p_t - d_t, \sum_{j=1}^{T} \rho^{j-1} r_{t+j}\right]}{var(p_t - d_t)}$	-0.14	-0.27	-0.68	-0.85

hiring				
T	20	30	40	50
ρ^T	0.03	0.005	0.0008	0.0001
$\frac{e}{varP/D}$	0.25	0.42	0.36	0.38
$\frac{cov\left[p_t-d_t,\sum_{j=1}^{T}\rho^{j-1}(d_{t+j+1}-d_{t+j})\right]}{var(p_t-d_t)}$	0.64	0.59	0.69	0.65
$\frac{cov\left[p_t-d_t,\sum_{j=1}^{T}\rho^{j-1}r_{t+j}\right]}{var(p_t-d_t)}$	-0.11	0.01	0.05	0.04

- (i) The relative error variance decreases monotonically with T for the investment equation (from around 0.65 to around 0) but changes non-monotonically for the hiring equation.

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- As T changes the sample size changes and so does the variance of the error and of the log price-dividend ratio.

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

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

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

Standard Deviations of Present Value Components

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

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- Note that $\partial i_t / \partial Q^k$ and $\partial h_t / \partial Q^n$ are positive due to convexity.
- Hence, when the marginal value of investment Q^K rises, both investment and hiring rise.
- A similar argument shows that they both rise when the marginal value of hiring Q^N rises.

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- Similarly, for given levels of hiring, total and marginal costs of hiring decline as investment increases.
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- 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.

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- $$\frac{g(0,\frac{h}{n})+g(\frac{i}{k},0)-g(\frac{i}{k},\frac{h}{n})}{g(\frac{i}{k},\frac{h}{n})}$$
- The statistic measures how much – in percentage terms – is simultaneous investment and hiring cheaper than non-simultaneous action.

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

Elasticities

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

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- Hiring is relatively inelastic with respect to its present value Q^N (an elasticity of about 0.3 to 0.4).
- The cross elasticities are very low for investment w.r.t Q^N (an elasticity of around 0.04-0.08) and moderate for hiring w.r.t Q^K (0.25 to around unitary elasticity).

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- The afore-going argument favors simultaneous hiring and investment, i.e., positive levels of both $(\frac{i}{k}, \frac{h}{n} > 0)$.
- Thus the representative firm is hiring and investing at the same time.
- But it does **not** necessarily imply highly positive co-movement or correlation between hiring and investment.
- In other words investment and hiring take place at the same time, but it is possible to have one rise while the other rises, stays the same or even declines.

- Suppose Q^K rises and Q^N declines at the same time.

- Suppose Q^K rises and Q^N declines at the same time.
- The rise in Q^K will lead to higher investment and higher hiring, while the fall in Q^N will lead to lower investment and lower hiring

A 1 std deviation rise in Q^K and fall in Q^N

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

Investment rises by 21% to 26% while hiring rises by only 2%.

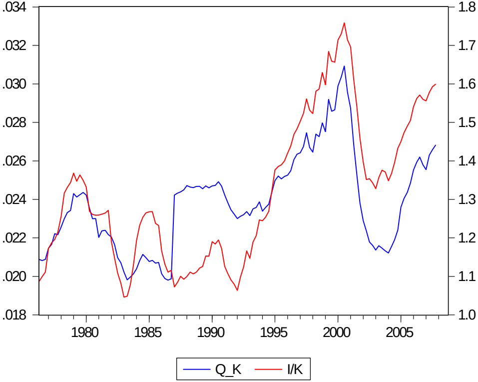

Figure 2a: $\frac{i}{k}$(left axis), Q^K (right axis)

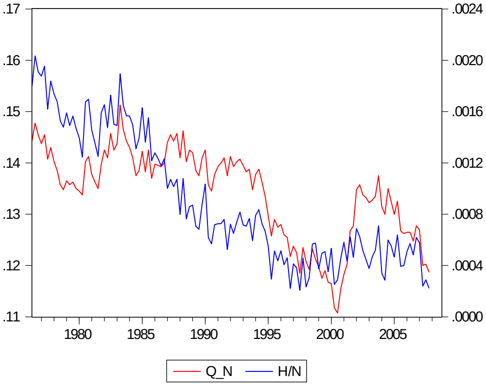

Figure 2b: $\frac{h}{n}$(left axis), Q^N (right axis)

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

- It should be noted that Q^N estimated using either linear hiring costs with no capital or using quadratic investment and hiring costs but no interaction between them are *negatively* correlated with the series reported here.

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- Indeed, in the sample period these estimated Q^N go up for the most part, in a way which is inconsistent with the behavior of the hiring rate.

- It should be noted that Q^N estimated using either linear hiring costs with no capital or using quadratic investment and hiring costs but no interaction between them are *negatively* correlated with the series reported here.
- Indeed, in the sample period these estimated Q^N go up for the most part, in a way which is inconsistent with the behavior of the hiring rate.
- Hence prevalent specifications – linear hiring costs or no interaction between hiring and investment costs – yield poor results.

Hiring and Investment Over the Business Cycle

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

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- Investment and hiring rates follow the same pattern of cross correlations as do the marginal costs on that activity and its marginal Q.
- Hence the model shows that the costs and benefits of investment and hiring – equal at the margin – behave cyclically in the way investment and hiring themselves.

Conclusions

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- This has to do with the differential relations with the relevant components of the present values driving these decisions.
- The present value of investment is pro-cyclical while that of hiring counter-cyclical.
- Investment seems to be driven mostly by variables that serve to discount future streams while hiring depends mostly on labor profitability.
- Costs crucially depend on the interaction between the two activities and are convex in their rates.

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