Aggregate Hours Adjustment in Frictional Labor Markets

Michael Krause
Deutsche Bundesbank

Thomas Lubik
Federal Reserve Bank of Richmond

Freie Universität Berlin

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Introduction

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• The aim of this paper is to explain this pattern in the real business cycle extension of the search and matching model, which includes both the extensive and intensive margins

• In the search and matching model with both margins:
  – employment adjustment is costly and subject to frictions
  – In response to shocks, firms instantaneously increase output by raising hours per employed worker
  – over time, demand is met by increasing employment
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  – hours per worker are too volatile relative to employment
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  – however, calibrations and shocks that help resolve the labor market volatility puzzle do not help fix this “hours puzzle”
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  – the correlation of hours and employment tents to be too high
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Outline

- Stylized facts
- Baseline RBC model with search frictions in the labor market
- Mechanisms and puzzles: the hours and employment margins
- Calibration and Simulation
- Exploring solutions: shocks and parameters
- Outlook and conclusions
Data

• Measures of hours worked and its components: average hours per worker times employment divided by the civilian labor force

• Establishment survey: 1964:1 to 2007:4
  – based on payroll data
  – employment numbers fairly exact; hours per worker not so much

• Household survey: 1976:1 to 2007:4
  – based on survey responses
  – both series imprecise, but cover all workers
Hours and Employment, Establishment Survey (red: hours per worker, blue: total hours, green: employment)
Hours and Employment, Household survey
The data

Table 1: Measures of Hours Worked

<table>
<thead>
<tr>
<th></th>
<th>Standard Deviation (%)</th>
<th>Correlation (N,H)</th>
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<tbody>
<tr>
<td></td>
<td>Total Hours</td>
<td>Employment</td>
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<tr>
<td>Data Set 1</td>
<td>1.55</td>
<td>1.28</td>
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<tr>
<td>Data Set 2</td>
<td>1.19</td>
<td>0.74</td>
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</table>
Table 2: Business Cycle Statistics

<table>
<thead>
<tr>
<th>Standard Deviation (%)</th>
<th>U</th>
<th>V</th>
<th>V/U</th>
<th>W</th>
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<tbody>
<tr>
<td></td>
<td>7.71</td>
<td>9.36</td>
<td>16.76</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>TH</td>
<td>I</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>1.10</td>
<td>4.86</td>
<td>1.41</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Correlation</th>
<th>(U,V)</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.93</td>
<td>0.72</td>
<td>0.71</td>
<td>0.72</td>
</tr>
</tbody>
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The Data

• Total hours about as volatile as output
• Hours per worker explain 33% to 50% of total hours variation
• Employment and hours are positively correlated
The Data

- Total hours about as volatile as output
- Hours per worker explain 33% to 50% of total hours variation
- Employment and hours are positively correlated

- High volatilities of vacancies, unemployment, and tightness
- Wages and hours are less volatile than output
- Hours positively correlated with wages, total hours, and output.
The model


- Aggregate household with continuum of workers, utility from bundle of consumption goods and hours worked, perfect risk sharing

- Monopolistically competitive firms with flexible prices, capital accumulation and investment adjustment costs
The model

- Aggregate household with continuum of workers, utility from bundle of consumption goods and hours worked; perfect risk sharing
- Monopolistically competitive firms with flexible prices, capital accumulation and investment adjustment costs
- Frictional labor market: matching function, hiring time-consuming
- Nash bargaining over wages and hours
- Shocks: technology, markup, labor supply, intertemporal preference, investment-specific technology, matching
Households

- Welfare of household

\[ W(N_{it}) = \max_{C_{it}} E_\tau \sum_{t=0}^{\infty} \beta^t \zeta_t \left[ \frac{C_{it}^{1-\sigma} - 1}{1 - \sigma} - \chi_t N_{it} \frac{H_{it}^{1+\mu}}{1 + \mu} \right] \]

- Budget constraint

\[ W_t H_{it} N_{it} + (1 - N_{it}) b + D_{it} + r_t K_{it-1} = T_t + I_{it} + C_{it} \]

- Capital accumulation (rented to firms)

\[ K_{it} = (1 - \delta) K_{it-1} + \psi_t I_{it} \left( 1 - S \left( \frac{I_{it}}{K_{it}} \right) \right) \]

- Consumption aggregate

\[ C_{it} = \left( \int_0^1 C_{it,j} \frac{\epsilon_{t-1}}{\epsilon_t} dj \right)^{\frac{\epsilon_t}{\epsilon_t - 1}} \]

- Yields: Euler equation, Q-theoretical equation, goods demand
Firms

• Present value of profits

\[ \mathcal{J} j(N_t) = E_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \left[ \left( \frac{P_{jt}}{P_t} \right)^{1-\epsilon} Y_t - W_{jt}N_{jt}H_{jt} - r_t K_{jt} - c(V_{jt}) \right], \]

• Demand for product

\[ Y_{jt} = \left( \frac{P_{jt}}{P_t} \right)^{-\epsilon_t} Y_t, \]

• Production function (capital rented from households)

\[ Y_{jt} = A_t K_{jt}^{1-\alpha} (H_{jt}N_{jt})^\alpha, \]

• Employment evolution (\( \rho \) constant)

\[ N_{jt} = (1 - \rho) \left[ N_{jt-1} + V_{jt-1}q(\theta_{t-1}) \right], \]

• Matching function \( M_t = V_t q(\theta_t) = m_tU_t^\xi V_t^{1-\xi}, \) with \( \theta_t = V_t/U_t \)
Bargaining over wage and hours

- Wages and hours chosen to maximize

\[
\left( \frac{1}{\lambda_t} \frac{\partial W_t(N_t)}{\partial N_t} \right)^\eta \left( \frac{\partial J_t(N_t)}{\partial N_t} \right)^{1-\eta}
\]

Bargaining yields a wage equation

\[
W_tH_t = \eta \phi_t \alpha \frac{Y_t}{N_t} + (1 - \eta) \left( b + \frac{C_t \chi_t H_t^{1+\mu}}{1 + \mu} \right) + \theta_t \eta c
\]

and an hours equation

\[
C_t \chi_t H_t^{1+\mu} = \varphi_t \alpha^2 Y_t / N_t
\]
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- Wages and hours chosen to maximize

\[
\left( \frac{1}{\lambda_t} \frac{\partial W_t(N_t)}{\partial N_t} \right)^{\eta} \left( \frac{\partial J_t(N_t)}{\partial N_t} \right)^{1-\eta}
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Bargaining yields a wage equation

\[
W_tH_t = \eta \varphi_t \alpha \frac{Y_t}{N_t} + (1 - \eta) \left( b + \frac{C_t^\sigma \chi_t H_t^{1+\mu}}{(1 + \mu)} \right) + \theta_t \eta c
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and an hours equation

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- Insert hours equation into wage equation

\[
W_tH_t = \left( \eta + (1 - \eta) \frac{\alpha}{1 + \mu} \right) \varphi_t \alpha \frac{Y_t}{N_t} + (1 - \eta) b + \theta_t \eta c
\]
Wages and job creation

- Job creation condition

\[
\frac{c}{q(\theta_t)} = (1 - \rho)E_{t+1} \beta_{t+1} \left[ \varphi_{t+1} \alpha \frac{Y_{t+1}}{N_{t+1}} - W_{t+1}H_{t+1} + \frac{c}{q(\theta_{t+1})} \right]
\]
Wages and job creation

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$$\frac{c}{q(\theta_t)} = (1 - \rho) E_t \beta_{t+1} \left[ \varphi_{t+1} \alpha \frac{Y_{t+1}}{N_{t+1}} - W_{t+1} H_{t+1} + \frac{c}{q(\theta_{t+1})} \right]$$

• Inserting the wage

$$W_t H_t = \left( \eta + (1 - \eta) \frac{\alpha}{1 + \mu} \right) \varphi_t \alpha \frac{Y_t}{N_t} + (1 - \eta) b + \theta_t \eta c$$

into job creation condition

$$\frac{c}{q(\theta_t)} = (1 - \rho) E_t \beta_{t+1}$$

$$\left[ (1 - \eta) \left( 1 - \frac{\alpha}{1 + \mu} \right) \varphi_{t+1} \alpha \frac{Y_{t+1}}{N_{t+1}} - (1 - \eta) b $$

$$- \left( \theta_{t+1} \eta c - \frac{c}{q(\theta_{t+1})} \right) \right]$$

• Analyse the responsiveness of return to posting vacancies to changes in expected variables
Why the model cannot explain labor market dynamics

• Linearized job creation condition \((\hat{\theta}_t = \hat{V}_t - \hat{U}_t)\)

\[
\xi \hat{\theta}_t = E_t \hat{\beta}_{t+1} \\
+ \frac{q(\theta)}{c} \Phi E_t \left[ \hat{\varphi}_{t+1} + \hat{Y}_{t+1} - \hat{N}_{t+1} \right] \\
- (1 - \rho) \beta [\eta q(\theta) \theta - \xi] E_t \hat{\theta}_{t+1}
\]

• with \(\Phi = (1 - \rho) \beta (1 - \eta) \left(1 - \frac{\alpha}{1+\mu}\right) \alpha \varphi \frac{Y}{N}\)

• Expected value of \(\hat{\theta}_{t+1}\) is multiplied by \(\eta q(\theta) \theta - \xi\).
Why the model cannot explain labor market dynamics

- Linearized job creation condition \( (\hat{\theta}_t = \hat{V}_t - \hat{U}_t) \)

\[
\xi \hat{\theta}_t = E_t \hat{\beta}_{t+1}
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+ \frac{q(\theta)}{c} \Phi E_t \left[ \hat{\varphi}_{t+1} + \hat{Y}_{t+1} - \hat{N}_{t+1} \right]
\]

\[-(1 - \rho) \beta [\eta q(\theta)\theta - \xi] E_t \hat{\theta}_{t+1}
\]

- with \( \Phi = (1 - \rho)\beta (1 - \eta) \left( 1 - \frac{\alpha}{1 + \mu} \right) \alpha \varphi_N^Y \)

- Expected value of \( \hat{\theta}_{t+1} \) is multiplied by \( \eta q(\theta)\theta - \xi \).

  - For plausible calibrations, this is close to zero. E.g. \( \eta = 0.5, \xi = 0.4, \) and job finding rate \( \theta q(\theta) = 0.8 \)
  - When \( \eta = 0 \), then future labor market tightness is not offset by coinciding wage increase. (Hall and Shimer)

- Expected values of \( \hat{\varphi}_{t+1}, \hat{Y}_{t+1}, \) and \( \hat{N}_{t+1} \) are multiplied by \( q(\theta)/c \)
Why the model cannot explain labor market dynamics

- Steady state job creation condition, simplified

\[
\frac{c}{q(\theta)} = B \left( (1 - \eta) [x - b] - \theta \eta c \right)
\]

or

\[
\frac{c}{q(\theta)}(1 + B \theta q(\theta) \eta) = B \left( (1 - \eta) [x - b] \right)
\]

with \( x = \left( 1 - \frac{\alpha}{1+\mu} \right) \varphi \alpha \frac{Y}{N} \) and \( B = \frac{(1-\rho)\beta}{1-(1-\rho)\beta} \).

- All depends on \( x - b \). If \( x \) close to \( b \), then \( c/q(\theta) \) very small.

- Shimer calibrated \( b \) to be about 0.5 which is about half \( x \).

- Hagedorn and Manovskii argue that \( b \) is large, close to \( x \). Then Mortensen-Pissaridies model can explain labor market volatilities.
Closing the model

• Symmetric equilibrium: individual choices equal aggregates.

• Aggregate output

\[ Y_t = C_t + I_t + cV_t \]

• Markup

\[ \varphi_t = \frac{\epsilon_t - 1}{\epsilon_t} \]

• Rental rate of capital

\[ r_t = (1 - \alpha)\varphi_t \frac{Y_t}{K_{t-1}} \]

• Investment dynamics

\[ Q_{it} = E_t\beta_{t+1}[Q_{it+1}(1 - \delta) + r_{t+1}] \]

\[ 1 = Q_{it}\psi_t \left[ \left( 1 - \Phi \left( \frac{I_{it}}{I_{it-1}} \right) \right) - \Phi' \left( \frac{I_{it}}{I_{it-1}} \right) \frac{I_{it}}{I_{it-1}} \right] \]

\[ + E_t\beta_{t+1}Q_{it+1}\psi_{t+1}\Phi' \left( \frac{I_{it+1}}{I_{it}} \right) \left( \frac{I_{it+1}}{I_{it}} \right)^2 \]
## Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.99</td>
<td>Discount Factor</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>1</td>
<td>Intertemporal substitution</td>
</tr>
<tr>
<td>$\mu$</td>
<td>1</td>
<td>labor supply elasticity</td>
</tr>
<tr>
<td>$b$</td>
<td>0.7</td>
<td>outside option of workers</td>
</tr>
<tr>
<td>$\eta$</td>
<td>0.5</td>
<td>bargaining power</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.1</td>
<td>job destruction rate</td>
</tr>
<tr>
<td>$\xi$</td>
<td>0.5</td>
<td>matching elasticity</td>
</tr>
<tr>
<td>$m$</td>
<td>0.4</td>
<td>match efficiency</td>
</tr>
<tr>
<td>$c$</td>
<td>0.05</td>
<td>cost of vacancies</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>11</td>
<td>demand elasticity</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.67</td>
<td>labor share</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.025</td>
<td>depreciation</td>
</tr>
<tr>
<td>$s$</td>
<td>0.5</td>
<td>investment adjustment</td>
</tr>
</tbody>
</table>
## Simulations

Table 4: Business Cycle Statistics: Alternative Shocks

<table>
<thead>
<tr>
<th></th>
<th>Standard Deviation (rel. to GDP)</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U  V  θ  H  TH  W  I</td>
<td>(U,V) (H,N) (H,W) (H,Y)</td>
</tr>
<tr>
<td>Data</td>
<td>7.71 9.36 16.76 0.30 1.10 0.67 4.86</td>
<td>-0.93 0.53 0.72 0.72</td>
</tr>
<tr>
<td>Tech.</td>
<td>0.39 0.46 0.75 0.30 0.32 0.76 3.14</td>
<td>-0.54 0.63 0.70 0.84</td>
</tr>
<tr>
<td>Demand</td>
<td>0.97 1.14 1.85 1.17 1.22 1.37 3.99</td>
<td>-0.52 0.79 0.92 0.94</td>
</tr>
<tr>
<td>Leisure</td>
<td>0.39 0.46 0.75 1.26 1.28 0.42 3.13</td>
<td>-0.56 0.79 -0.76 0.97</td>
</tr>
<tr>
<td>Discount</td>
<td>0.40 0.47 0.81 0.73 0.93 0.73 7.36</td>
<td>-0.73 0.58 -0.29 0.74</td>
</tr>
<tr>
<td>Invest.</td>
<td>0.28 0.32 0.60 0.85 0.86 0.82 6.83</td>
<td>-0.92 0.30 -0.42 0.65</td>
</tr>
</tbody>
</table>
Simulations

- No shock can generate realistic unemployment or vacancy volatility
- Almost all variation is due to hours per worker
- Only investment specific shock: realistic Beveridge curve
- Leisure, intertemporal, and investment shock: negative hours-wage correlation
- Matching shock delivers volatilities, but gets comovement wrong
- However, hours-employment correlation about right.
Robustness

- Results obtained under baseline calibration with elastic labor supply and moderate outside option of workers
- lower labor supply elasticity should reduce hours variation
- higher unemployment benefit should increase labor market volatility
- lower bargaining power should increase volatility
Table 5: Business Cycle Statistics: Robustness

<table>
<thead>
<tr>
<th></th>
<th>Standard Deviation (rel. to GDP)</th>
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</tr>
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<tbody>
<tr>
<td></td>
<td>U  V  θ  H  TH  W  I</td>
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<td>7.71 9.36 16.76 0.30 1.10 0.67 4.86</td>
<td>-0.93 0.53 0.72 0.72</td>
</tr>
<tr>
<td>Labor Supply</td>
<td></td>
<td></td>
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<tr>
<td>μ = 5</td>
<td>0.04 0.05 0.09 0.09 1.05 3.03</td>
<td>-0.99 0.58 0.69 0.78</td>
</tr>
<tr>
<td>μ = 0</td>
<td>0.81 5.28 5.60 0.55 0.64 0.49 3.24</td>
<td>-0.31 -0.62 -0.76 -0.27</td>
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</tbody>
</table>

Benefit

Bargaining
Table 6: Business Cycle Statistics: Robustness

<table>
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<tr>
<th></th>
<th>Standard Deviation (rel. to GDP)</th>
<th>Correlation</th>
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<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(U,V)</td>
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<tr>
<td>Benefit</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( b = 0.95 )</td>
<td>1.92 4.45 5.90 0.25 0.57 0.41 2.85</td>
<td>-0.64 -0.57 -0.53 -0.35</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>( b = 0.40 )</td>
<td>0.05 0.06 0.11 0.30 0.30 0.89 3.15</td>
<td>-0.97 0.60 0.62 0.81</td>
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<tr>
<td>Bargaining</td>
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Table 7: Business Cycle Statistics: Robustness

<table>
<thead>
<tr>
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<th>Standard Deviation (rel. to GDP)</th>
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<tr>
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<tr>
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<td></td>
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<td></td>
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<tr>
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<td>0.11</td>
</tr>
<tr>
<td>(b = 0.40)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\eta = 0.99)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.26</td>
<td>1.20</td>
<td>1.40</td>
</tr>
<tr>
<td>(\eta = 0.01)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.69</td>
<td>1.78</td>
<td>3.46</td>
</tr>
</tbody>
</table>
Understanding hours variation

• Optimal hours choice

\[ H_t = \left( \varphi_t \alpha^2 \frac{Y_t C_t^{-\sigma}}{N_t \chi_t} \right)^{\frac{1}{1+\mu}} \]

• For simplicity assume that there is no capital so that \( C_t = Y_t = A_t N_t H_t \):

\[ H_t^{\mu+\sigma} = \varphi_t A_t^{1-\sigma} \frac{1}{\chi_t N_t^\sigma} \]

• The less employment \( N \) responds to an initial shock, the more will hours \( H \) be moving

• Movements in \( N \) will reduce response of hours

• As employment rises over time, hours per worker will fall

• The more volatility in \( N_t = 1 - U_t \), the lower is volatility in \( H_t \), and the more realistic comoments
A More Formal Empirical Approach

- Calibration and simulation analysis shows that no single specific shock nor parameterization can resolve the various puzzles.
- However, each specification is able to match selected statistics.
- Likelihood-based estimation of the full model delivers a weighting scheme that reconciles the different directions.
- Consequently, we estimate the model on data for unemployment, vacancies, hours, output, and investment using Bayesian methods:
  - prior: based on baseline calibration
  - shocks: technology, mark-up, disutility, matching, investment
Results

• Estimation algorithm resolves the tension in the model in the following way:
  – low hours elasticity $\mu$ -> match relative hours volatility
  – low worker bargaining power $\eta$ and benefit $b$ -> high incentive for vacancy creation
  – important role of mark-up and matching shocks

• Estimation results are at odds with typical parameter choices and shock processes used in calibration studies

• Estimation reveals advantage of systems approach of taking models to the data
## Posterior Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Prior</th>
<th>Posterior</th>
<th>90% Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Risk Aversion</td>
<td>$\sigma$</td>
<td>1.00</td>
<td>0.60</td>
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<tr>
<td>Labor Supply Elasticity</td>
<td>$\mu$</td>
<td>1.00</td>
<td>4.92</td>
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<tr>
<td>Elast. of Matching</td>
<td>$\xi$</td>
<td>0.30</td>
<td>0.22</td>
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<tr>
<td>Scaling Factor Matching Function</td>
<td>$m$</td>
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<td>0.73</td>
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<tr>
<td>Elast. of Vacancy Cost</td>
<td>$\psi$</td>
<td>1.00</td>
<td>4.96</td>
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<tr>
<td>Vacancy Creation Cost</td>
<td>$\kappa$</td>
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<td>0.05</td>
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<tr>
<td>Bargaining Power</td>
<td>$\eta$</td>
<td>0.50</td>
<td>0.00</td>
</tr>
<tr>
<td>Worker Outside Option</td>
<td>$b$</td>
<td>0.40</td>
<td>0.09</td>
</tr>
<tr>
<td>Separation Rate</td>
<td>$\rho$</td>
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<td>0.12</td>
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<tr>
<td>Elasticity of Demand</td>
<td>$\epsilon$</td>
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<td>9.80</td>
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<tr>
<td>Input Elasticity</td>
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<td>0.64</td>
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<tr>
<td>Investment Adjustment Elasticity</td>
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<td>10.00</td>
<td>6.04</td>
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</table>

## Variance Decompositions

<table>
<thead>
<tr>
<th></th>
<th>Technology</th>
<th>Markup</th>
<th>Lab.Supply</th>
<th>Matching</th>
<th>Inv.Specific</th>
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</thead>
<tbody>
<tr>
<td>$U$</td>
<td>0.11</td>
<td>0.00</td>
<td>0.00</td>
<td>0.88</td>
<td>0.00</td>
</tr>
<tr>
<td>$V$</td>
<td>0.50</td>
<td>0.21</td>
<td>0.00</td>
<td>0.28</td>
<td>0.00</td>
</tr>
<tr>
<td>$H$</td>
<td>0.02</td>
<td>0.35</td>
<td>0.31</td>
<td>0.05</td>
<td>0.25</td>
</tr>
<tr>
<td>$Y$</td>
<td>0.72</td>
<td>0.02</td>
<td>0.02</td>
<td>0.17</td>
<td>0.06</td>
</tr>
<tr>
<td>$I$</td>
<td>0.23</td>
<td>0.05</td>
<td>0.00</td>
<td>0.00</td>
<td>0.72</td>
</tr>
</tbody>
</table>
Conclusions

• Attempt to match stylized facts about hours and employment when there are search and matching frictions in the labor market

• In the data, 30% to 50% of total hours variation is due to variation in hours per worker.
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- We find that the model predicts almost all variation in total hours is due to variation in hours per worker.

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• Estimation basically imposes real wage rigidity, but requires atypical parameter values

• Further work: contemporaneous hiring, overtime and effort, wage setting assumptions