

Course in Heterogeneity and Fluctuations

VI: Wealth, Wages, and Employment

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Based on joint work with Per Krusell and Jinfeng Luo



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 - Not numerically well-behaved.
- We offer an alternative: competitive job search with commitment to a wage (or wage schedule) while the job lasts.

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 - Pose quits, on the job search, and explicit role for leisure so quitting is not only to search for better jobs
 - Use new potent tools to address the study of fluctuations in complicated economies ?



- The study of Business cycles including gross flows in and out of employment, unemployment and outside the labor force
- Policy analysis where now risk, employment, wealth (including its distribution) and wages are all responsive to policy.



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3. On the Job Search workers may get outside offers and take them. (Some in ?). Fluctuations.



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- General equilibrium: Workers own firms.



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5. Job Matching : $M(V, U)$: Some vacancies meet some unemployed job searchers. A match becomes operational the following period.
Job finding and job filling rates $\psi^h(\theta) = \frac{M(V, U)}{U}$, $\psi^f(\theta) = \frac{M(V, U)}{V}$.



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No QUILTS MODEL: HOUSEHOLD PROBLEM

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 - If employed: (a, w)
 - If unemployed: (a)
- Problem of the employed: (Standard)

$$V^e(a, w) = \max_{c, a'} u(c) + \beta [(1 - \delta)V^e(a', w) + \delta V^u(a)]$$

$$\text{s.t. } c + a' = a(1 + r) + w, \quad a \geq 0$$



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- Problem of the unemployed: Choose which wage to look for

$$V^u(a) = \max_{c, a', w} u(c) + \beta \{ \psi^h[\theta(w)] V^e(a', w) + [1 - \psi^h[\theta(w)]] V^u(a') \}$$
$$\text{s.t. } c + a' = a(1 + r) + b, \quad a \geq 0$$

$\theta(w)$ is an equilibrium object



- Value of a job with wage w : uses constant \bar{k} capital that depreciates at rate δ^k

$$\Omega(w) = z - \bar{k}\delta^k - w + \frac{1 - \delta^f}{1 + r} [(1 - \delta^h)\Omega(w) + \delta^h \bar{k}]$$



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- Affine in w :
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FIRMS POST VACANCIES: CHOOSE WAGES & FILLING PROBABILITIES

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- Free entry condition requires that for all offered wages

$$\bar{c} + \bar{k} = \psi^f[\theta(w)] \frac{\Omega(w)}{1 + r} + [1 - \psi^f[\theta(w)]] \frac{\Omega}{1 + r},$$



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3. An interest rate r clears the asset market

$$\int a \, dx = \int \Omega(w) \, dx.$$



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CHARACTERIZATION OF A WORKER'S DECISIONS

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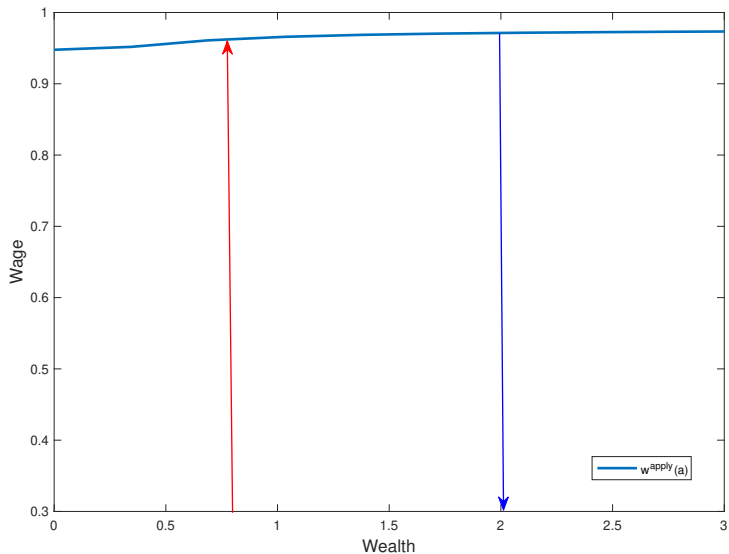
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- Households with more wealth are able to insure better against unemployment risk.
- As a result they apply for higher wage jobs and we have dispersion

HOW DOES THE MODEL WORK



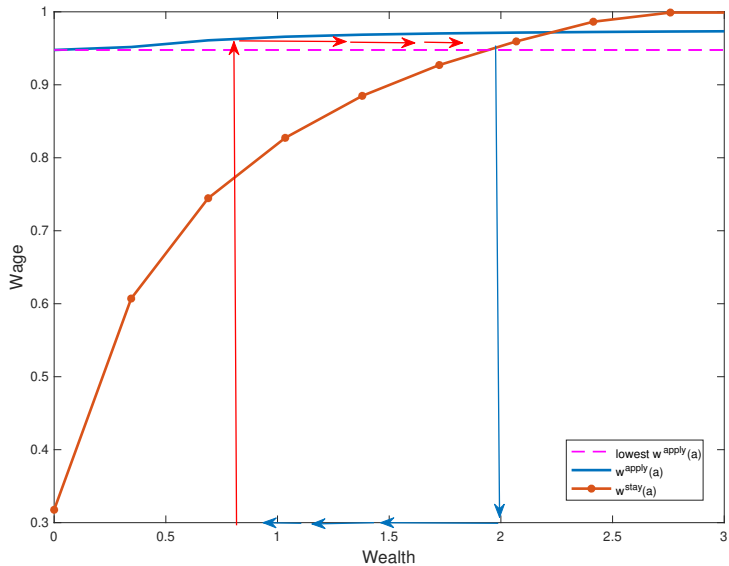
WORKER'S WAGE APPLICATION DECISION



HOW DOES THE MODEL WORK



WORKER'S SAVING DECISION





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2. In the following we examine the implications of a quitting choice

2 Endogenous Quits

ENDOGENOUS QUILTS: BEAUTY OF EXTREME VALUE SHOCKS

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6. We end up with a model with little wage dispersion but with endogenous quits that respond to the cycle.

QUITTING MODEL: TIME-LINE

1. Workers enters period with or without a job: $\{e, u\}$.
2. Production occurs and consumption/saving choice ensues:
3. Exogenous job/firm destruction happens.
4. Quitting:
 - e draw shocks $\{\epsilon^e, \epsilon^u\}$ and make quitting decision.
Job losers cannot search this period.
 - u draw shocks $\{\epsilon_1^u, \epsilon_2^u\}$. No decision but same expected means.
5. Search: New or Idle firms post vacancies. Choose $\{w, \theta\}$.
Wealth is not observable. (Unlike ?).
Yet it is still Block Recursive
6. Matches occur

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- If shocks are Type-I Extreme Value dbtn (Gumbel), then \widehat{V} has a closed form and the ex-ante quitting probability $q(a, w)$ is

$$q(a, w) = \frac{1}{1 + e^{\alpha[V^e(a, w) - V^u(a)]}}$$

higher parameter $\alpha \rightarrow$ lower chance of quitting.

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- Workers receive i.i.d shocks $\{\epsilon^e, \epsilon^u\}$ to the utility of working or not
- Value of the employed right before receiving those shocks:

$$\widehat{V}^e(a', w) = \int \max\{V^e(a', w) + \epsilon^e, V^u(a') + \epsilon^u\} dF^\epsilon$$

V^e and V^u are values after quitting decision as described before.

- If shocks are Type-I Extreme Value dbtn (Gumbel), then \widehat{V} has a closed form and the ex-ante quitting probability $q(a, w)$ is

$$q(a, w) = \frac{1}{1 + e^{\alpha[V^e(a, w) - V^u(a)]}}$$

higher parameter $\alpha \rightarrow$ lower chance of quitting.

- Hence higher wages imply longer job durations. Firms could pay more to keep workers longer.

QUITTING MODEL: WORKERS PROBLEM

- Problem of the employed: just change \widehat{V}^e for V^e

$$V^e(a, w) = \max_{c, a'} u(c) + \beta \left[(1 - \delta) \widehat{V}^e(a', w) + \delta V^u(a) \right]$$

s.t. $c + a' = a(1 + r) + w, \quad a \geq 0$

- Problem of the unemployed is like before except that there is an added term $E\{\max[\epsilon_1^u, \epsilon_2^u]\}$

So that there is no additional option value to a job.

QUITTING MODEL: VALUE OF THE FIRM

- $\Omega^j(w)$: Value with with j -tenured worker.

Free entry condition requires that for all offered wages

$$\bar{c} + \bar{k} = \frac{1}{1+r} \{ \psi^f[\theta(w)] \Omega^0(w) + [1 - \psi^f[\theta(w)]] \Omega \},$$

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- Probability of retaining a worker with tenure j at wage w is $\ell^j(w)$.

(One to one mapping between wealth and tenure)

$$\ell^j(w) = 1 - q^e[g^{e,j}(a, w), w]$$

$g^{e,j}(a, w)$ savings rule of a j – tenured worker that was hired with wealth a

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- Firm's value

$$\Omega^j(w) = z - \bar{k}\delta^k - w + \frac{1 - \delta^f}{1+r} \{ \ell^j(w) \Omega^{j+1}(w) + [1 - \ell^j(w)] \Omega \}$$

QUITTING MODEL: SOLVING FORWARD FOR THE VALUE OF THE FIRM

$$\Omega^0(w) = (z - w - \delta^k k) Q^1(w) + (1 - \delta^f - \delta_k) k Q^0(w),$$

$$Q^1(w) = 1 + \sum_{\tau=0}^{\infty} \left[\left(\frac{1 - \delta^f}{1 + r} \right)^{1+\tau} \prod_{i=0}^{\tau} \ell^i(w) \right],$$

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- New equilibrium objects $\{Q^0(w), Q^1(w)\}$. Rest is unchanged.

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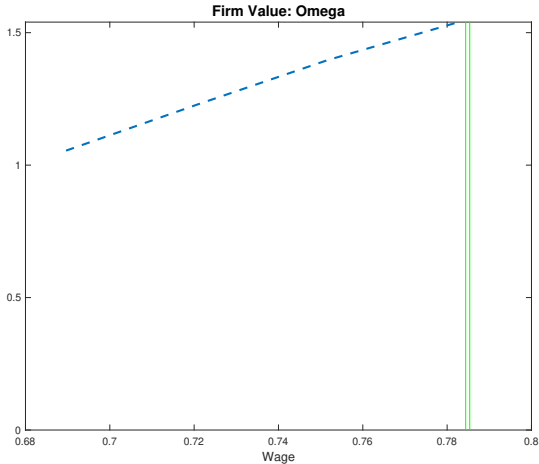
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- New equilibrium objects $\{Q^0(w), Q^1(w)\}$. Rest is unchanged.
- It is Block Recursive because wealth can be inferred from w and j . (No need to index contracts by wealth (as in ?)).

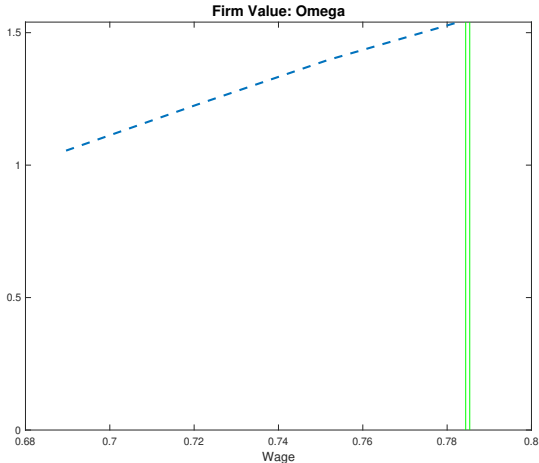
VALUE OF THE FIRM AS WAGE VARIES: THE POOR

- For the poorest, employment duration increases when wage goes up.



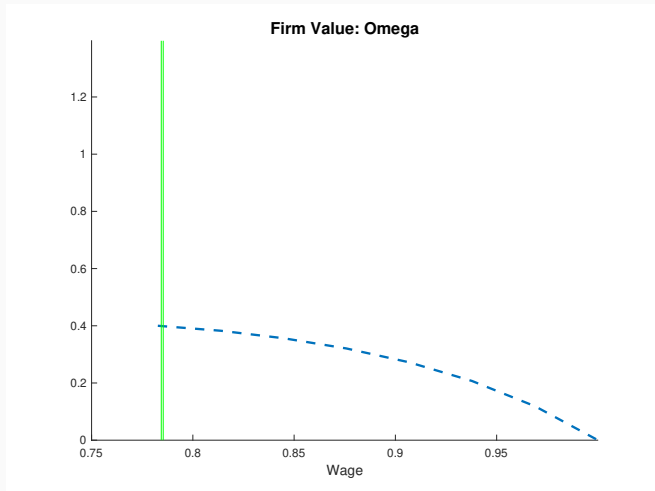
VALUE OF THE FIRM AS WAGE VARIES: THE POOR

- For the poorest, employment duration increases when wage goes up.
- Firms value is increasing in the wage



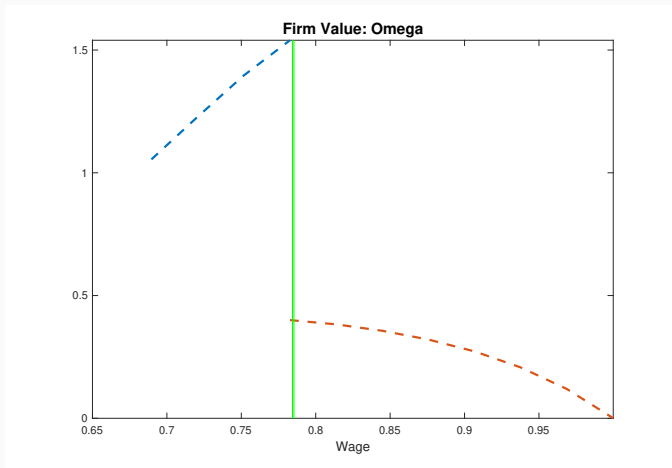
VALUE OF THE FIRM AS WAGE VARIES: THE RICH

- For the richest, employment duration increases but not fast enough.
- Firm value is slowly decreasing in wages (less than static profits).



VALUE OF THE FIRM: ACCOUNTING FOR WORKER SELECTION

- Large drop from below to above equilibrium wages.
- In Equilibrium wage dispersion COLLAPSES due to selection.



- Related to the Diamond dispersion paradox but for very different reasons.

EFFECT OF QUITTING: THE MECHANISM

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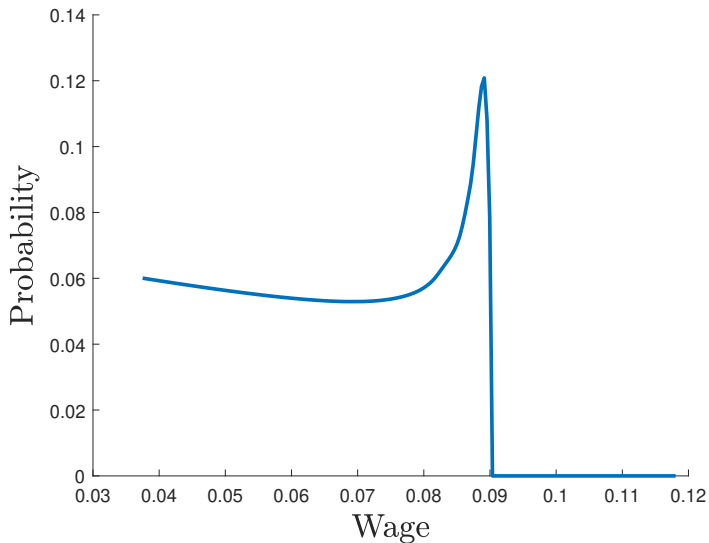
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 - However, by paying higher wages, firms attract workers with more wealth.
- Wealthy people quit more often, shrink employment duration.
- In equilibrium, the wage gap is narrow (disappears?) and the effect of wealth dominates.
- Need to weaken link between wages and wealth but not today (this is achieved via *aiming* (extreme value) shocks).

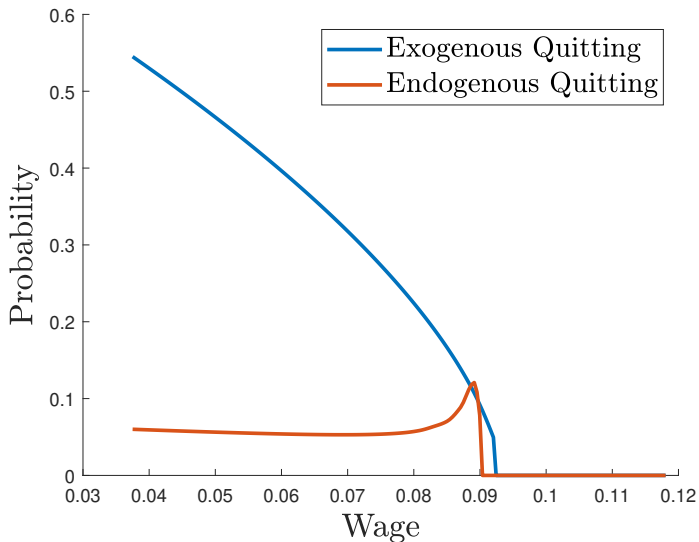
VALUE OF THE FIRM: ZERO PROFIT JOB FINDING PROBABILITY

- Increasing in Wage (up to Grid calculation): Unique wage.



QUITTING MAKES A BIG DIFFERENCE

- Job finding prob with Endo



3 On the Job Search

ON THE JOB SEARCH MODEL: TIME-LINE

1. Workers enter period with or without a job: V^e, V^u .
2. Production & Consumption:
3. Exogenous Separation
4. Quitting? Searching? Neither?: Employed draw shocks ($\epsilon^e, \epsilon^u, \epsilon^s$) and make decision to quit, search, or neither. Those who quit become u' , those who search join the u , in case of finding a job become $\{e', w'\}$ but in case of no job finding remain e' with the same wage w and those who neither become e' with w . $\widehat{V}^E(a', w)$, is determined with respect to this stage.
5. Search : Potential firms decide whether to enter and if so, the market (w) at which to post a vacancy; u and s assess the value of all wage applying options, receive match specific shocks $\{\epsilon^{w'}\}$ and choose the wage level w' to apply. Those who successfully find jobs become e' , otherwise become u' .
6. $\widehat{V}^u(a'), \{\Omega^j(w)\}$ are determined with respect to this stage.
7. Match

- After saving, the unemployed problem is

$$\widehat{V}^u(a') = \int \max_{w'} \left[\psi^h(w') V^e(a', w') + (1 - \psi^h(w')) V^u(a') + \epsilon^{w'} \right] dF^\epsilon$$

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- After saving, the employed choose whether to quit, search or neither

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- The value of searching is

$$V^s(a', w) = \int \max_{w'} \left[\psi^h(w') V^e(a', w') + [1 - \psi^h(w')] V^e(a', w) + \epsilon^{w'} \right] dF^\epsilon$$

- The probabilities of quitting and of searching

$$q(a', w) = \frac{1}{1 + \exp(\alpha[V^e(a', w) - V^u(a')]) + \exp(\alpha[V^s(a', w) - V^u(a') + \mu^s])},$$

$$s(a', w) = \frac{1}{1 + \exp(\alpha[V^u(a') - V^s(a', w)]) + \exp(\alpha[V^e(a', w) - V^s(a', w) - \mu^s])}.$$

$\mu^s < 0$ is the mode of the shock ϵ^s which reflects the search cost.

ON THE JOB SEARCH: HOUSEHOLD CHOICES

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$\mu^s < 0$ is the mode of the shock ϵ^s which reflects the search cost.

- Households solve

$$V^e(a, w) = \max_{a' \geq 0} u[a(1+r) + w - a'] + \beta \left[\delta V^u(a') + (1-\delta) \widehat{V}^e(a', w) \right]$$

$$V^u(a) = \max_{c, a' \geq 0} u[a(1+r) + b - a'] + \beta \widehat{V}^u(a')$$

- The value of the firm is again given like in the Quitting Model

$$\Omega^0(w) = (z - w - \delta^k k) Q^1(w) + (1 - \delta - \delta_k) k Q^0(w),$$

$$Q^1(w) = 1 + \sum_{\tau=0}^{\infty} \left[\left(\frac{1-\delta}{1+r} \right)^{1+\tau} \prod_{i=0}^{\tau} \ell^i(w) \right],$$

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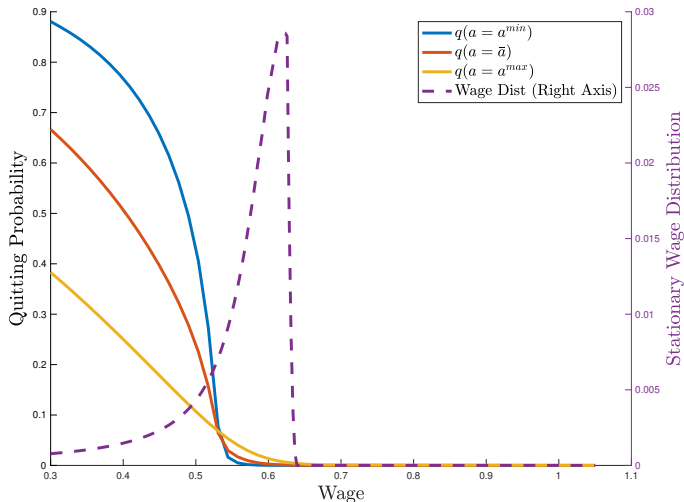
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- Except that now the probability of keeping a worker after j periods is

$$\begin{aligned} \ell^j(w) = & 1 - \int h(w; a) q[g^{e \cdot j}(a, w), w] dx^u(a) - \\ & \int h(w; a) s[w; g^{e \cdot j}(a, w)] \left[\int \hat{h}[\tilde{w}; g^{e \cdot j}(a, w), w] \xi \phi^h(\tilde{w}) d(\tilde{w}) \right] dx^u(a) \end{aligned}$$

OJS QUITTING PROBABILITIES, VARIOUS WEALTHS & WAGE DENSITY



- The rich pursue often other activities (leisure?)

Extensions:

Wages depend on the Aggregate State

Firms Choose Search Intensity

WAGES MOVE SOME WITH THE AGGREGATE STATE OF THE ECONOMY

- Wages are indexed to the Aggregate state z
- The firm is hard wired to pay not w but

$$w[1 + \gamma(z - 1)]$$

- It will reduce (depending on γ the incentive to quit and look for another job in an expansion)
- Very easy to implement
- Same steady state

FIRMS CHOOSE SEARCH INTENSITY

- The number of vacancies posted is chosen by firms
- Easy to implement
- Slightly Different steady state

- Let $v(\bar{c})$ be a technology to post vacancies where \bar{c} is the cost paid.

FREE ENTRY WITH VARIABLE RECRUITING INTENSITY

- Let $v(\bar{c})$ be a technology to post vacancies where \bar{c} is the cost paid.
- Then the free entry condition requires that for all offered wages

$$0 = \max_{\bar{c}} \left\{ v(\bar{c}) \psi^f[\theta(w)] \frac{\Omega(w)}{1+r} + [1 - v(\bar{c}) \psi^f[\theta(w)]] \frac{\bar{k}(1 - \delta_k)}{1+r} - \bar{c} - \bar{k} \right\},$$

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- With FOC given by

$$v_{\bar{c}}(\bar{c}) \left\{ \psi^f[\theta(w)] \left[\frac{\Omega(w)}{1+r} - \frac{\bar{k}(1 - \delta_k)}{1+r} \right] \right\} = 1,$$

- If $v(\bar{c}) = \frac{v_1 \bar{c}^2}{2} + v_2 \bar{c}$, we have

$$(v_1 \bar{c} + v_2) \left\{ \psi^f[\theta(w)] \left[\frac{\Omega(w)}{1+r} - \frac{\bar{k}(1-\delta_k)}{1+r} \right] \right\} = 1,$$

HOW TO MAKE IT CONSISTENT WITH THE CURRENT STEADY STATE

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- Solving for $\{v_1, v_2\}$ that satisfy both equations given our choice of \bar{c} we are done

- Limited Comparable Results
- Right now we have three Economies
 1. Only Exogenous Quitting
 2. Endogenous Quitting
 3. Exogenous Quitting with On-the-job Search
- Yearly Potential output is Normalized to 1.

HALF-QUARTERLY CALIBRATION

IN HALF QUARTER UNITS

- $K = 3, Y = 1/8, r = 0.37\%$
- firm destruction rate $\delta^f = 0.36\%$
- Exogenous Quits rate $\delta^h = 1.07\%$
- capital maintenance rate $\delta^k = 0.8\%$ from $I/Y = 25\%$.
- matching function: $\chi = 0.15, \eta = 0.62$
- For on-the-job search: $\chi = 0.3, \eta = 0.5$
- β adjusted to make wealth equal the stock market value

β

interest rate

avg consumption

avg wage

avg wealth

stock market value

avg labor income

consumption to wealth ratio

labor income to wealth ratio

quit ratio

unemployment rate

job losers

wage of newly hired unemployed

std consumption

std wage

std wealth

mean-min consumption

mean-min wage

UE transition

total vacancy

avg unemp duration

avg emp duration

OJS move rate

Steady States: $r = 1.5\%$ 1/2 quarter Closed Economies

	Exogen Quits
β	0.994
interest rate	0.030
avg consumption	0.685
avg wage	0.705
avg wealth	3.016
stock market value	3.016
avg labor income	0.656
consumption to wealth ratio	0.227
labor income to wealth ratio	0.218
quit ratio	0.086
unemployment rate	0.121
job losers	0.113
wage of newly hired unemployed	0.706
std consumption	0.015
std wage	0.001
std wealth	2.950
mean-min consumption	2.284
mean-min wage	1.013
UE transition	0.118
total vacancy	0.565
avg unemp duration	1.023
avg emp duration	7.469
OJS move rate	-

Steady States: $r = 1.5\%$ 1/2 quarter Closed Economies

	Endogen Quits
β	0.990
interest rate	0.030
avg consumption	0.664
avg wage	0.731
avg wealth	2.455
stock market value	2.455
avg labor income	0.640
consumption to wealth ratio	0.270
labor income to wealth ratio	0.261
quit ratio	0.083
unemployment rate	0.210
job losers	0.110
wage of newly hired unemployed	0.731
std consumption	0.011
std wage	0.000
std wealth	1.935
mean-min consumption	2.213
mean-min wage	1.002
UE transition	0.102
total vacancy	0.164
avg unemp duration	2.019
avg emp duration	7.625
OJS move rate	-

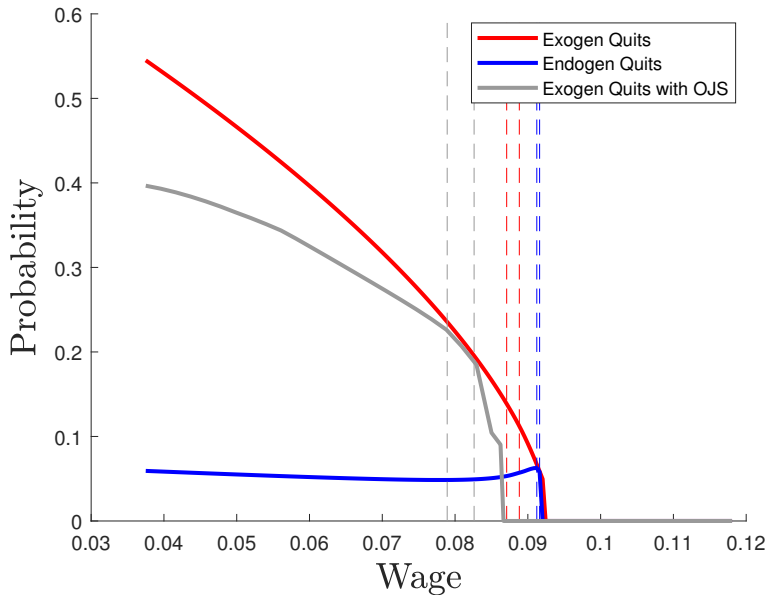
Steady States: $r = 1.5\%$ 1/2 quarter Closed Economies

	Exogen Quits & OJS
β	0.994
interest rate	0.030
avg consumption	0.674
avg wage	0.675
avg wealth	2.949
stock market value	2.949
avg labor income	0.646
consumption to wealth ratio	0.229
labor income to wealth ratio	0.219
quit ratio	0.086
unemployment rate	0.078
job losers	0.113
wage of newly hired unemployed	0.653
std consumption	0.013
std wage	0.001
std wealth	2.905
mean-min consumption	2.247
mean-min wage	1.071
UE transition	0.124
total vacancy	0.740
avg unemp duration	0.626
avg emp duration	7.469
OJS move rate	0.428

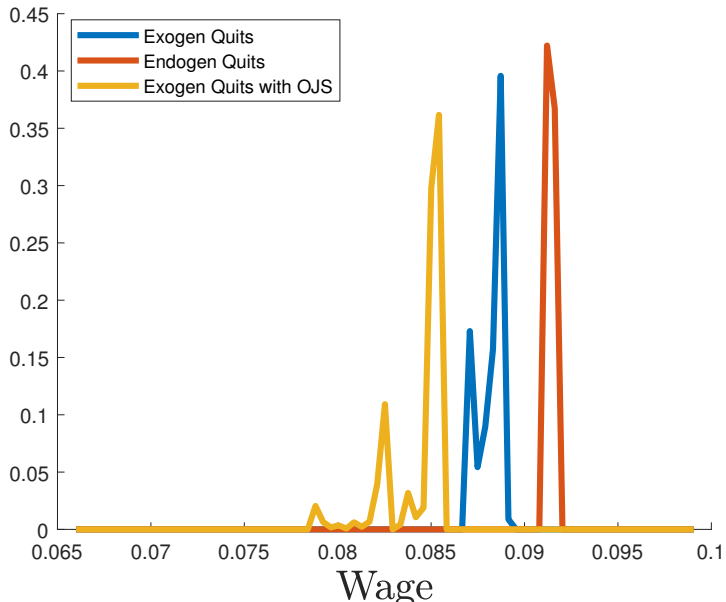
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	Exogen Quits	Endogen Quits	Exogen Quits & OJS
β	0.994	0.990	0.994
interest rate	0.030	0.030	0.030
avg consumption	0.685	0.664	0.674
avg wage	0.705	0.731	0.675
avg wealth	3.016	2.455	2.949
stock market value	3.016	2.455	2.949
avg labor income	0.656	0.640	0.646
consumption to wealth ratio	0.227	0.270	0.229
labor income to wealth ratio	0.218	0.261	0.219
quit ratio	0.086	0.083	0.086
unemployment rate	0.121	0.210	0.078
job losers	0.113	0.110	0.113
wage of newly hired unemployed	0.706	0.731	0.653
std consumption	0.015	0.011	0.013
std wage	0.001	0.000	0.001
std wealth	2.950	1.935	2.905
mean-min consumption	2.284	2.213	2.247
mean-min wage	1.013	1.002	1.071
UE transition	0.118	0.102	0.124
total vacancy	0.565	0.164	0.740
avg unemp duration	1.023	2.019	0.626
avg emp duration	7.469	7.625	7.469
OJS move rate	-	-	0.428

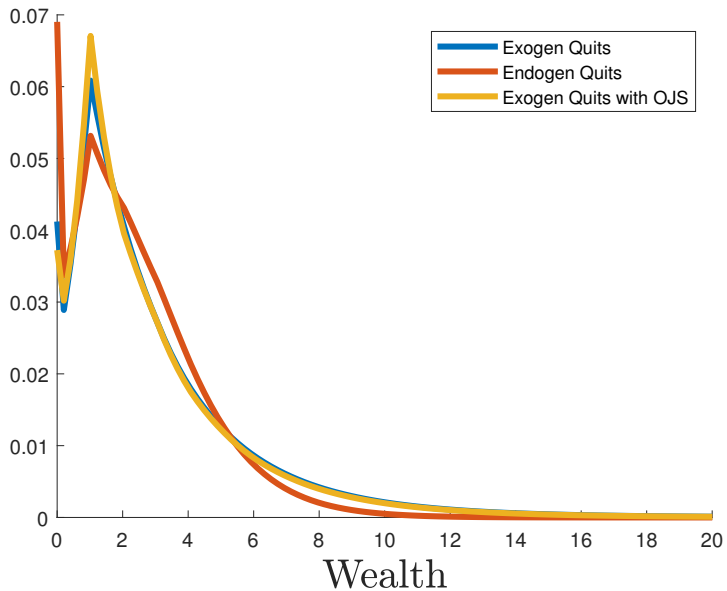
JOB FINDING PROBABILITY CURVE



WAGE DISTRIBUTION



WEALTH DISTRIBUTION



SUMMARY, CLOSED ECONOMIES

- Higher wages but lower consumption with endogenous quitting.
- Because the unemployment duration is much higher. So is the unemployment rate.
- On-the-job search enlarges the wage dispersion, but not much.
- On-the-job search lowers average wage a lot but consumption less so. Because finding a job is easier, and thus unemployment duration is lower.

5 Aggregate Fluctuations

WHAT IS NEEDED?

- Two steps

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- The transition is a large but doable problem:
 - Firms need to know functions $\{Q_t^0(w), Q_t^1(w), \psi^f(w)\}$ at each stage (no block recursivity)
 - Households need to know $\phi_t^h(w)$ job finding probabilities every period.

WHAT IS NEEDED?

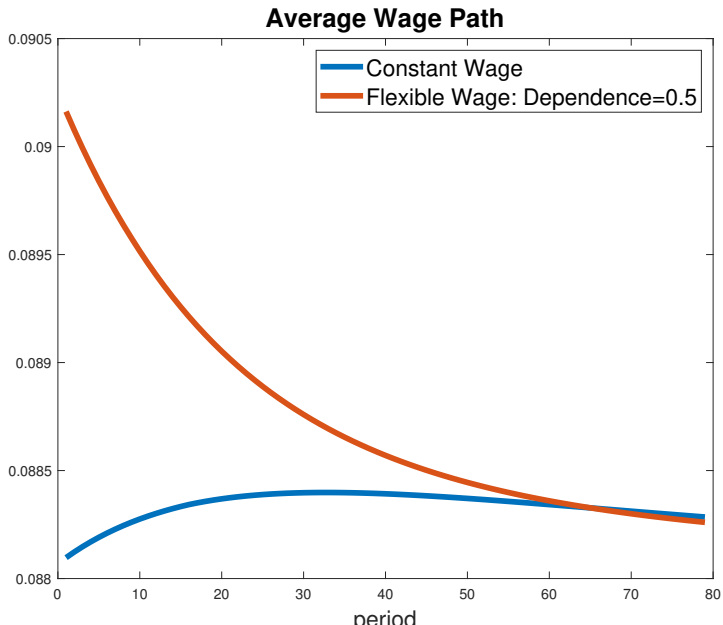
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 - Firms need to know functions $\{Q_t^0(w), Q_t^1(w), \psi^f(w)\}$ at each stage (no block recursivity)
 - Households need to know $\phi_t^h(w)$ job finding probabilities every period.
 - Also need to know sequence of interest rates (not today)

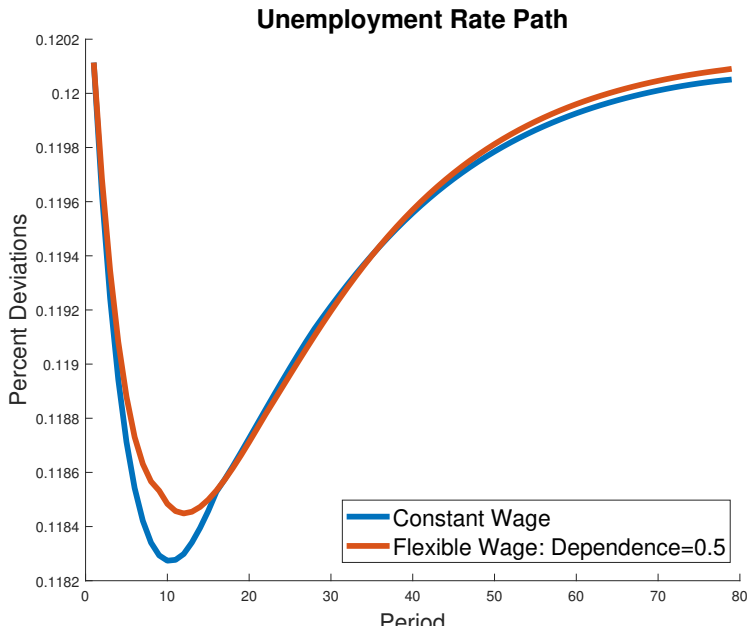
WHAT IS NEEDED?

- Two steps
 1. Compute the TRUE impulse response to an MIT Shock
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- So it is a second order difference functional equation.



No QUILTS. 5% PRODUCTIVITY SHOCK ($\rho = .95$)

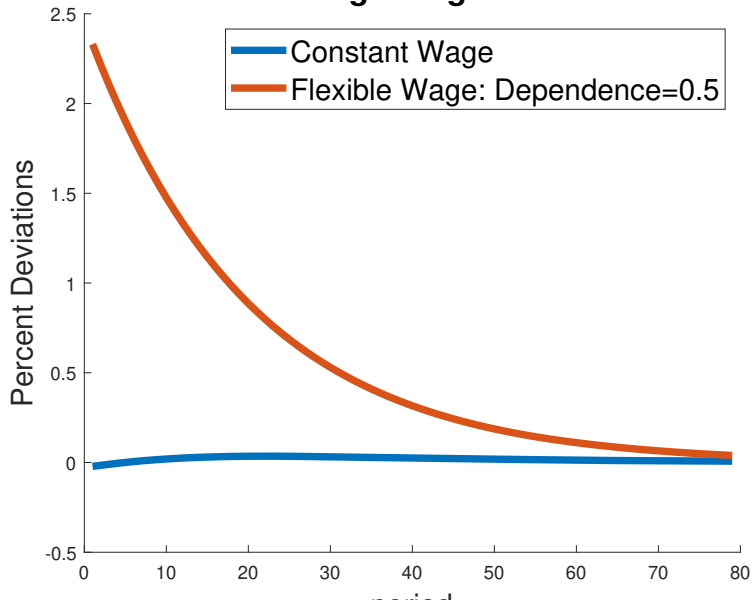




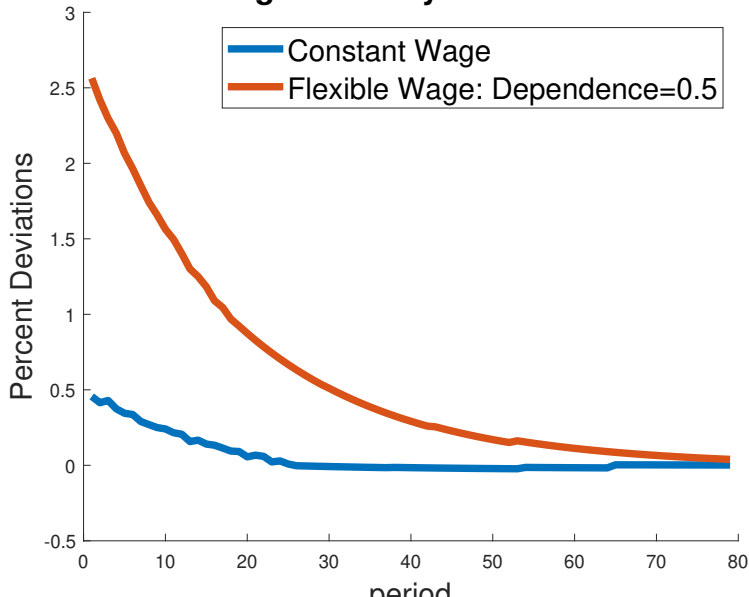
SUMMARY, EXOGENOUS QUILTS

- Large Shock creates little employment .15% (out of 5%)
- Also small wage increases if constant (1.5%) larger if adjusted 3%
- Big bottleneck in job market (Curvature of matching function)
- Yet less quits (need to recalibrate to get the same)
- In endogenous quits, the quits are judicious

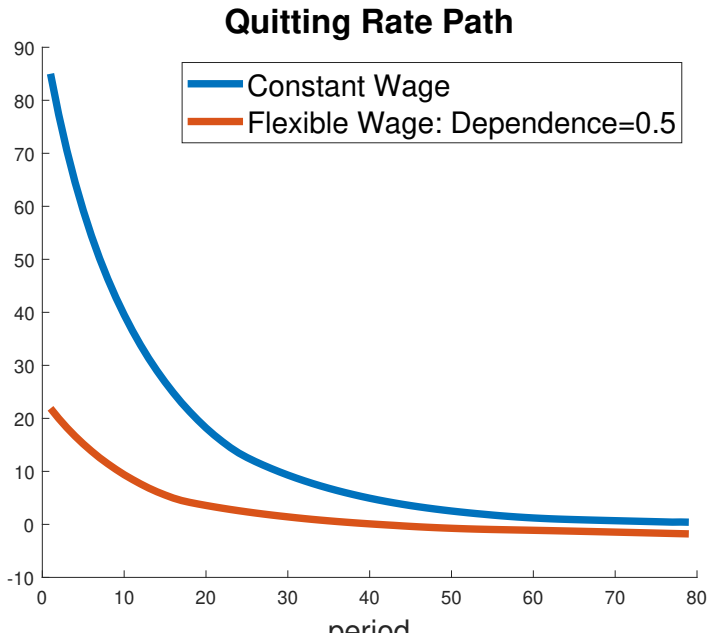
Average Wage Path



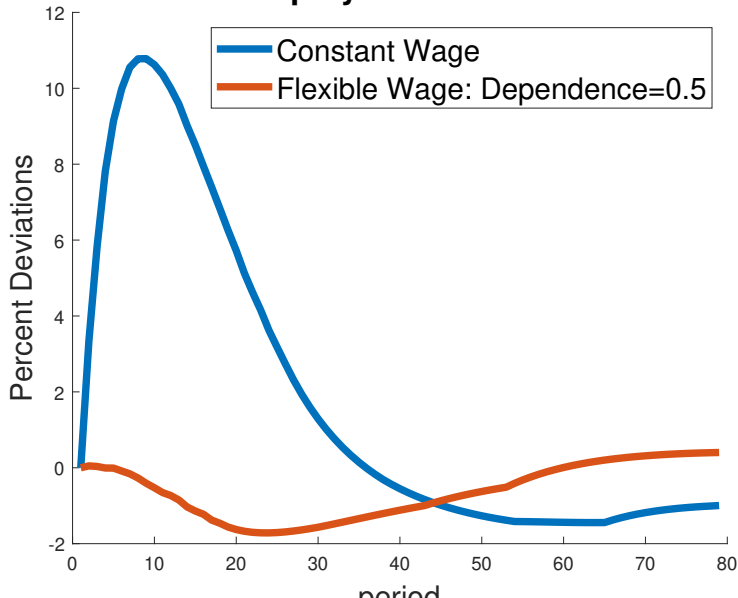
Wage of Newly Hired Path



graphsvie/net_inflow_of_workers_path-eps-converted-to.pdf



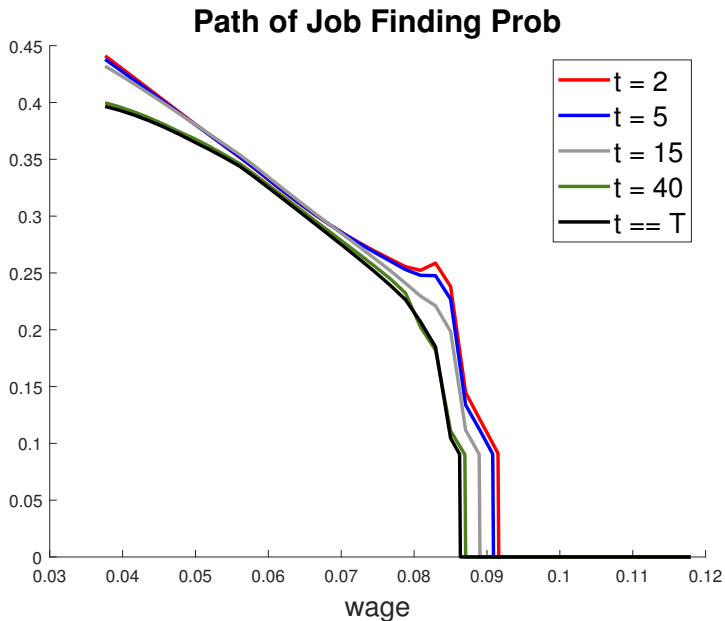
Unemployment Rate Path

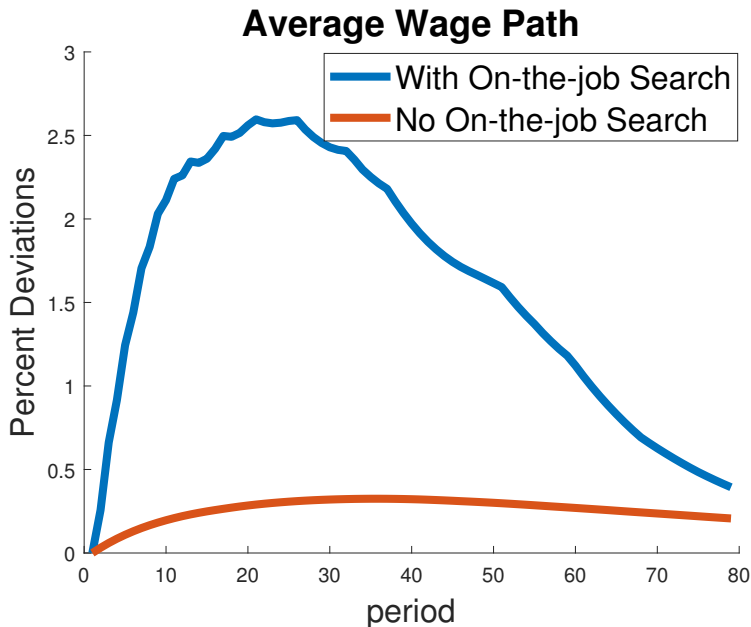


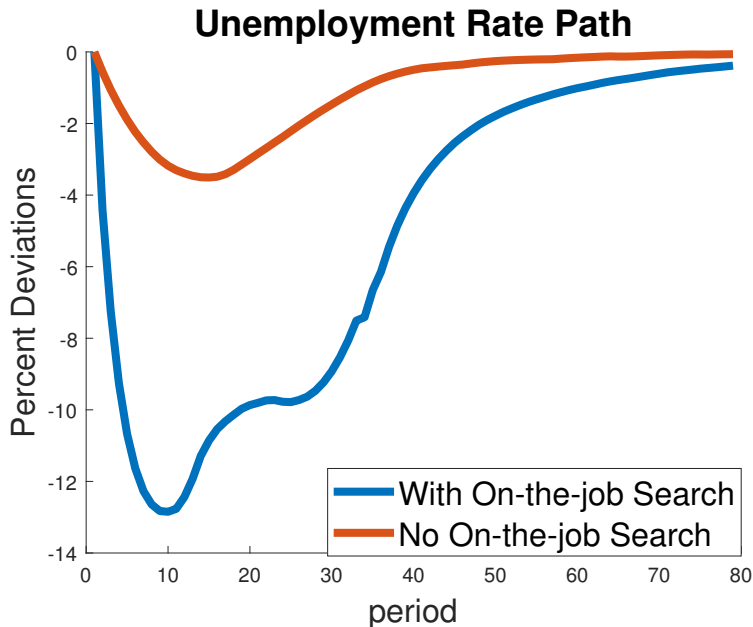
- With Fixed Wages Unemployment Increases
- With Adjusted wages Unemployment Drops .1% (3 times more than with Exog Quits)

6 Business Cycle Behavior of On the Job Search

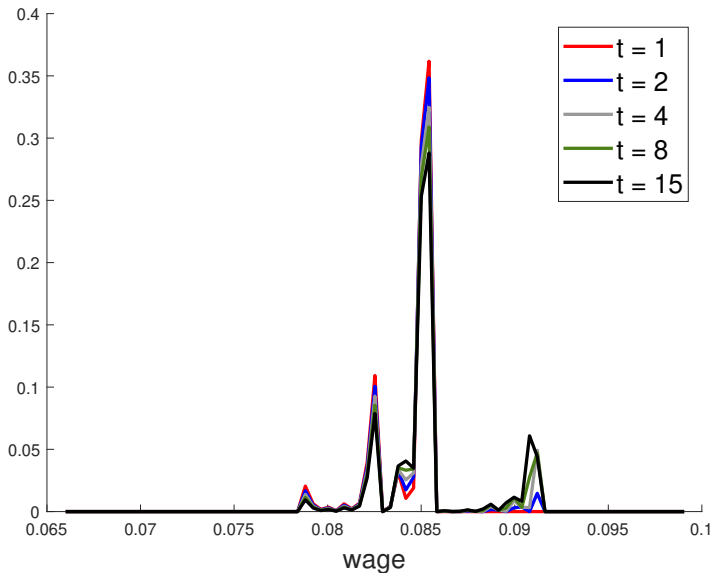
- Very Preliminary Assessment
- OJS Switches are Pro-cyclical: more job searchers and higher job finding probability
- OJS search amplifies the responses of wages and employment: for 5% shock
 - average wage response: 2.5%
 - unemployment rate response: -13% (or employment rate response: 1%)







OJS 5% SHOCK ($\rho = .95$) WAGE DTBONS OVER THE CYCLE, % DEVS



CONCLUSIONS I

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- On the Job Search seems to Magnify Fluctuation a lot

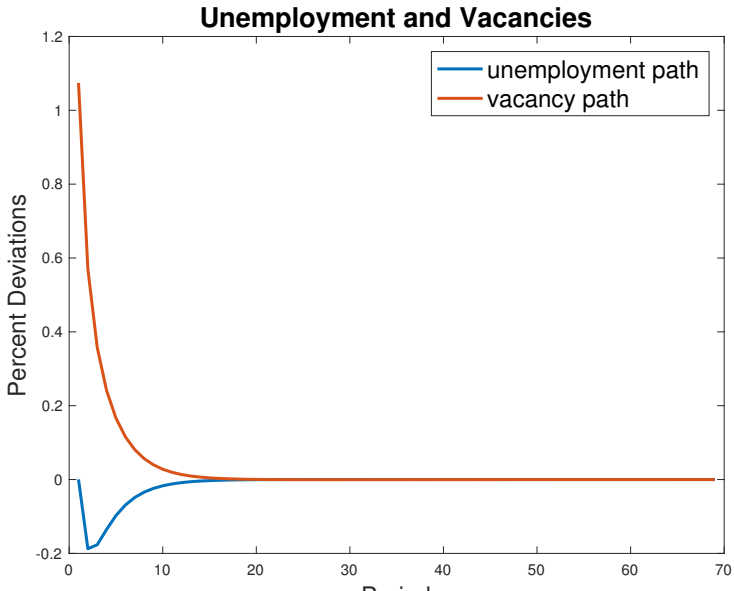
- Exciting set of continuation projects:
 1. Endogenous Search intensity on the part of firms
 2. Aiming Shocks to soften correlation between wages and wealth
 3. Efficiency Wages: Endogenous Productivity (firms use different technologies with different costs of idleness)
 4. Move towards more sophisticated life cycle movements

7 Appendix

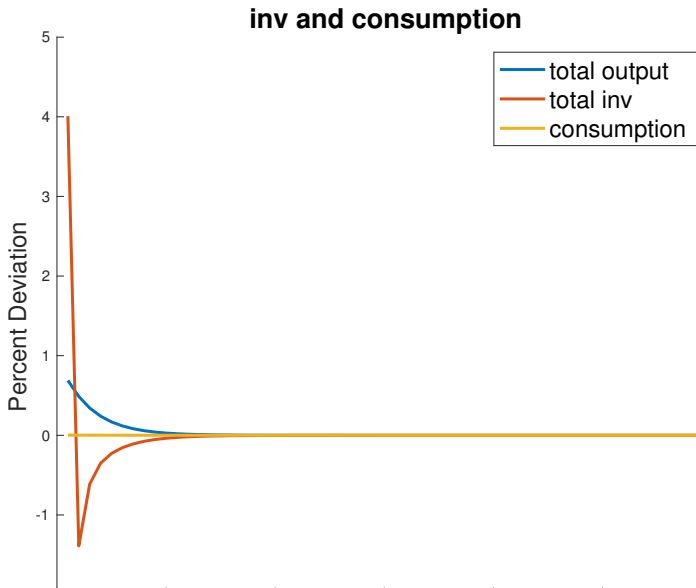
APPENDIX A: INSUFFICIENT EMPLOYMENT VOLATILITY

- The model features strong response of investment but insufficient response of employment.
 - We examine the mechanics of this.
- Consider for simplicity the model with aiming shocks but no quitting shocks (ANQ model). For a 1% productivity shock (with persistence 0.7), it generates
 - 1% increase of vacancies
 - 0.2% decrease of unemployment, which translates to only 0.01% increase of employment
 - and 4% increase of investment

ANQ: 1% PRODUCTIVITY SHOCK ($\rho = .7$) UNEMPLOYMENT AND VACANCIES

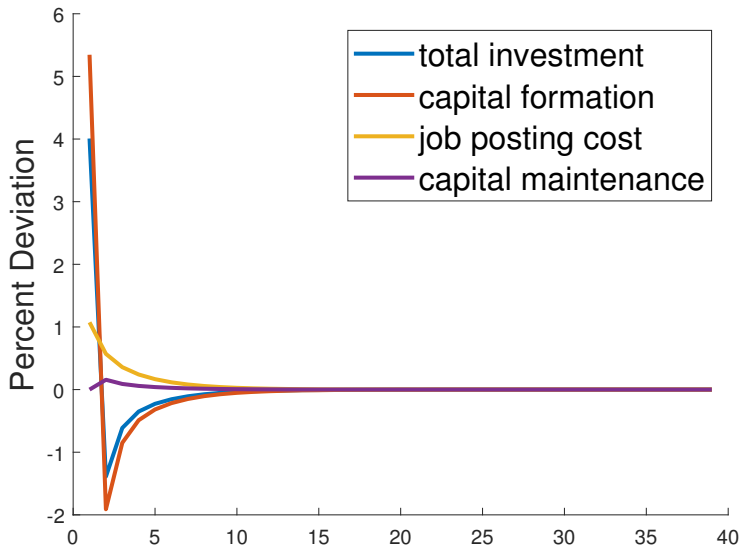


ANQ: 1% PRODUCTIVITY SHOCK ($\rho = .7$) OUTPUT, INVESTMENT AND CONSUMPTION



ANQ: 1% PRODUCTIVITY SHOCK ($\rho = .7$) DECOMPOSITION OF THE INVESTMENT

Investment Path



APPENDIX A: INSUFFICIENT EMPLOYMENT VOLATILITY

- Why does 1% increase of vacancies v generate 4% increase of investment?
 - At the steady state, about 80% of the vacancies are posted by old idle firms and 20% by newly created firms.
 - Investment = wage posting cost + capital maintenance cost + new capital formation
 - As the shock hits the economy, firstly it only increases the creation of new firms, generating massive movements of investment in the form of capital formation (ek).
- Why does 1% increase of vacancies v generate only 0.01% increase of employment?
 - As an approximation, $\hat{m} = (1 - \eta)\hat{v} + \eta\hat{u}$.
 - Upon facing the shock, at first u does not move. So the response of matches depend on the response of v and the parameter η .
 - $\hat{m} \approx (1 - 0.72) \times 1\% = 0.28\%$, and $\frac{\Delta m}{1-u} = \frac{0.28\% \times 0.03}{0.95} \approx 0.01\%$
 - Lower η relieves the problem (see the next page).

LOWER η AND TRUNCATED 5% SHOCK: AQ ECONOMY

