Unemployment and the Search and Matching Model (Part 2)

PSE – Masters Year 2 (M2) – Quantitative Macro Term 1 (QM1)

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Recap

Last week:

- Last lecture we introduced the search and matching model, aka the DMP model
- Data show that flows (especially job finding rate) explain unemployment dynamics
- We discussed how to solve the model, and used steady state elasticity to get an initial glimpse into its quantitative performance

This week:

- Key question: Does the DMP model explain why unemployment is so volatile?
  - Shimer (2005) puzzle: no, the basic model does not
  - Discuss resolutions, focusing on *wage rigidity* and *surpluses*
  - Brief discussion of other avenues
- Problem set: How to solve the model on the computer?

The Shimer (2005) puzzle

The Shimer (2005) puzzle

In a nutshell, Shimer (2005) claimed the following:

"This paper argues that the textbook search and matching model cannot generate the observed business-cycle-frequency fluctuations in unemployment and job vacancies in response to shocks of a plausible magnitude."

- What use is a theory of unemployment that cannot explain why unemployment goes up in recessions?
- The puzzle is entirely **quantitative**: we know the model *can* generate unemployment that moves, but the claim is that these movements are much smaller than in the data
- Since the claim is quantitative, we first need to discuss how Shimer calibrated the model
- Background on calibration vs estimation ▸ details

Recap of model equations and variables

Let's recap our equations, and add functional form assumptions that $M(u,v) = Au^{\alpha}v^{1-\alpha}$ and that y_t follows an AR(1) process. Write in time domain since will use Dynare today:

$$U_t = z + \beta \, \mathrm{E}_t \left[(1-f_t) U_{t+1} + f_t W_{t+1} \right] \tag{1}$$

$$W_t = w_t + \beta \, \mathrm{E}_t \left[(1-s) W_{t+1} + s U_{t+1} \right] \tag{2}$$

$$J_t = y_t - w_t + \beta(1-s) \, \mathrm{E}_t \left[J_{t+1} \right] \tag{3}$$

$$W_t - U_t = \frac{\phi}{1-\phi} J_t \tag{4}$$

$$c = \beta q_t \, \mathrm{E}_t \, J_{t+1} \tag{5}$$

$$u_{t+1} = \left(1 - f_t\right) u_t + s(1-u_t) \tag{6}$$

$$\theta_t = \frac{v_t}{u_t} \tag{7}$$

$$f_t = A\theta_t^{1-\alpha} \tag{8}$$

$$q_t = A\theta_t^{-\alpha} \tag{9}$$

$$\log y_t = (1-\rho_y) \log y_{ss} + \rho_y \log y_{t-1} + \sigma_y \varepsilon_t \tag{10}$$

10 equations for 10 endogenous variables: $W_t, U_t, J_t, w_t, \theta_t, v_t, u_t, f_t, q_t, y_t$. Shock $\varepsilon_t \sim N(0,1)$, iid.

A Shimer (2005) style calibration ▸ hag man

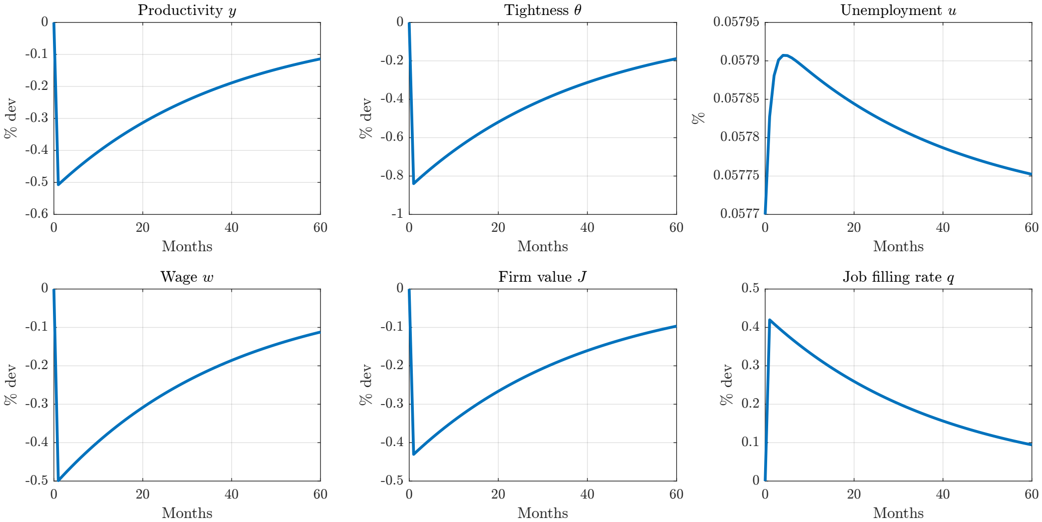
Shimer (2005) calibrates all parameters in steady state (apart from the stochastic process for productivity). Let's calibrate the model closely to what he did:

Parameter	Value	Source / Target
Discount factor β	0.996	Monthly discount rate, $\approx$ 5% annual real interest rate
Separation rate s	0.0322	Average EU rate (Shimer approach)
Mean productivity y_{ss}	1	Normalisation
Unemployed value z	0.385	**UI replacement rate of** 40%
Matching elasticity α	0.5	Standard value
Bargaining power ϕ	0.5	**Impose Hosios condition**
Matching scale A	0.6498	Average u rate 5.77%
Vacancy posting cost c	0.8245	Average θ of 0.6550
Productivity persistence ρ_y	0.975	Autocorrelation of quarterly HP filtered Y/L
Productivity shock std. σ_y	0.0051	Std. of quarterly HP filtered Y/L

Note: Shimer (2005) style calibration. One model period is one month. Data for labour moments are from 1951M1 to 2019M12. Calibration implies steady state $w_{ss} = 0.96 y_{ss}$.

In the problem set you will perform this calibration step by step

Result: A sensible-seeming calibration $\Longrightarrow$ u barely moves ▸ hall ▸ hag man



Log-linearised solution using Dynare. Response of model to negative 1 st. dev. productivity shock. All variables are 100× log dev. from steady state, apart from u which is converted to level. [$w_{ss} = 0.96 y_{ss}$, $\eta_{\theta,y} = 1.73$]

Intuition for the puzzle

Building intuition from the IRFs:

- Wages fell as much as productivity $\implies$ very flexible wages
- Small fall in profits $\implies$ small fall in firm value J $\implies$ small fall in θ $\implies$ small rise in unemployment u.

Connecting back to Ljungqvist and Sargent (2017) "fundamental surplus"

- Ljungqvist and Sargent (2017) tell us it is not just wage flexibility, but also the size of the fundamental surplus:

$$\eta_{\theta,y} = \underbrace{\frac{(r+s)+\phi f(\theta)}{\alpha(r+s)+\phi f(\theta)}}_{1.0649} \underbrace{\frac{y}{y-z}}_{1.6260} = 1.7315$$

  where our Shimer calibration implies (all steady state values) $y = 1$, $z = 0.385$, $\alpha = \phi = 0.5$, $f = 0.526$, $s = 0.322$, $r = 0.0043$
- In our data, $\text{std}(\theta) = 0.3931$ and $\text{std}(y) = 0.0160$, implying need $\eta_{\theta,y} \simeq 25$ to match the data. The sensible-looking calibration of Shimer (2005) gives $\eta_{\theta,y} = 1.7315$ which is $10\times$ too low $\implies$ **DMP model fails to generate volatile unemployment!**

Shimer (2005) puzzle resolution 1: Wage rigidity

Why wage rigidity?

Consider the chain of causality for y shock to θ. Continue to let $q_t = A\theta_t^{-\alpha}$, and consider an arbitrary w rather than Nash bargaining. Focus on steady-states to simplify the algebra:

Firm value:

$$J = y - w + \beta(1-s)J \implies J = \frac{y-w}{1-\beta(1-s)} \tag{11}$$

Free entry:

$$c = \beta q J \implies \theta = \left(\frac{\beta A J}{c}\right)^{\frac{1}{\alpha}} \implies \theta = \left(\frac{y-w}{1-\beta(1-s)}\frac{\beta A}{c}\right)^{\frac{1}{\alpha}} \tag{12}$$

- $\downarrow y \implies \downarrow \theta$, while $\downarrow w \implies \uparrow \theta$
- Clearly, if wages fall less (i.e. are more sticky) during a recession, profits can fall more, and so hiring will fall more and unemployment will rise more
- **Two key questions:**
  1. Why would wages be rigid in theory?
  2. Are they rigid in the data, and how important is this quantitatively?

Theory I: Wage rigidity as a valid assumption

Recall that after meeting, the firm and worker each have surpluses, which give the value of staying in the match vs. walking away. These depend on the wage they agree on, w:

$$S_t^w(w) = w - z + \beta \, \mathrm{E}_t \left[(1 - s - f_t)(W_{t+1} - U_{t+1}) \right]$$

$$S_t^f(w) = y_t - w + \beta(1 - s) \, \mathrm{E}_t \left[J_{t+1} \right]$$

Any w satisfying $S_t^w(w) \geq 0$ and $S_t^f(w) \geq 0$ will be preferable to both parties than walking away. This gives an upper and lower bound for agreeable wages

$$S_t^w(\underline{w}_t) = 0 \implies \underline{w}_t = z - \beta \, \mathrm{E}_t \left[(1 - s - f_t)(W_{t+1} - U_{t+1}) \right]$$
$$S_t^f(\bar{w}_t) = 0 \implies \bar{w}_t = y_t + \beta(1 - s) \, \mathrm{E}_t \left[J_{t+1} \right]$$

where any wage w_t such that $\underline{w}_t \leq w_t \leq \bar{w}_t$ is, in this sense, a valid equilibrium wage.

- Nash bargaining simply picks one wage from this range using $W_t - U_t = \frac{\phi}{1-\phi} J_t$
- But Hall (2005) points out that a constant wage $w_t = \hat{w}$ is also valid for business cycle sized shocks, since i) business cycle shocks to y_t are not too large, and ii) the bargaining set for wage determination is relatively wide

Hall (2005) style model equations

Hall (2005) style model has the following equations: *[note the removal of* $W_t - U_t = \frac{\phi}{1-\phi} J_t$*]*

$$U_t = z + \beta \, \mathrm{E}_t \left[(1 - f_t) U_{t+1} + f_t W_{t+1} \right]$$

$$W_t = \hat{w} + \beta \, \mathrm{E}_t \left[(1 - s) W_{t+1} + s U_{t+1} \right]$$

$$J_t = y_t - \hat{w} + \beta (1 - s) \, \mathrm{E}_t \left[J_{t+1} \right]$$

$$c = \beta q_t \, \mathrm{E}_t \, J_{t+1}$$

$$u_{t+1} = \left(1 - f_t\right) u_t + s(1 - u_t)$$

$$\theta_t = \frac{v_t}{u_t}$$

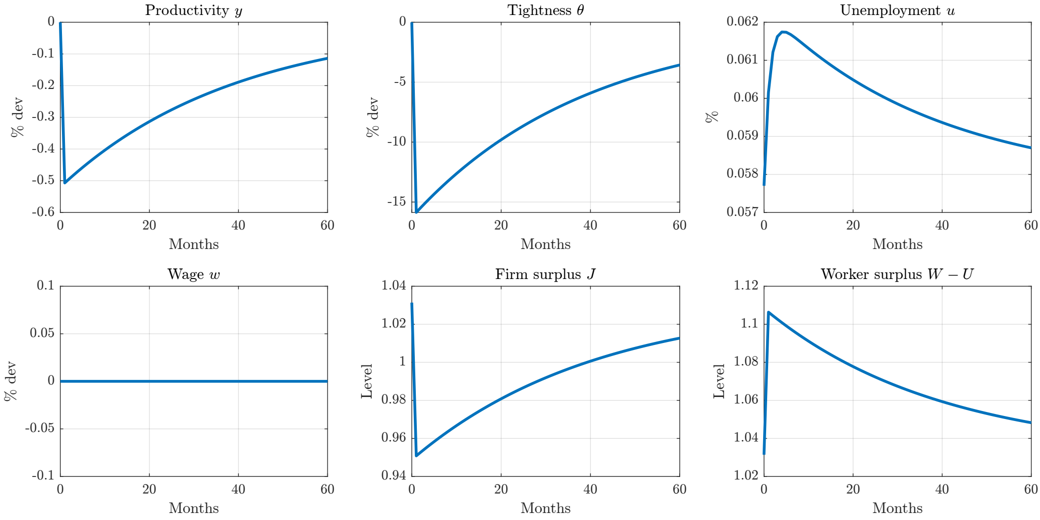
$$f_t = A \theta_t^{1-\alpha}$$

$$q_t = A \theta_t^{-\alpha}$$

$$\log y_t = (1 - \rho_y) \log y_{ss} + \rho_y \log y_{t-1} + \sigma_y \varepsilon_t$$

where $\hat{w}$ is the fixed wage (e.g. equal to the steady state Nash bargained wage) and we need to verify ex-post that $J_t \geq 0$ and $W_t - U_t \geq 0$ at all times for $\hat{w}$ to be a valid fixed-wage equilibrium.

Result: Hall (2005) fully sticky wages $\Longrightarrow$ u very volatile ▸ shimer ▸ hag man



Log-linearised solution using Dynare. Response of model to negative 1 standard deviation productivity shock. Steady state calibrated as in Shimer (2005), but fix $w_t = w_{ss}$ during simulation. [$w_{ss} = 0.96 y_{ss}$, $\eta_{\theta,y} = 53.4$]

Theory II: Wage rigidity from alternating-offer bargaining

Baseline Nash bargaining assumption: *["cooperative bargaining" game]*

- Wage set by Nash bargaining: $W_t - U_t = \frac{\phi}{1-\phi} J_t$
- Outside option for worker is to walk away and return to unemployment, getting U_t
- Being unemployed is *very bad in a recession* $\implies$ worker outside option U_t falls a lot in recessions $\implies$ bargained wage w_t falls a lot in recessions so wages are flexible

Hall and Milgrom (2008): Alternating offer bargaining: *["non-cooperative bargaining" game]*

- Outside option (returning to unemployment to search) is not a credible threat as long as the match surplus is positive
- Replace Nash bargaining with alternating offer bargaining (Binmore et al., 1986)
- Threat during bargaining is *delaying agreement*, not permanently walking away
  - Outside option replaced with *disagreement payoff*: how costly is delay for you?
  - This loosens the link between w_t and U_t, generating *endogenous wage rigidity*

Alternating-offer wage bargain: set up

Re-express worker and firm values by splitting out the value of wage payments:

$$
\begin{aligned}
U_t &= z + \beta\, \mathrm{E}_t\big[f_t(E_{t+1} + C_{t+1}) + (1 - f_t)U_{t+1}\big]\,, \\
C_t &= \beta\, \mathrm{E}_t\big[sU_{t+1} + (1 - s)C_{t+1}\big]\,, \\
E_t &= w_t + \beta(1 - s)\, \mathrm{E}_t\big[E_{t+1}\big], \\
Z_t &= y_t + \beta(1 - s)\, \mathrm{E}_t\big[Z_{t+1}\big],
\end{aligned}
$$

- E_t: discounted sum of wage payments in this job,
- C_t: worker "career value" after the current job ends, Z_t discounted sum of output
- Worker value from the match is $W_t = E_t + C_t$
- Firm's value from the match is $J_t = Z_t - E_t$.

Alternating-offer bargaining game: Each period, one side (worker or firm) makes a proposal for the wage value E_t. If the offer is rejected:

- bargaining breaks down with probability $\delta \implies$ worker gets U_t, firm $V_t = 0$
- bargaining is delayed one period w.p. $1 - \delta$, and the other side makes next offer
- during delay, no production, the worker receives z, the firm pays a cost χ

Equilibrium wage in the alternating offer game

Let E_t^w be the worker's indifference value when the *firm* proposes an offer, and E_t^f the firm's indifference value when the *worker* proposes an offer:

Equilibrium: each side makes worst acceptable offer, and first offer is accepted

$$E_t^w + C_t = \delta U_t + (1-\delta)\Big(z + \beta\,\mathrm{E}_t[E_{t+1}^f + C_{t+1}]\Big),$$

$$Z_t - E_t^f = (1-\delta)\Big(-\chi + \beta\,\mathrm{E}_t[Z_{t+1} - E_{t+1}^w]\Big).$$

Following Hall (2017), let's not take a stand on who moves first. Instead assume equilibrium wage value is average of values if worker or firm made the first offer: $E_t = \frac{1}{2}\Big(E_t^w + E_t^f\Big)$. This gives:

$$E_t = \frac{1}{2}\Bigg[(1-\delta)(z+\chi) + \delta U_t + Z_t - C_t\Bigg] + (1-\delta)\beta\,\mathrm{E}_t\left[E_{t+1} + \frac{C_{t+1} - Z_{t+1}}{2}\right]$$

Breakdown prob. δ controls wage flexibility. Limit cases:

- $\delta = 1$: bargaining guaranteed to break down $\implies$ return to Nash bargain with equal bargaining weights: $E_t = 0.5(U_t + Z_t - C_t) \implies W_t - U_t = J_t$
- $\delta = 0$: bargaining never breaks down. $\delta U_t = 0$ so worker's current unemployment value U_t has no effect on bargained wage $\implies$ wage rigidity

How sticky are wages in the data? Which wages matter in DMP?

1. Which wage matters? New hire wages are key for hiring volatility:

- In DMP models, vacancy posting depends on the *present value of wages for new hires*, not the aggregate average wage or wages of already-employed workers
- Pissarides (2009) summarised evidence and argued that wages of *new hires* appear highly flexible, even if wages of incumbent workers are sticky (see e.g. Bils, 1985)
- Evidence *not supportive* of sticky wages being important in DMP model

2. Gertler et al. (2020) re-assessment:

- Use SIPP panel data to separate:
  - new hires from employment (EE "job changers"), vs.
  - new hires from unemployment (UE hires).
- Show that the classic "new hires have very cyclical wages" result is entirely driven by job changers and hence procyclical *match upgrading* (composition).
- Once you focus on workers hired from unemployment, their wages are no more cyclical than incumbents' wages. *(see also Hazell and Taska (2025) for firm-side evidence)*

Summary: once we measure the *right* wage (new hires from unemployment), the evidence supports genuine wage rigidity at the hiring margin

How important are rigid wages quantitatively in the DMP model?

Are rigid wages enough to generate volatile u in the DMP model?

- Ljungqvist and Sargent (2017) show that in the fully sticky wage Hall (2005) model,

$$\eta_{\theta,y} = \frac{1}{\alpha}\frac{y}{y-\hat{w}} \equiv \Upsilon^{\text{Sticky}}\frac{y}{y-\hat{w}}$$

- Recall that $\Upsilon^{\text{Nash}} \simeq 1$, and $\Upsilon^{\text{Sticky}} = 1/\alpha = 2$. So even fully sticky wages can only **double** the volatility of unemployment (holding the second term constant)
- But this formula shows immediately that **sticky wages aren't enough on their own** to generate volatile unemployment
- Since $1/\alpha = 2$, even with completely sticky wages, still need $\frac{y}{y-\hat{w}} \geq 10$ to generate sufficiently volatile unemployment. If wages are *sticky but low*, it's not enough
- $\frac{y}{y-\hat{w}} \geq 10 \implies \frac{y-\hat{w}}{y} \leq 0.1$, and papers which claim success from sticky wages tend also to assume low profit margins (i.e. high wages $\geq$ 90% of y)

Summary: Rigid wages can generate unemployment volatility in the DMP model, but only when combined with small surpluses

Shimer (2005) puzzle resolution 2:
The role of small surpluses

Hagedorn and Manovskii (2008)

Quoting directly from their paper:

A prominent explanation of the findings in Shimer (2005) is that the elasticity of wages is too high in his model ($\epsilon_{w,p} = 0.9642$). The argument is then that an increase in productivity is largely absorbed by an increase in wages, leaving profits (and, thus, the incentives to post vacancies) little changed over the business cycle. This argument is not quite correct...

The correct argument is a subtle but crucial modification of the argument given above. The elasticity of wages does not matter per se. What matters for the incentives to post vacancies is the size of the percentage changes of profits in response to changes in productivity. These percentage changes are large ***if the size of profits is small and the increase in productivity is not fully absorbed by an increase in wages.***

- This is an early version of the Ljungqvist and Sargent (2017) fundamental surplus idea
- Hagedorn and Manovskii (2008) show that a simple but important recalibration of the Nash bargaining model can generate volatile unemployment

A Hagedorn and Manovskii (2008) style calibration ▸ shimer

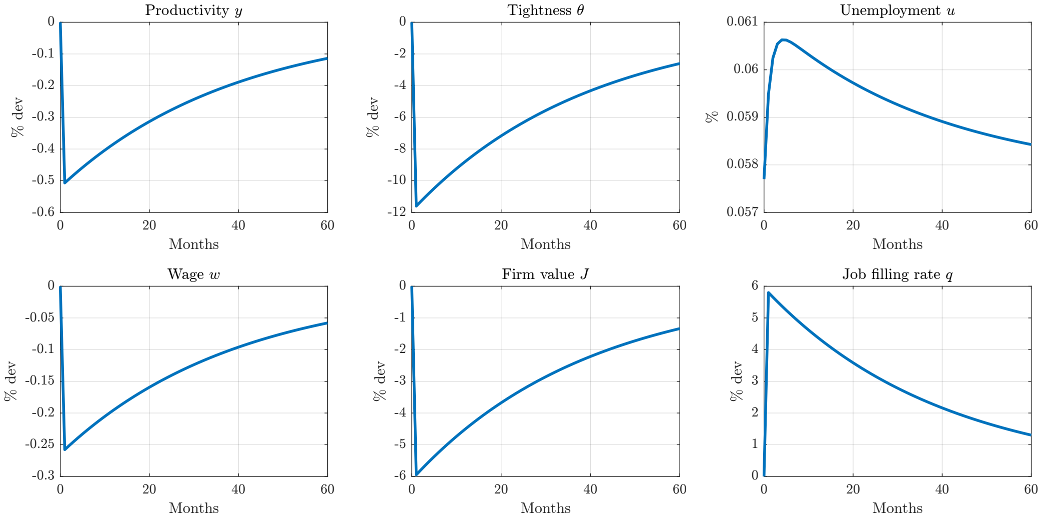
Hagedorn and Manovskii (2008) simply swap two calibration targets relative to Shimer (2005). Target wage flexibility and average vacancy posting costs:

Parameter	Value	Source / Target
Discount factor β	0.996	Monthly discount rate, $\approx$ 5% annual real interest rate
Separation rate s	0.0322	Average EU rate (Shimer approach)
Mean productivity y_{ss}	1	Normalisation
Unemployed value z	0.9523	**Vacancy posting costs 58.4% of w_{ss}**
Matching elasticity α	0.5	Standard value
Bargaining power ϕ	0.052	**Elasticity of wages to productivity** $\eta_{w,y} = 0.449$
Matching scale A	0.6498	Average u rate 5.77%
Vacancy posting cost c	0.5689	Average θ of 0.6550
Productivity persistence ρ_y	0.975	Autocorrelation of quarterly HP filtered Y/L
Productivity shock std. σ_y	0.0051	Std. of quarterly HP filtered Y/L

Note: Hagedorn and Manovskii (2008) style calibration. One model period is one month. Data for labour moments are from 1951M1 to 2019M12. Calibration implies steady state $w_{ss} = 0.97 y_{ss}$.

In the problem set you will perform this calibration and explore it

Result: Sticky wage + small surplus $\implies$ volatile J and u ▸ shimer ▸ hall



Log-linearised solution using Dynare. Response of model to negative 1 st. dev. productivity shock. All variables are 100× log dev. from steady state, apart from u which is converted to level. [$w_{ss} = 0.97 y_{ss}$, $\eta_{\theta,y} = 29.3$]

Ljungqvist and Sargent (2017): the Fundamental Surplus

Quoting directly from their paper: *"The second factor $y/(y - x^j)$ is the inverse of what we define as the fundamental surplus fraction.* ***The fundamental surplus*** *$y - x^j$ equals a quantity that deducts from productivity y a value x^j* ***that the invisible hand cannot allocate to vacancy creation****, a quantity whose economic interpretation differs across models"*

TABLE 1—ELASTICITIES OF MARKET TIGHTNESS AND FUNDAMENTAL SURPLUSES

	Elasticity	Key variables
Business cycle context		
Nash bargaining (Hagedorn and Manovskii 2008)	$\Upsilon^{Nash}\frac{y}{y-z}$	z, value of leisure
Sticky wage (Hall 2005)	$\Upsilon^{sticky}\frac{y}{y-\hat{w}}$	$\hat{w}$, sticky wage
… and financial accelerator (Wasmer and Weil 2004)	$\Upsilon^{sticky}\frac{y}{y-\hat{w}-k}$	k, annuitized value of credit search costs
Alternating-offer bargaining (Hall and Milgrom 2008)	$\Upsilon^{sticky}\frac{y}{y-z-\beta(1-s)\gamma}$	γ, firm's cost of delay in bargaining*
Fixed matching cost (Pissarides 2009)	$\Upsilon^{Nash}\frac{y}{y-z-\beta(r+s)H}$	H, fixed matching cost*
Welfare state context†		
Unemployment insurance	$\Upsilon^{Nash}\frac{y}{y-z-b}$	b, unemployment benefit
Layoff costs	$\Upsilon^{Nash}\frac{y}{y-z-\beta s\tau}$	τ, layoff tax*

Notes: *Other parameters are the discount factor $\beta = (1+r)^{-1}$, and the separation rate s. †Theories that attribute high European unemployment to productivity changes include a widened earnings distribution in Mortensen and Pissarides (1999), higher capital-embodied technological change in Hornstein, Krusell, and Violante (2007), and shocks to human capital in Ljungqvist and Sargent (2007).

Why is this useful?

- Clarifies the common theme across several responses to Shimer (2005):
- For unemployment to be volatile, you need a small fundamental surplus. This can be achieved in many ways.
- What these solutions have in common is that they add costs or frictions which make profits more volatile by shrinking the fundamental surplus available to be split between firms and workers.

Shimer (2005) puzzle resolution 3: Other approaches

Other approaches to explaining why unemployment is so volatile

We focused on **wage stickiness**, which is a leading explanation, but not the only one

Other mechanisms and shocks are also potentially important:

- Amplification through financial frictions (see e.g. Wasmer and Weil, 2004)
- Training costs to shrink the fundamental surplus (Pissarides, 2009)
- Rationing unemployment (Michaillat, 2012)
- Embedding into NK model yields amplification through aggregate demand channels, and the possibility of exploring additional shocks (see e.g. Christiano et al., 2016)
- Discounts (see e.g. Hall, 2017; Clymo, 2020)
- HANK meets SaM: amplification through precautionary saving (see e.g. Challe et al., 2017; Ravn and Sterk, 2021)
- The role of job destruction and removing free entry (see e.g. Elsby et al., 2009; Coles and Moghaddasi Kelishomi, 2018; Broer et al., 2025; Carrillo-Tudela et al., 2025)

Summary

Summary and discussion of QM2

What we learned:

- **Flows** (especially job finding rate) explain unemployment dynamics
- **DMP model** provides a tractable framework, emphasising role of market tightness θ, and where unemployment is not **efficient** (implying a role for policy)
- **Wage rigidity** provides a data-consistent explanation for why unemployment is so volatile, but needs to be coupled with **small surpluses** to generate volatile profits

What we will do in QM2: *[topics subject to final tweaks]*

- Focus on **heterogeneous agent models**
- Worker-side: using the DMP model to endogenise earnings risk in the HANK model
- Firm side: hiring, firing, on-the-job search across heterogeneous firms
- Happy to take suggestions for topics if there is demand!

Reading list and further topics

Core Textbooks and required reading

Core textbooks: *[not required reading, but useful resources]*

- Pissarides (2000): *Equilibrium Unemployment Theory (2nd ed)*. Foundation of the DMP framework, Chapters 1–4
- Ljungqvist and Sargent (2018): *Recursive Macroeconomic Theory (4th ed)*. Chapters on search model.

Background reading / history of economic thought: *[not required reading]*

- Their Nobel prize acceptance speeches are great, see e.g. Pissarides (2011)

The following papers are considered required reading:

- Shimer (2005) "The Cyclical Behavior of Equilibrium Unemployment and Vacancies"
- Hall (2005) "Employment Fluctuations with Equilibrium Wage Stickiness"
- Ljungqvist and Sargent (2017) "The Fundamental Surplus"
- *[no need to memorise or perfectly understand everything, but you must at least read these]*

Further Reading: Empirical Foundations

Labour market flows:

- Elsby et al. (2009), "The Ins and Outs of Cyclical Unemployment"
  Critique of Shimer (2012) decomposition, reaching a different conclusion
- Shimer (2012), "Reassessing the Ins and Outs of Unemployment"
  Unemployment fluctuations are driven mostly by job finding, not separations.
- Elsby et al. (2013), "Unemployment Dynamics in the OECD"
  Cross-country flows and decomposition taking Shimer (2012) to other countries

Matching function estimation:

- Big review in Petrongolo and Pissarides (2001)
- Borowczyk-Martins et al. (2013) discuss how to use IV approaches to better estimate the matching function

Other:

- Davis et al. (2012) and Davis et al. (2013): firm-level vacancy and hiring patterns over the cycle.
- Barnichon (2010): constructs vacancy measures in pre-JOLTS sample

Further Reading: DMP Fundamentals

DMP classics and overview:

- (Some of) their key early papers are Diamond (1982), Mortensen (1982), and Pissarides (1985)
- Rogerson et al. (2005) is an accessible survey

Micro-founding the matching function

- Lots of discussion of different approaches in Petrongolo and Pissarides (2001)

Directed and competitive search:

- See Wright et al. (2021) for a modern survey. Alternatives to random search, where workers and firms can direct their search towards specific markets in ways that often restore efficiency

Further Reading: RBC / NK + DMP

The original RBC + DMP papers:

- Merz (1995), "Search in the labour Market and the Real Business Cycle"
- Andolfatto (1996), "Business Cycles and Labor-Market Search"

NK + DMP:

- Blanchard and Galí (2010), "Labor Markets and Monetary Policy: A New Keynesian Model with Unemployment": An early NK + DMP paper setting up the key ideas
- Galí (2011), "Unemployment Fluctuations and Stabilization Policies: A New Keynesian Perspective": Detailed book outlining Gali's approach
- Christiano et al. (2016), "Unemployment and Business Cycles": Rich modern model

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Appendix

Calibrating and estimating models ▸ return

Terminology:

- Estimation: choosing parameters to make the model match the data in a well-defined statistical sense (e.g., maximum likelihood, GMM, Bayesian estimation, ...)
- Calibration: choosing parameters to make the model match specific moments or facts that we consider structurally meaningful. Typically no statistical objective function

Calibration:

- We calibrate each parameter so that the model hits targeted features of the data
- Sometimes, each parameter is used to hit one associated moment (with the understanding that all parameters and moments might interact)
- Other times, multiple parameters are chosen to jointly minimise the error relative to many moments
- Typically two kinds of moments to target
  - Steady state: e.g. *we choose b to match a UI replacement rate of 40% in steady state*
  - Cyclical: e.g. *we choose ϕ to match the cyclical correlation of wages and productivity*