Industry Dynamics and Economic Growth with Labor Market Frictions

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- How does aggregate labor market perform in the context of industrial dynamics and structural change?

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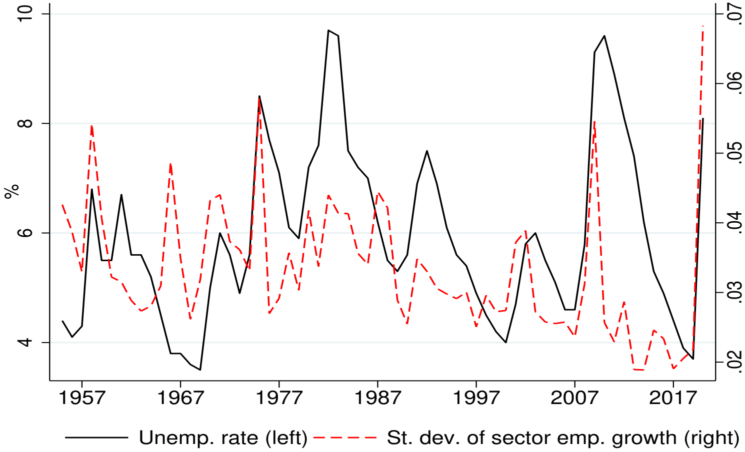

▸ See More Supporting Evidence

What we do

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- Endogenous capital accumulation drives incessant structural change: labor-intensive industries are gradually replaced by more capital-intensive ones.
- We analytically characterize the life-cycle dynamics of each of the infinite industries and show how skill mismtach and on-job learning may lead to repeated cycles of the aggregate unemployment rate as industries endogenously replaced by more capital-intensive ones.

Contributions to the Literature

- **Sectorial reallocation and mismatch:** Shimer (AER, 2007), Alvarez and Shimer (Econometrica, 2012), Hosios (AER, 1994), Restrepo (2015).
  Our paper differs in that (1) skill mismatch instead of quantity mismatch; (2) industries are asymmetric; (3) skill type of a worker may change .

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- **Labor market frictions in asymmetric sectors:** Zagler (Economic Journal, 2009), Lee and Wolpin (Econometrica, 2006), Pissaridies (IER, 2007), Hoffman and Shi (RED, 2016), Pilossoph (working paper, 2014) etc.
  Our paper differs in that (1) industries are heterogeneous in capital intensities rather than the rate of productivity growth or income demand elasticities; (2) structural change is driven by capital accumulation (Ju, Lin and Wang 2015 JME).

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- Consumption goods sector consists of four industries:

$$X = \sum_{n=0}^{3} x_n, \tag{2}$$

where

$$x_n = F_n(k, l) = \begin{cases} l, \text{ if } n = 0 \\ \lambda^n \min\{\frac{k}{a^n}, l\}, \text{ if } n = 1,2 \\ \frac{\lambda^3}{a^3} k, \text{ if } n = 3 \end{cases}, \tag{3}$$

where $a > \lambda > 1$.

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- In industry 2, inexperienced workers suffer from mismatch and their job finding rate is πf $(\pi < 1)$.
- Learning by doing: employed inexperienced workers in industry 2 becomes experienced at a poisson arrival rate ξ.

labor Market Dynamics:

Let λ_n^i denote the fraction of labor with skill type $i \in \{l, h\}$ in industry $n \in \{0, 1, 2\}$. $\sum_{n=0}^{2} \lambda_n^i = 1$.

$$\dot{E}_0^i = fU_i\lambda_0^i - \delta E_0^i, i = l \text{ or } h \tag{4}$$

$$\dot{E}_1^i = fU_i\lambda_1^i - \delta E_1^i, i = l \text{ or } h \tag{5}$$

$$\dot{E}_2^l = \pi \cdot fU_l\lambda_2^l - \delta E_2^l - \xi E_2^l \tag{6}$$

$$\dot{E}_2^h = fU_h\lambda_2^h - \delta E_2^h + \xi E_2^l \tag{7}$$

$$\dot{U}_h = -fU_h + \delta(E_0^h + E_1^h + E_2^h) \tag{8}$$

$$\dot{U}_l = -fU_l(1 - \lambda_2^l) - \pi \cdot fU_l\lambda_2^l + \delta(E_0^l + E_1^l + E_2^l) \tag{9}$$

Theorem

Theorem

The factor allocation in the decentralized equilibrium is the same as in the artifical social planner problem.

- The intuition is as follows. The well-known Hosios condition states that when the bargaining power of workers is the same as its matching elasticity, the decentralized equilibrium maximizes the net surplus. Hosios' condition is trivially satisfied in our model: the job finding rate is a constant, so the matching elasticity is one. Meanwhile, the surplus share for worker is also one because of no cost to post vacancy.

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- subject to

$$\dot{K} = AK - E(C, E_0^l + E_0^h, E_1^l + E_1^h, E_2^l + E_2^h) \tag{11}$$
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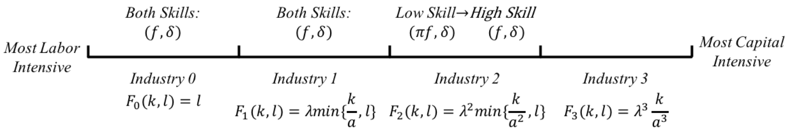
- and labor market conditions (4)-(9).



Instantaneous Equilibrium

- To derive a closed form solution, we consider the "instantaneous equilibrium" following Restrepo (2015).

Theorem

For the instantaneous equilibrium where $f = \kappa\widehat{f}$, $\delta = \kappa\widehat{\delta}$, and $\kappa \to \infty$, if $\xi < \overline{\xi}$ the dynamic optimization requires an optimal steady state equilibrium to produce $C(t)$ at each instant.

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- The intuition is that when the job finding and separation rate are sufficiently large, the reallocation of labor fully catches up with expanding consumption demand and ensures an optimal steady state allocation at each instant.

Optimal Steady State Equilibrium

- To find the optimal steady state, we solve the following dual problem:

$$\max_{E_j^i, K_j} \{ (E_0^l + E_0^h) + \lambda \min\{ E_1^l + E_1^h, \frac{K_1}{a} \} + \lambda^2 \min\{ E_1^l + E_2^l, \frac{K_2}{a^2} \} + \lambda^3 \frac{K_3}{a^3} \} \tag{12}$$

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- subject to

$$K_1 + K_2 + K_3 \leq E, \quad (13)$$

$$E_0^l \frac{\widehat{f} + \widehat{\delta}}{\widehat{f}} + E_1^l \frac{\widehat{f} + \widehat{\delta}}{\widehat{f}} + E_2^l \frac{\pi \widehat{f} + \widehat{\delta}}{\pi \widehat{f}} \leq L^l, \quad (14)$$

$$(E_0^h + E_1^h + E_2^h) \frac{\widehat{f} + \widehat{\delta}}{\widehat{f}} \leq L^h. \quad (15)$$

Optimal Steady State Equilibrium

Theorem

Given labor endowment L^l, L^h and capital expenditure on consumption goods Ω, Table 1 summarizes the optimal consumption C and labor allocation E_i^j

(1). $0 \le \Omega < a\frac{\hat{f}}{\hat{f}+\hat{\delta}}(L^h+L^l)$	(2). $a\frac{\hat{f}}{\hat{f}+\hat{\delta}}(L^h+L^l) \le \Omega < \frac{\hat{f}}{\hat{f}+\hat{\delta}}(aL^l+a^2L^h)$
$C = \frac{\lambda-1}{a}\Omega + \frac{\hat{f}}{\hat{f}+\hat{\delta}}(L^h+L^l)$ $E_0^l + E_0^h = \frac{\hat{f}}{\hat{f}+\hat{\delta}}(L^h+L^l) - \frac{\Omega}{a}$ $E_1^l + E_1^h = \frac{\Omega}{a}$ $E_2^l = 0,\ E_2^h = 0$	$C = \frac{\lambda^2-\lambda}{a^2-a}\Omega + \frac{\lambda(a-\lambda)}{a-1}\frac{\hat{f}}{\hat{f}+\hat{\delta}}(L^h+L^l)$ $E_0^l = 0,\ E_0^h = 0$ $E_1^l = \frac{\hat{f}}{\hat{f}+\hat{\delta}}L^l,\ E_1^h = \frac{a^2\frac{\hat{f}}{\hat{f}+\hat{\delta}}(L^h+L^l)-\Omega}{a^2-a} - \frac{\hat{f}}{\hat{f}+\hat{\delta}}L^l$ $E_2^l = 0,\ E_2^h = \frac{\Omega-a\frac{\hat{f}}{\hat{f}+\hat{\delta}}(L^h+L^l)}{a^2-a}$
(3). $\frac{\hat{f}}{\hat{f}+\hat{\delta}}(aL^l+a^2L^h) \le \Omega < a^2(\frac{\pi\hat{f}}{\pi\hat{f}+\hat{\delta}}L^l + \frac{\hat{f}}{\hat{f}+\hat{\delta}}L^h)$	(4). $\Omega \ge a^2(\frac{\pi\hat{f}}{\pi\hat{f}+\hat{\delta}}L^l + \frac{\hat{f}}{\hat{f}+\hat{\delta}}L^h)$
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Dynamic Model

- For the instantaneous equilibrium, we rewrite the problem as follows

$$\max_{C} \int_0^{t_1} e^{-\rho t} \frac{C^{1-\sigma}-1}{1-\sigma} dt + \int_{t_1}^{t_{2,h}} e^{-\rho t} \frac{C^{1-\sigma}-1}{1-\sigma} dt + \int_{t_{2,h}}^{t_{2,l}} e^{-\rho t} \frac{C^{1-\sigma}-1}{1-\sigma} dt + \int_{t_{2,l}}^{+\infty} e^{-\rho t} \frac{C^{1-\sigma}-1}{1-\sigma} dt \tag{16}$$

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- subject to

$$\dot{K} = \begin{cases} AK - E_{0,1}(C) & \text{when } t \leq t_1 \\ AK - E_{1,2,h}(C) & \text{when } t_1 < t \leq t_{2,h} \\ AK - E_{1,2,l}(C) & \text{when } t_{2,h} < t \leq t_{2,l} \\ AK - E_{2,3}(C) & \text{when } t > t_{2,l} \end{cases} \tag{17}$$

$$\dot{L}^h = \xi E_2^l, \dot{L}^l = -\xi E_2^l. \tag{18}$$

Dynamic Model

Assumption

The following conditions are satisfied:

$$\text{(i) } 0 < A - \rho < \sigma A;$$
$$\text{(ii) } f = \kappa \widehat{f},\ \delta = \kappa \widehat{\delta},\ \kappa \to \infty;$$
$$\text{(iii) } \xi < \bar{\bar{\xi}};$$
$$\text{(iv) } \frac{\pi \widehat{f}}{\pi \widehat{f} + \widehat{\delta}} > \left(\frac{1}{\lambda} + \frac{1}{a}\right) \frac{\widehat{f}}{\widehat{f} + \widehat{\delta}}$$

Conditions: (i) ensures the long-run growth rate is strictly positive but not explosive; (ii) ensures labor reallocation is sufficiently fast so we could focus on the instantaneous equilibrium;(iii) ensures the on-the-job learning efficiency is small enough so that the planner minimizes the flow of capital used for producing the consumption good at each instant; (iv) ensures mismatch is sufficiently mild so that inexperienced workers finally move into industry 2.

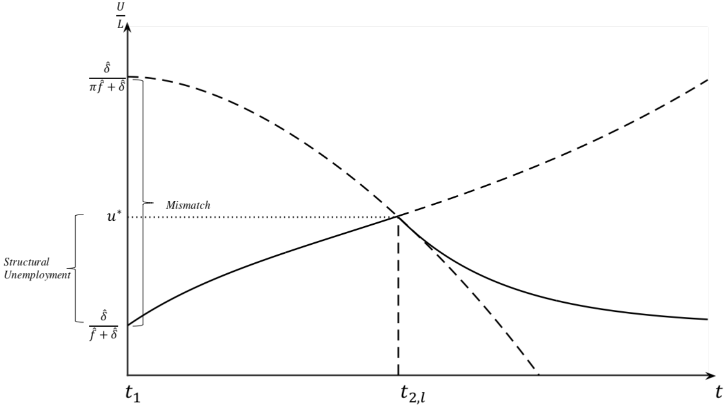
Aggregate Unemployment Rate: hump-shaped pattern

Theorem

The aggregate unemployment rate exhibits a hump-shaped pattern: it first rises due to skill mismatch during industrial upgrading, and then gradually declines to the level without mismatch because inexperienced workers become experienced through on-job learning.

- Remark: **not** at the business cycle frequency, **not** due to exogenous shocks

Aggregate Unemployment Rate: hump-shaped pattern



Comparative Static Analysis

Theorem

(1) **learning efficiency:** *when ξ increases, u shifts downward, and it takes longer to reach its peak value.*
(2) **ISTC rate:** *when A increases, u shifts upward and it takes longer to reach its peak value.*
(3) **mismatch:** *when π decreaes, u shifts upward and it takes less time to reach its peak value.*

See Figures

The Infinite-Industry Model

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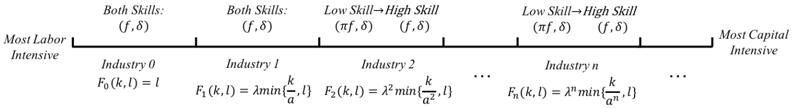
- The production function of the final consumption good is

$$X = \sum_{n=0}^{\infty} x_n \tag{20}$$

The Infinite-Industry Model

- Regardless of whether a worker is inexperienced or experienced in industry $n-1$, he will be a inexperienced worker when he first enters industry n.



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The following conditions are satisfied:

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$$\text{(iv) } \frac{\pi\widehat{f}}{\pi\widehat{f} + \widehat{\delta}} > \frac{a + \lambda}{a\lambda + 1}\frac{\widehat{f}}{\widehat{f} + \widehat{\delta}}.$$

Conditions (i) and (ii) are the same as our benchmark model while (iii) and (iv) change with different thresholds; (iv) ensures that mismatch is sufficiently mild so that workers have no incentives to skip any industry, say, directly move from industry j to industry $j + 2$.

The Infinite-Industry Model

Proposition

In equilibrium, the industrial upgrading process from industry n to industry $n+1$ $(n \geq 2)$ experiences four stages:

- *at stage I, all workers stay in the labor market for industry n, aggregate consumption grows at a strictly positive speed lower than g_c;*
- *at stage II, inexperienced workers in industry n gradually move into industry $n+1$, consumption grows at speed g_c;*
- *at stage III, all the experienced workers in industry n stay in industry n, and consumption grows at a rate which is strictly positive but smaller than g_c;*
- *at stage IV, experienced workers in industry n gradually move into industry $n+1$, the consumption grows at speed g_c.*

See Figure

The Infinite-Industry Model

Proposition

The numbers of inexperienced and experienced workers in the economy change in the following fashion during the structural change from industry n to industry $n+1$ ($n \geq 2$):

- *at stage I, inexperienced workers in industry n decreases, and experienced workers in industry n increases;*
- *at stage II, inexperienced workers in industry n decreases, while experienced workers in industry n increases; both experienced and inexperienced workers in industry $n+1$ increases;*
- *at stage III, there are no inexperienced workers working or looking for jobs in industry n, and the number of experienced workers stays constant in industry n; inexperienced workers in industry $n+1$ decreases and experienced workers in industry $n+1$ increases because of on-the-job learning;*
- *at stage IV, experienced workers in industry n decreases, but experienced and inexperienced workers in industry $n+1$ both increase.*

The Infinite-Industry Models

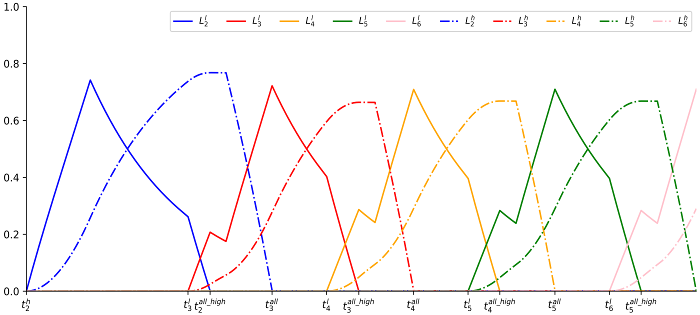


Figure: Inexperienced and experienced workers in each industry

The Infinite-Industry Models

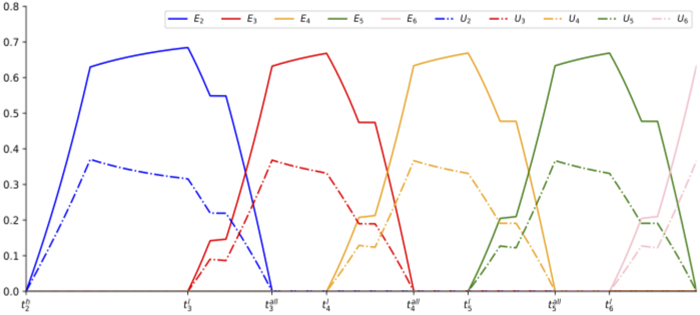


Figure: Employed and unemployed workers in each industry

The Infinite-Industry Models

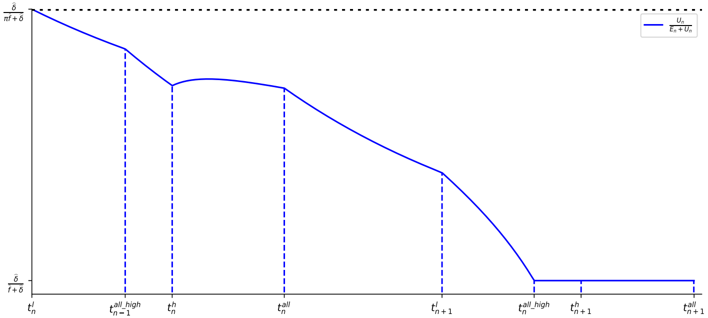


Figure: Industrial unemployment rate for labor market of industry n

The Infinite-Industry Model

Proposition

If ξ converges to 0, the life span of an industry in the long run is

$$\lim_{\substack{\xi \to 0 \\ n \to \infty}} \left(t_{n+2}^{all} - t_{n+1}^{l}\right) = \frac{2\log(\lambda)}{g_c} - \frac{\log\left(\frac{a(a-1)}{\lambda(\lambda-1)} \frac{\lambda \frac{\pi \hat{f}}{\pi \hat{f} + \hat{\delta}} - \frac{\hat{f}}{\hat{f} + \hat{\delta}}}{a \frac{\pi \hat{f}}{\pi \hat{f} + \hat{\delta}} - \frac{\hat{f}}{\hat{f} + \hat{\delta}}}\right)}{A - \rho}, \qquad (21)$$

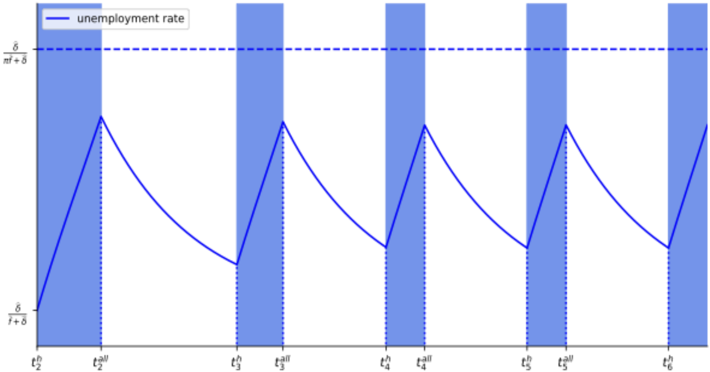
which implies that more serious mismatch (smaller π) results in a longer industry life span.

See Figure

The Infinite-Industry Models

Proposition

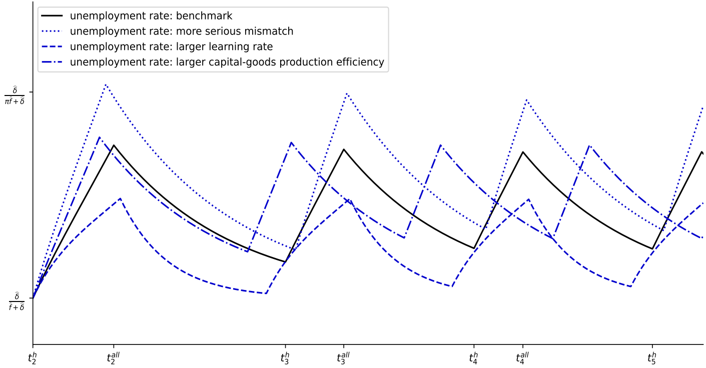
The aggregate unemployment rate in the infinite-industry model exhibits a recurrent cyclical pattern: it increases when experienced workers in an old industry move into the new industry and decreases at all the other stages.



The Infinite-Industry Models

Proposition

When the labor market mismatch becomes severer, or the on-the-job learning rate decreases, or the capital-goods production efficiency increases, both the peak and bottom values of the aggregate unemployment rate become larger.



Extensions

We show that the cyclicality pattern of the aggregate unemployment rate and the comparative results for production efficiency, mismatch and learning efficiency still hold for the following extensions:

- different productivity of workers

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- different productivity of workers
- a matching function which is concave and constant returns to scale

Conclusion

- We develop a highly tractable dynamic model with infinite industries to explore how frictional labor market affects industry dynamics and aggregate economic growth and how labor market performs in the context of industry dynamics

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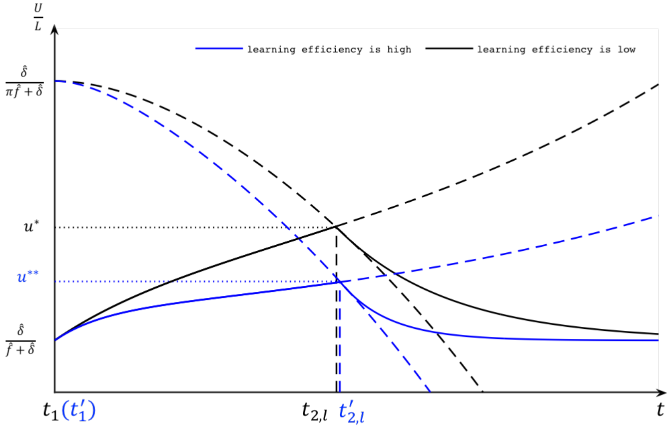
- We develop a highly tractable dynamic model with infinite industries to explore how frictional labor market affects industry dynamics and aggregate economic growth and how labor market performs in the context of industry dynamics
- We show that the aggregate unemployment rate exhibits a hump-shaped pattern: it rises when experienced workers in a sunset industry move into a sunrise industry and suffers from skill mismatch. The unemployment rate declines later on when those inexperienced workers become experienced through on-job learning. The unemployment rate goes up again as the current industry is again gradually replaced by an even more capital-intensive industry, ad infinitum.

Conclusion

- We develop a highly tractable dynamic model with infinite industries to explore how frictional labor market affects industry dynamics and aggregate economic growth and how labor market performs in the context of industry dynamics
- We show that the aggregate unemployment rate exhibits a hump-shaped pattern: it rises when experienced workers in a sunset industry move into a sunrise industry and suffers from skill mismatch. The unemployment rate declines later on when those inexperienced workers become experienced through on-job learning. The unemployment rate goes up again as the current industry is again gradually replaced by an even more capital-intensive industry, ad infinitum.
- We show how investment-specific technological change rate, on-job learning efficiency and skill mismatch affect industry life spans and aggregate unemployment rate.

Aggregate Unemployment Rate: comparative analysis



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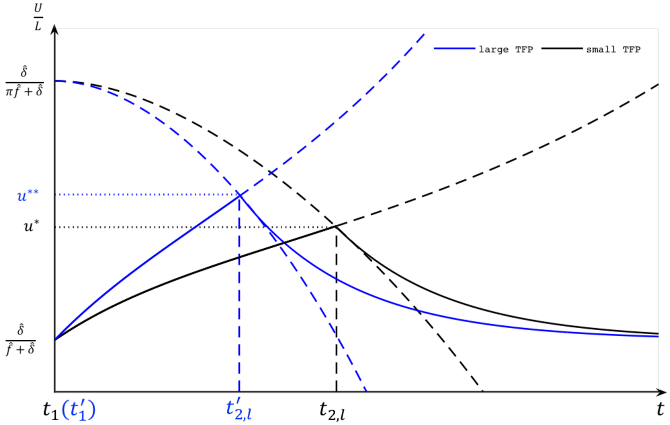
Aggregate Unemployment Rate: comparative analysis



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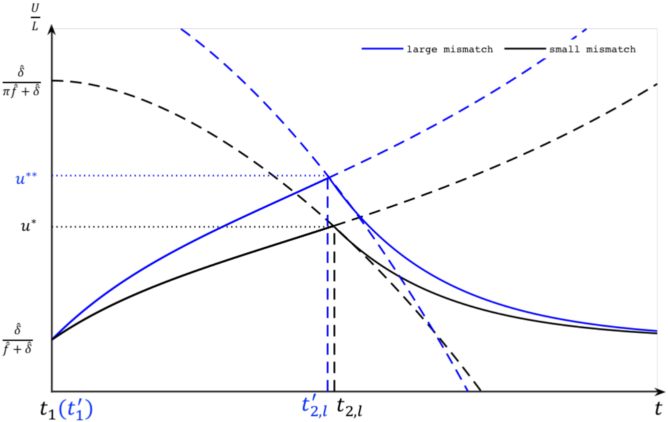
Aggregate Unemployment Rate: comparative analysis



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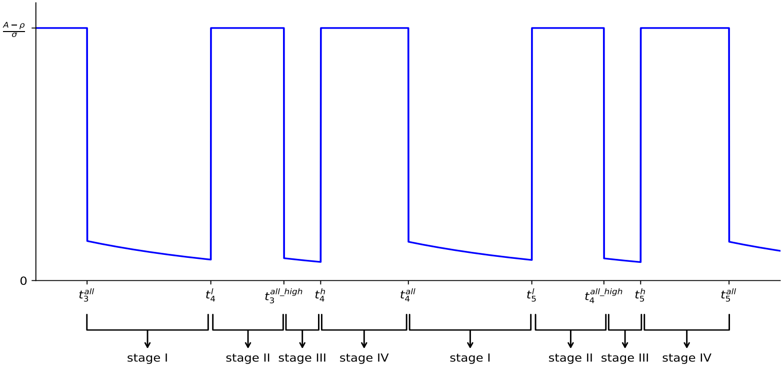
Consumption growth rate at four stages



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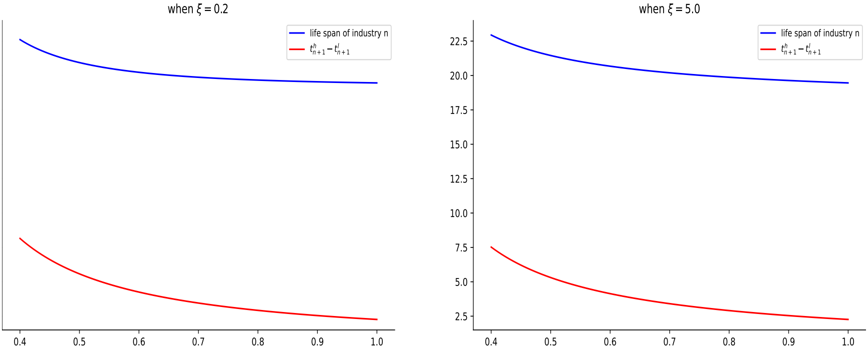
How does the life span of industries change with mismatch



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Supporting Evidence

Table: Correlation between Unemployment Rate and Cross-Sector Employment Reallocation Rate

	(1) wgt.=emp_t		(2) wgt.=emp_{t-1}		(3) unweighted	
Reallocation	0.55***	0.59**	0.53***	0.57***	0.30**	0.26*
	(0.19)	(0.22)	(0.19)	(0.21)	(0.13)	(0.13)
Recession D	N	Y	N	Y	N	Y
Post2001 D	N	Y	N	Y	N	Y
R^2	0.11	0.14	0.11	0.14	0.08	0.10
Obs.	66	66	66	66	66	66

Note: This table show the results of regressing unemployment rate on cross-sector employment reallocation rate from 1955-2020.

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Supporting Evidence

Table: Average Working Experience

	Working experience until year t
Workers who change sectors in years (t,t+2]	2.74
Workers who do not change sectors in year (t,t+2]	4.10

Data Source: PSID 1999-2019. This table shows the average working years until year t in a sector between those who changed to a different sector in year $(t, t+2]$ and those who did not.

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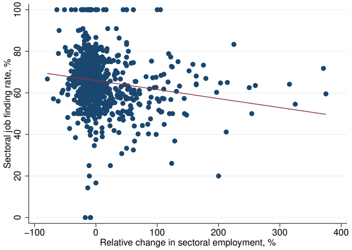
Supporting Evidence



(a) Job Finding Rate (b) Unemployment Rate

Figure: Correlation between Sectoral Employment Change and Sectoral Job Finding Rate & Unemployment Rate

The figure plots the unemployment rate (vertical) *v.s.* the relative change in employment across 55 sectors annually from 2003-2021. Unemployment in a sector refers to the unemployed whose last job was in the given sector.

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Supporting Evidence

Table: Correlation between Job Finding Rate, Unemployment Rate and Sector Employment Change

	Dep. var: JF_{it}		Dep. var: UN_{it}	
	(1)	(2)	(1)	(2)
EC_{it}	-0.043^{***}	-0.027^{**}	0.025^{***}	0.026^{***}
	(0.009)	(0.012)	(0.002)	(0.001)
Sector FE	N	Y	N	Y
Year FE	N	Y	N	Y
R^2	0.03	0.32	0.14	0.84
Obs.	863	863	1086	1086

Note: The sample covers 55 3-digit sectors annually from 2003 to 2021.

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