Vacancy Chains

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[Preliminary and Incomplete]

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* This research was conducted with restricted access to Bureau of Labor Statistics (BLS) data. The views expressed here do not necessarily reflect the views of the BLS, the Federal Reserve Bank of Philadelphia, the Federal Reserve Board, or the Federal Reserve System as a whole.

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Connotes some sunk investment.

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What is a "position"?

Connotes some sunk investment.

Our project: this has interesting implications.

I. Implications for frictions

New plant-level facts on *replacement hiring*.

A lot of recruitment replaces positions vacated by quits.

Plants report no *net* change in employment, often for years at a time, despite gross turnover via quits.

Who cares?

Nature of labor frictions: origins in production structure?

Vacancy chains: positive feedback in job creation…

II. Implications for fluctuations

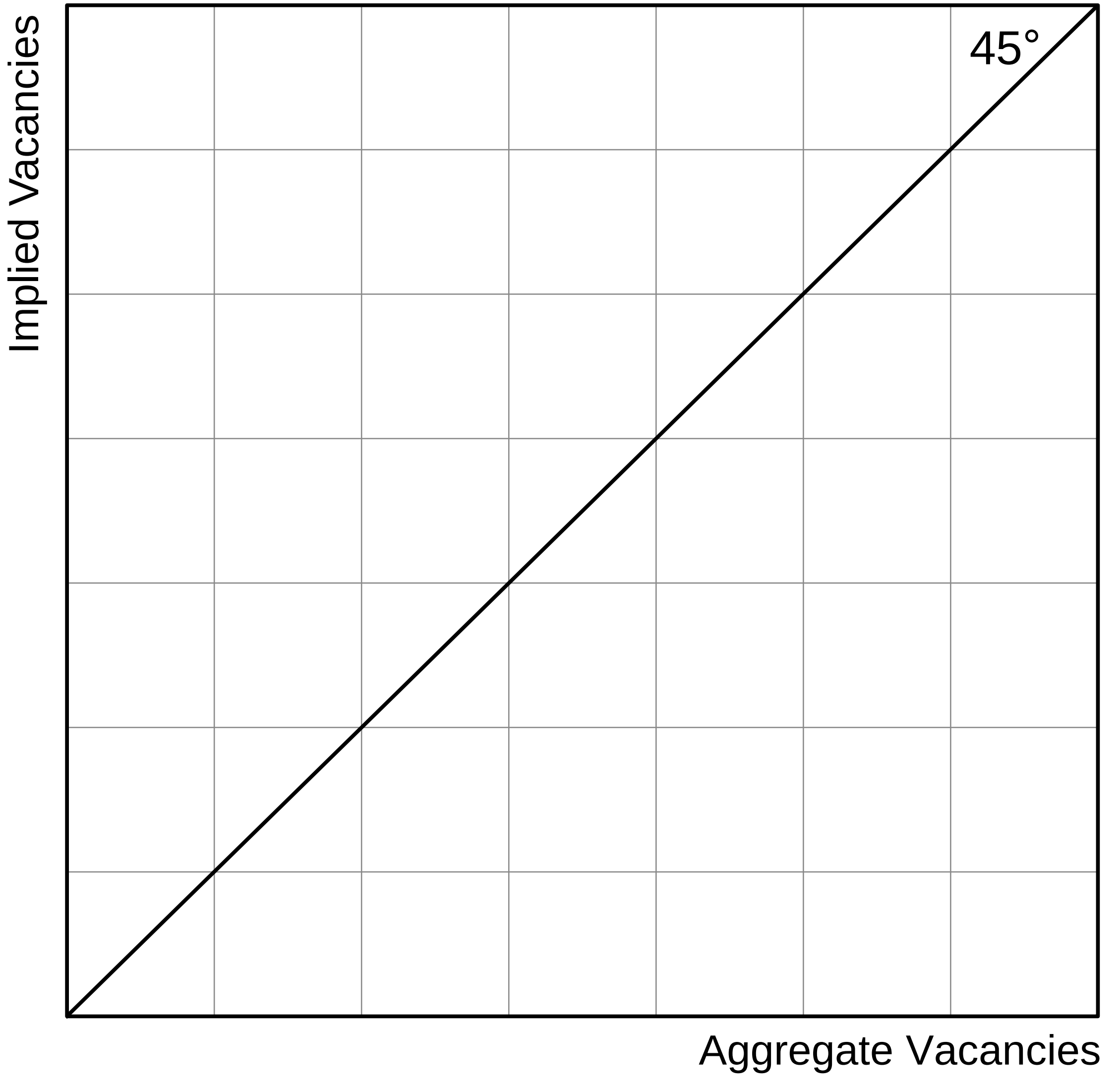
Vacancy chains.

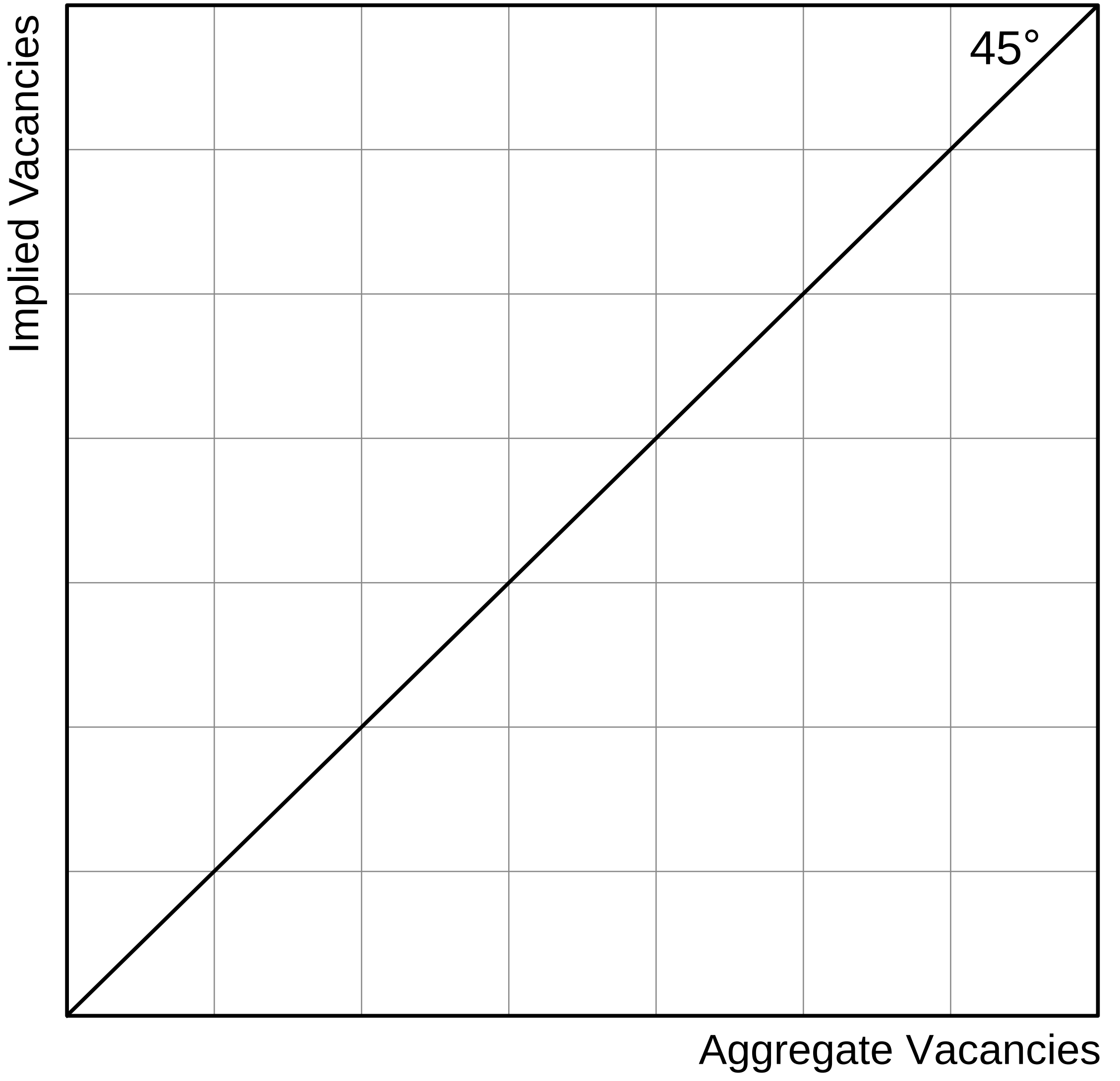
Vacancies

$\Rightarrow$ Poaching

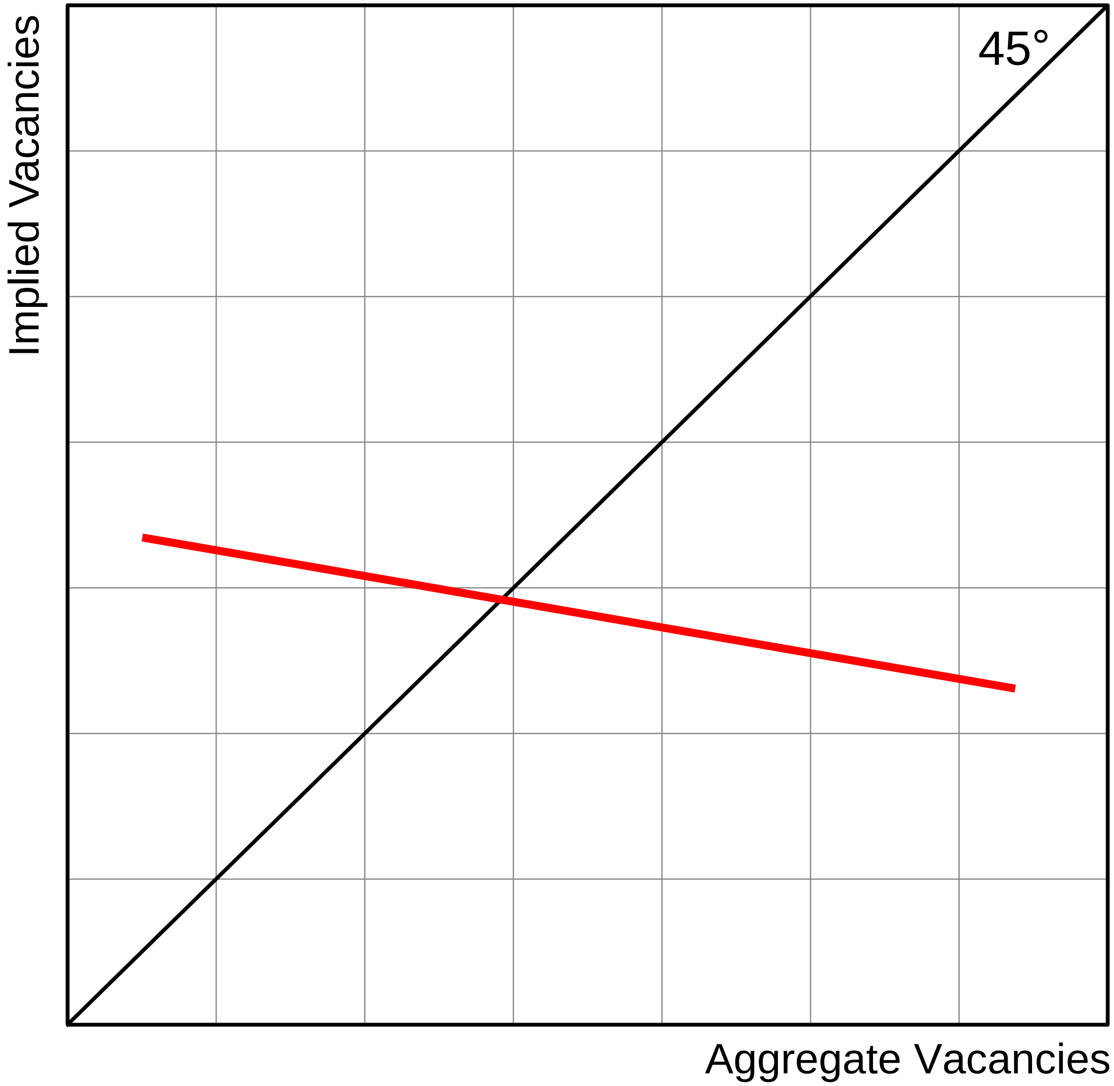
$\Rightarrow$ Replacement

$\Rightarrow$ Vacancies…


45°
Implied Vacancies
Aggregate Vacancies



Search model: $V\uparrow \Rightarrow$ Hiring cost $\uparrow \Rightarrow$ Desired hires $\downarrow$: $-$**ve feedback**



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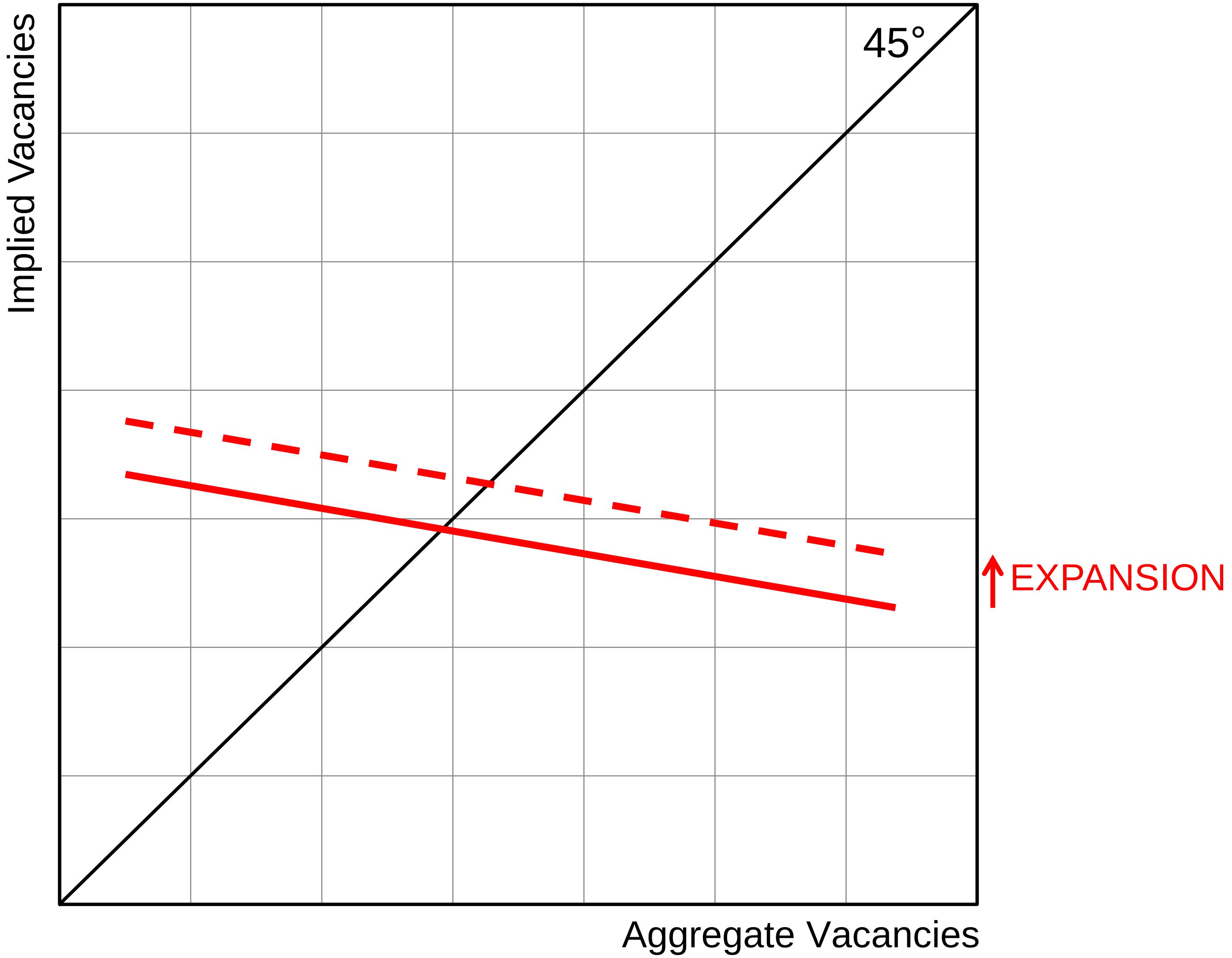

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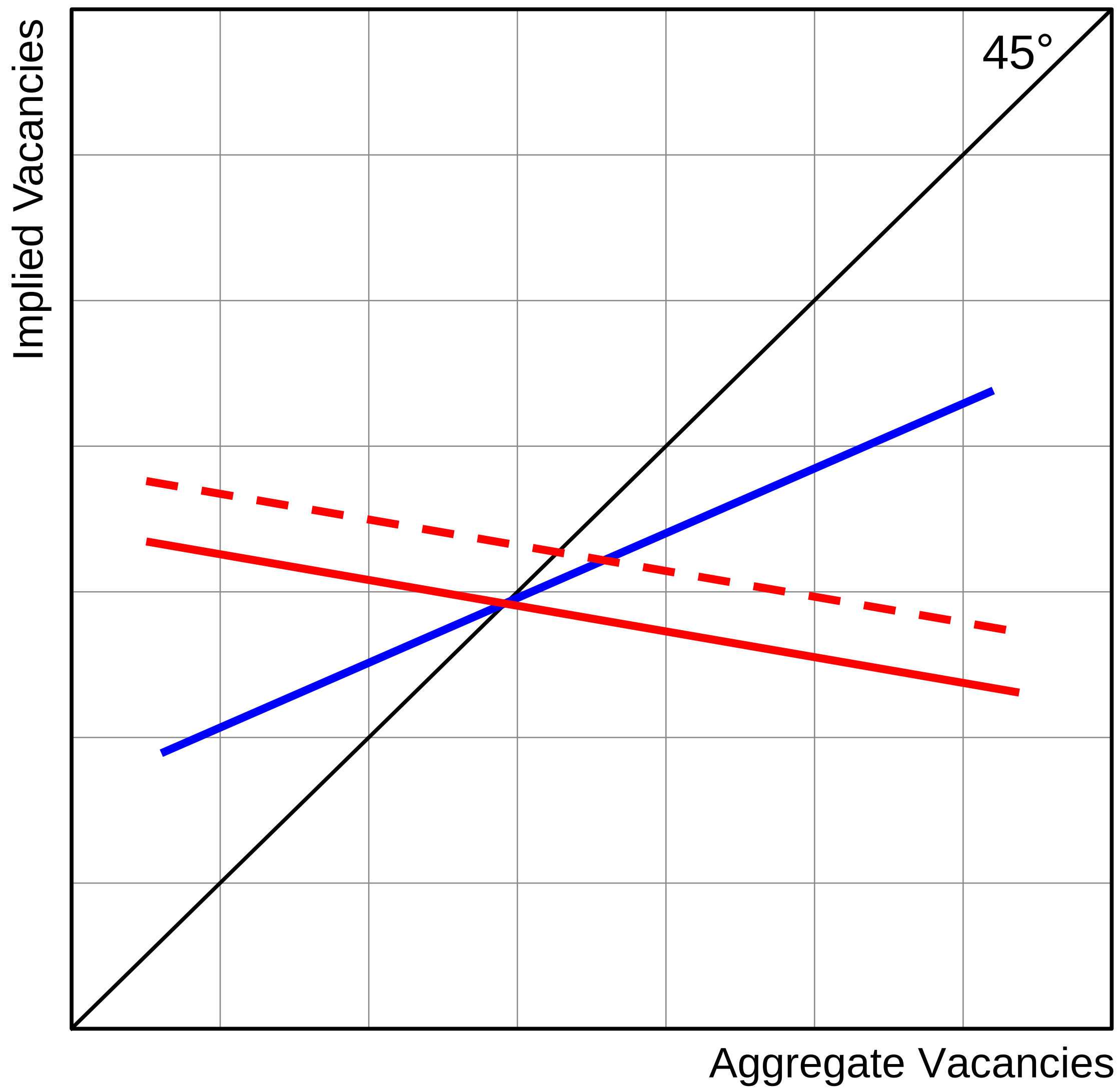
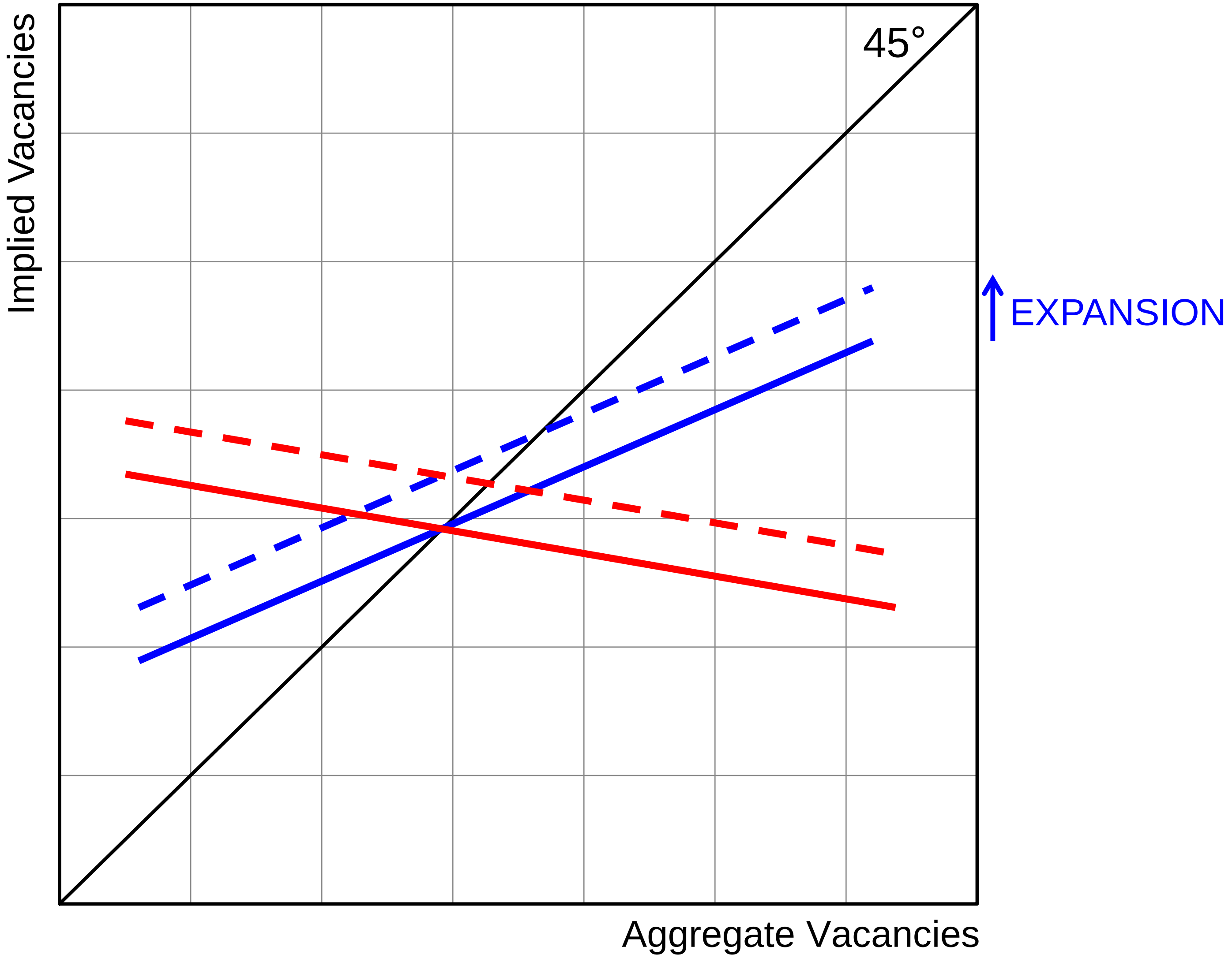


Replacement: $V\uparrow \Rightarrow$ Quits $\uparrow \Rightarrow$ Desired hires $\uparrow$: +**ve feedback**



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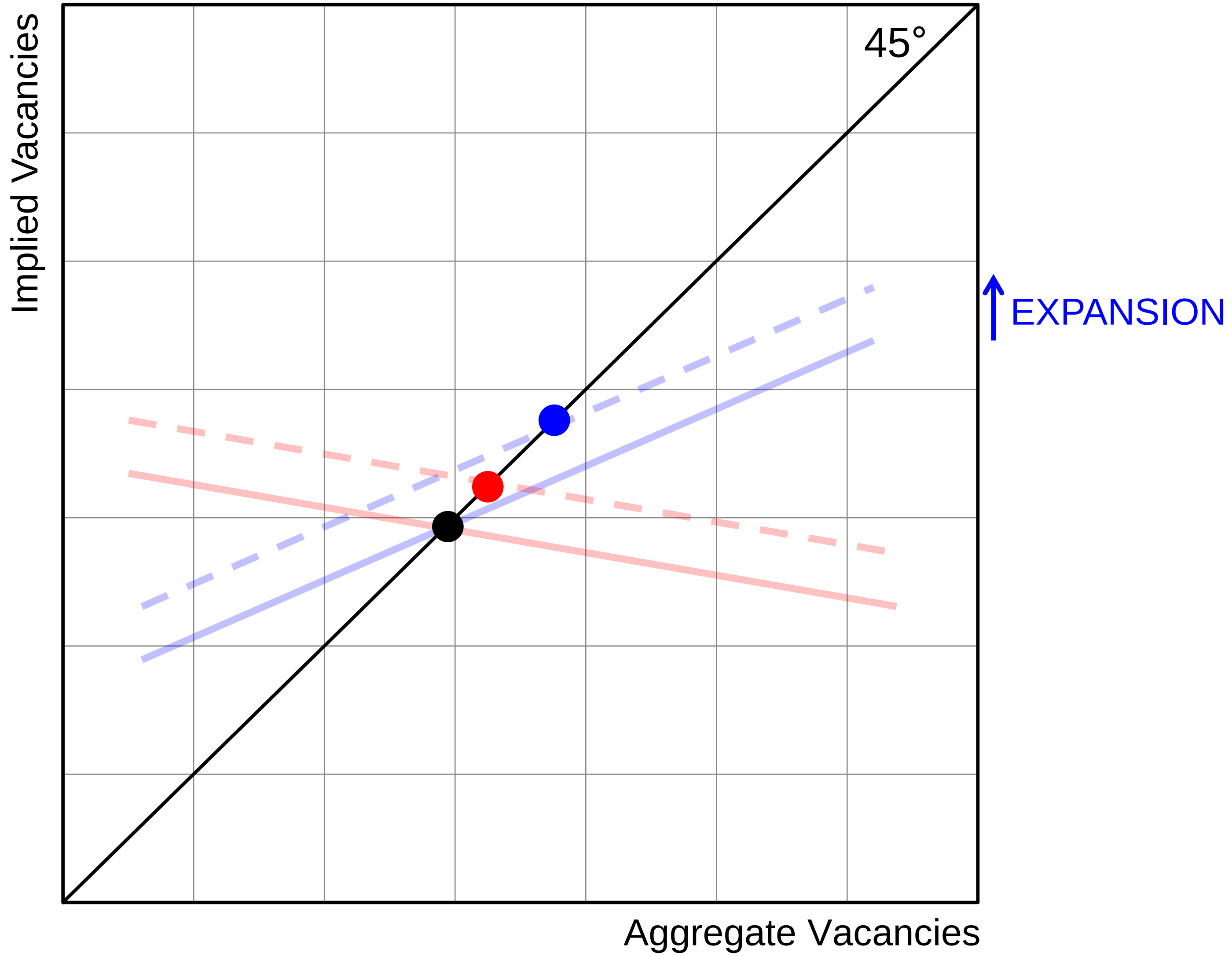

Replacement: Amplification of aggregate labor market responses.

Questions / contributions

Why are labor market stocks and flows so volatile over the business cycle?

And what are the microeconomic foundations that give rise to this volatility?

[How to model interaction of on-the-job search with firm dynamics, and why it's important.]

Related literature

- Faberman and Nagypal (2008).

  Current quits predict future hires.

- Akerlof, Rose and Yellen (1988).

  Vacancy chains $\Rightarrow$ procyclical quits. But no amplification.

- Lentz and Mortensen (2012).

  Large firms $\cap$ on-the-job search. But no shocks.

Data

1. Quarterly Census of Employment and Wages.

   Census of UI-covered ($\approx$ 98%) employment in U.S.

- Establishment microdata onsite at BLS.

  Excludes MA, NH, NY, WI, FL, IL, MS, OR, WY, PA.

  Restrict analysis to continuing, private establishments.

  Broad coverage $\Rightarrow$ natural establishment panel

- 2014q2: 5 million establishments; 77 million workers

Data

2. Job Openings and Labor Turnover Survey.

   ≈ 16,000 establishments per month

   “Certainty sample” + 24-month rotating panel

- Establishment microdata onsite at BLS.

- Key: JOLTS measures *gross* flows at estab. Level

  Gross hires and separations.

  Separations decomposed into Quits, Layoffs and Other.

Facts on replacement hiring

1. Inaction over **net** employment changes.

   Despite nontrivial quit rates.

2. Slow **decay** of inaction by frequency of adj.

   Much slower than geometric decay.

3. Large cumulative gross turnover | inaction.

   Cumulative replacement is nontrivial.

4. Replacement is a large share of total hires

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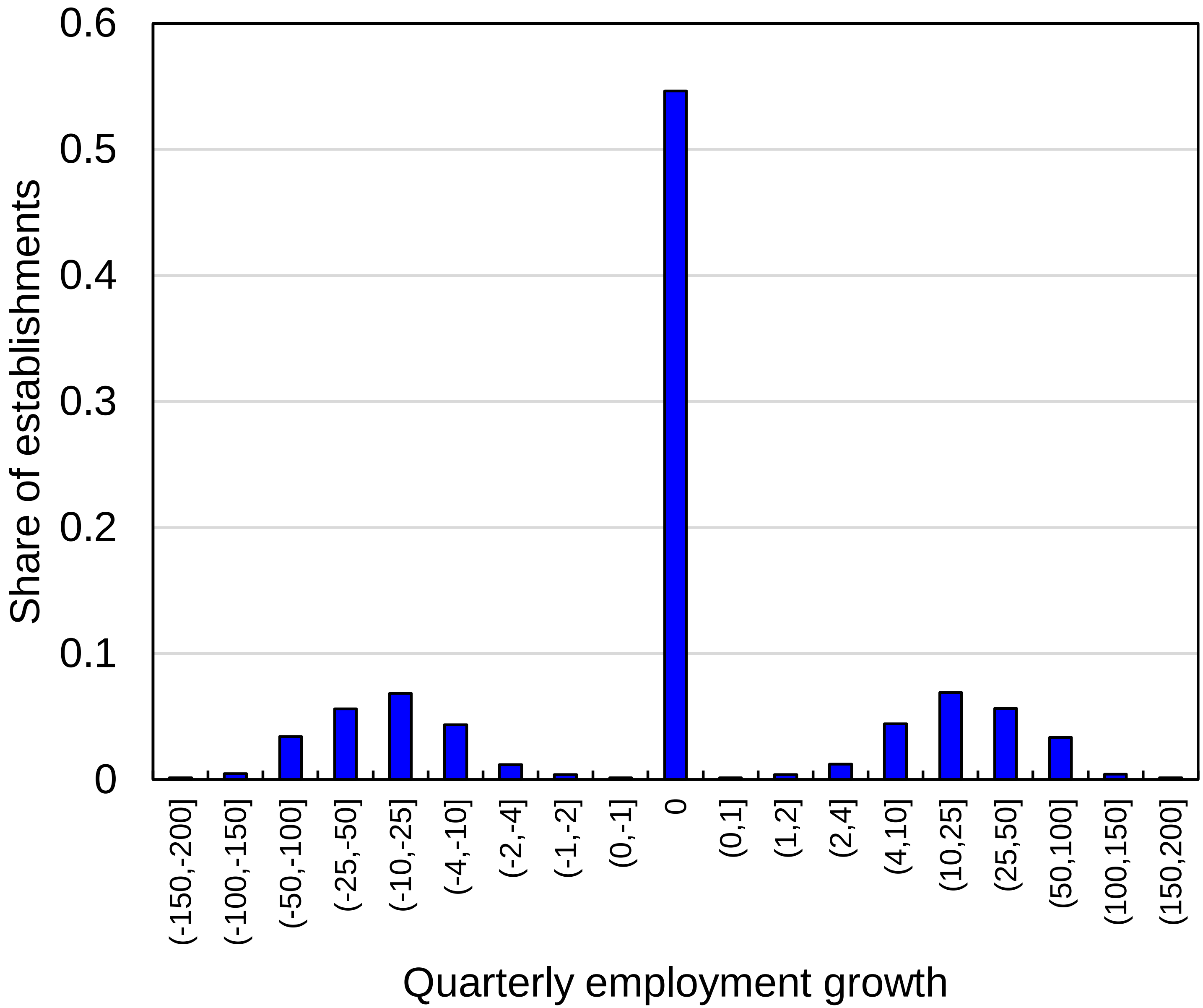
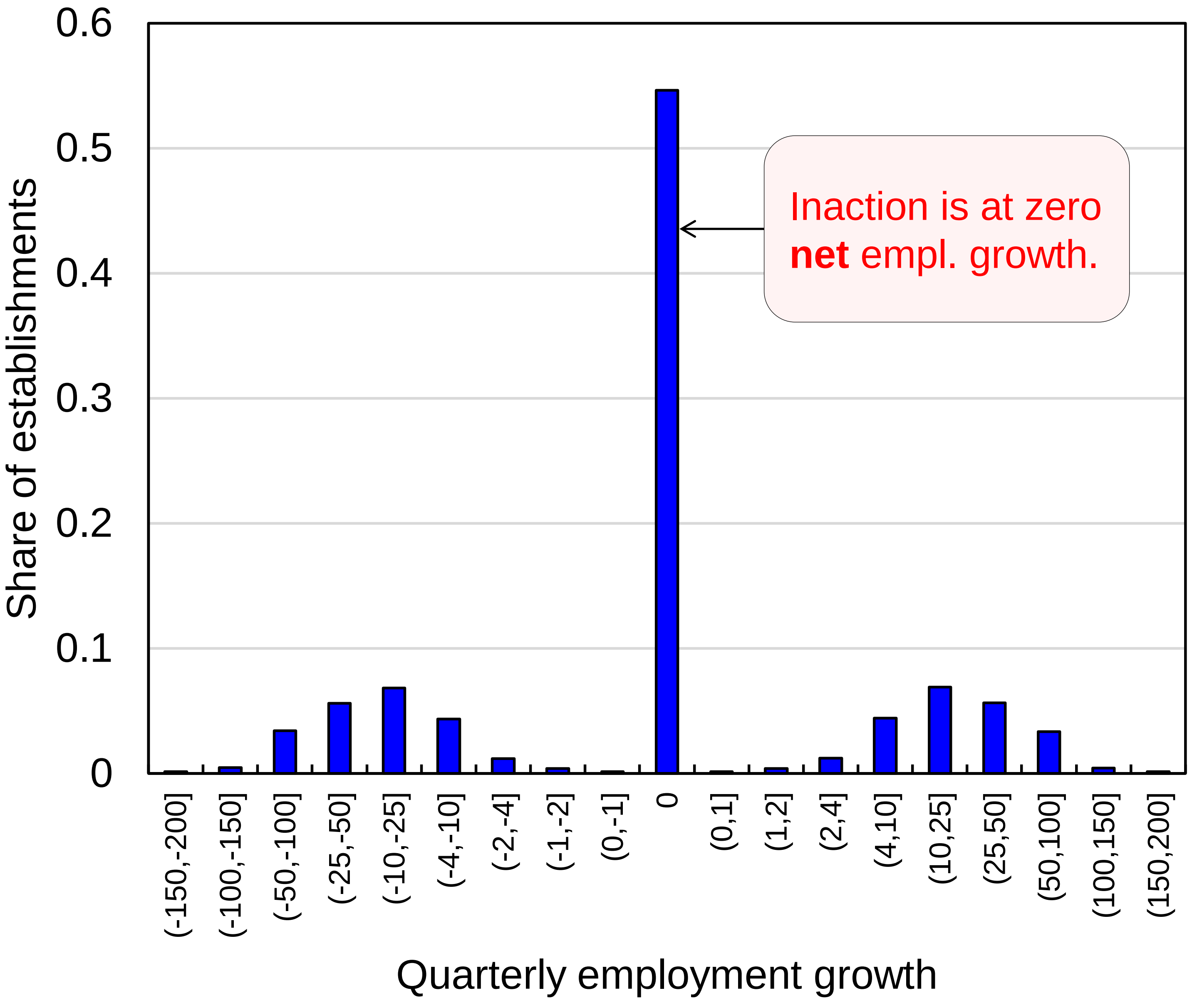


Distribution of employment growth, QCEW



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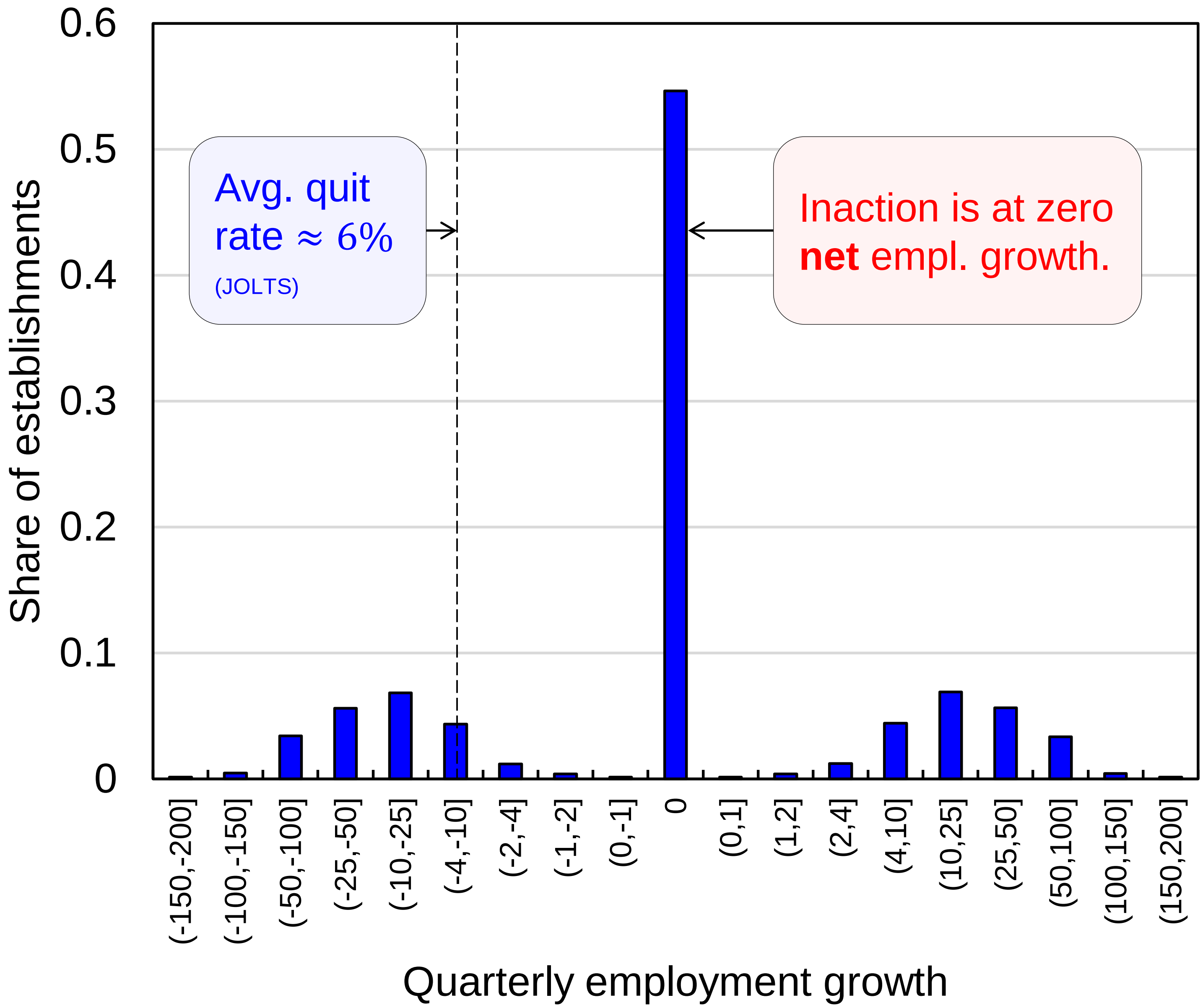

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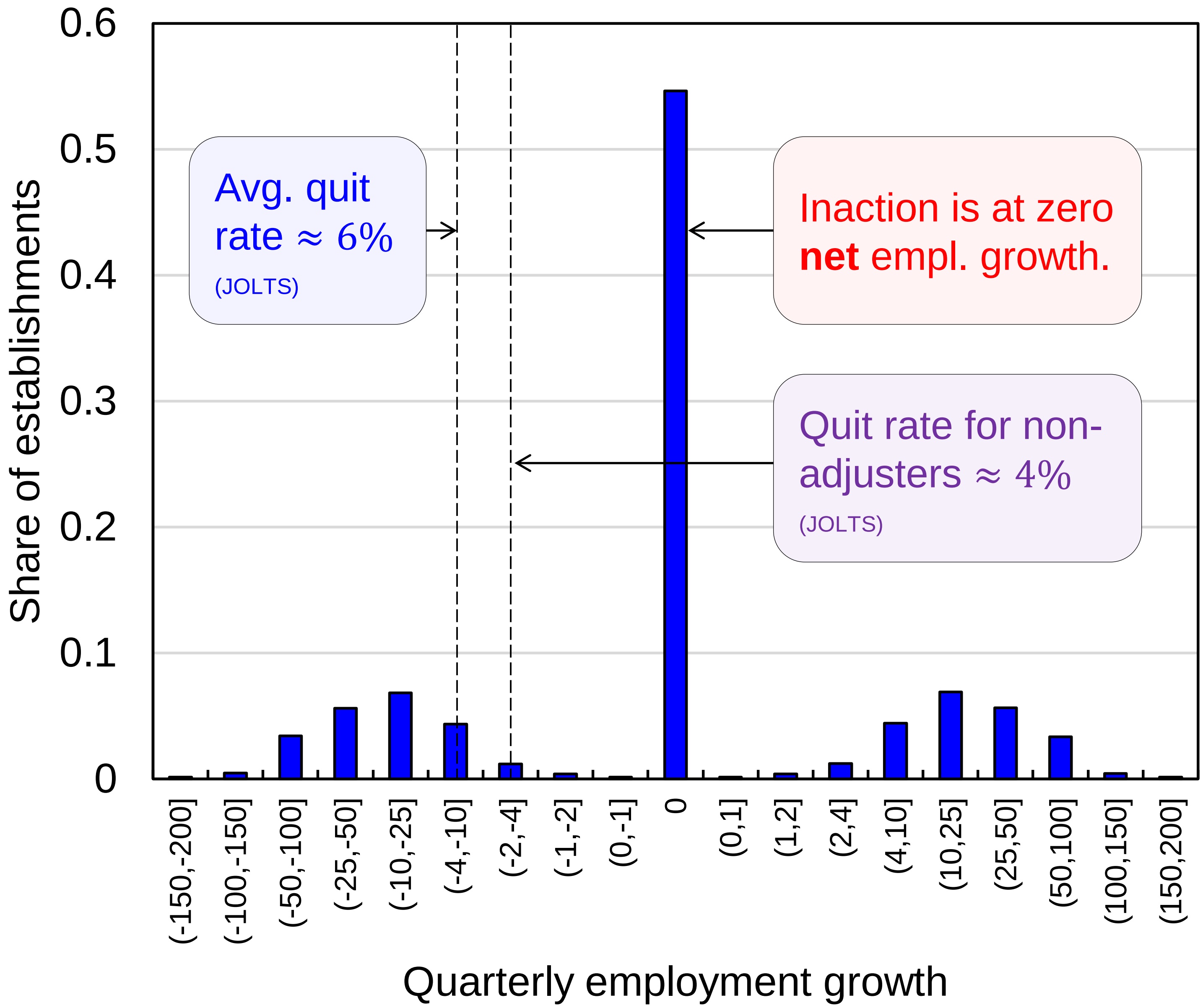

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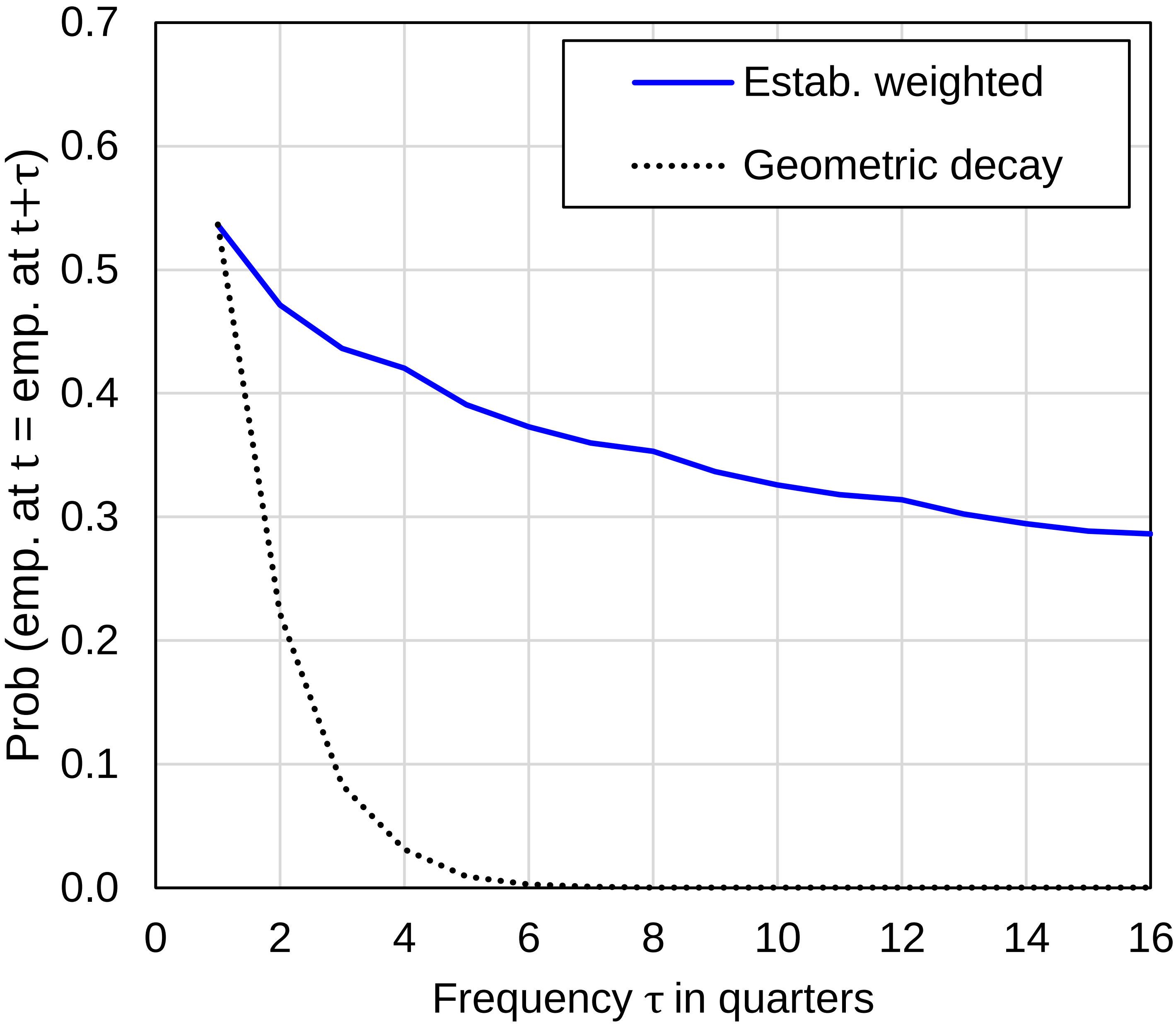
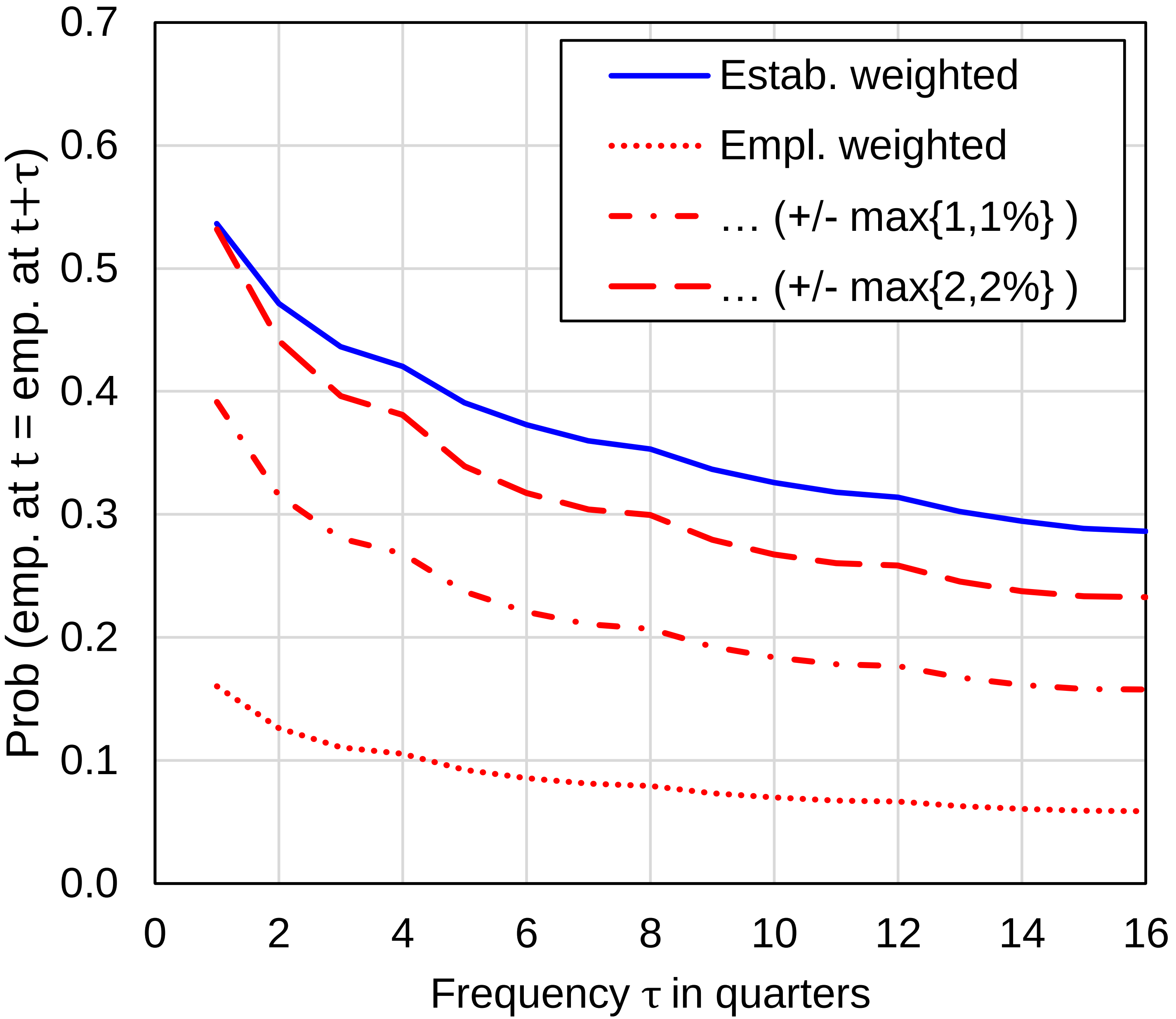


Slow decay of inaction, QCEW, Establishment weighted



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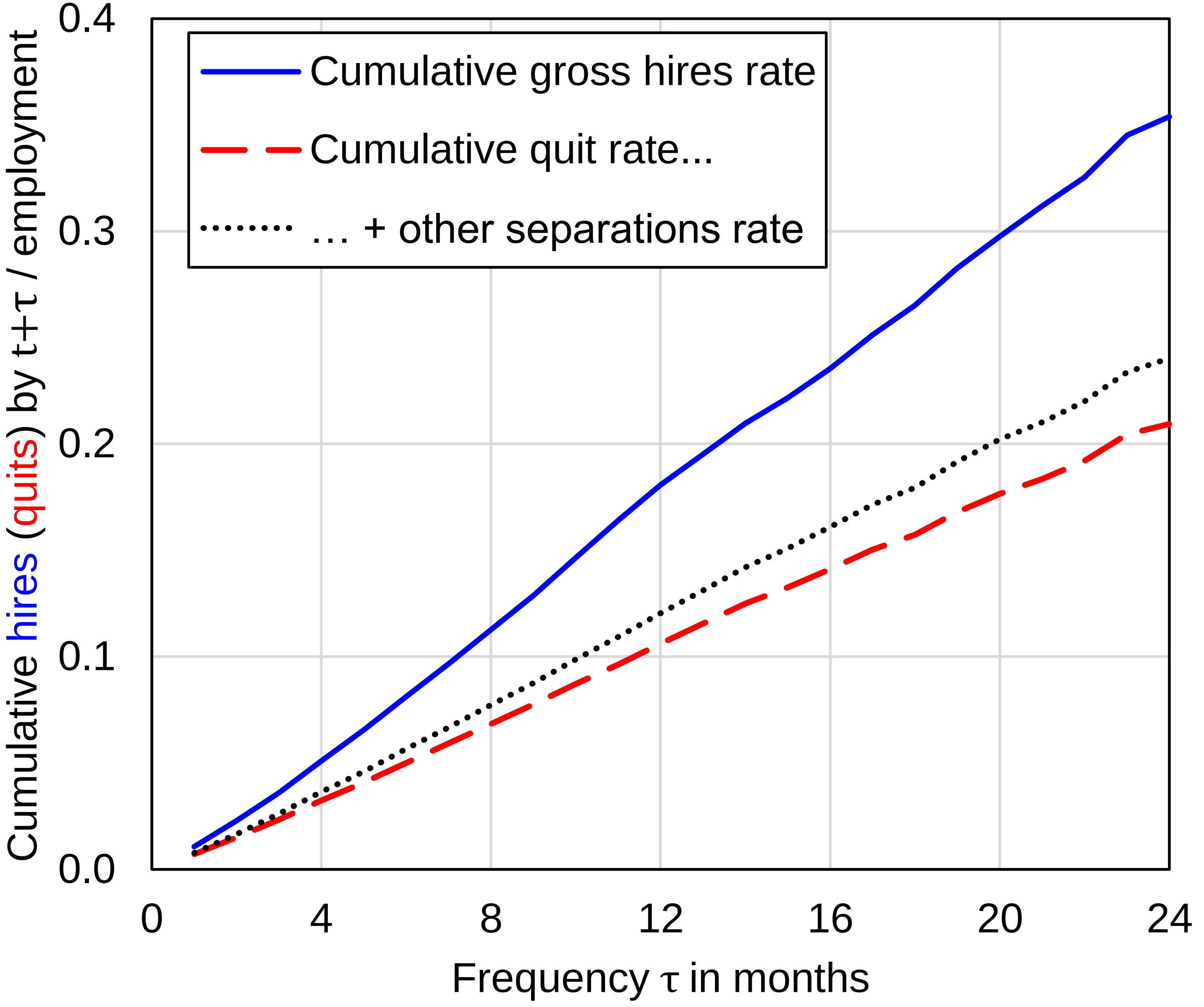

Cumulative gross turnover at inactive establishments, JOLTS

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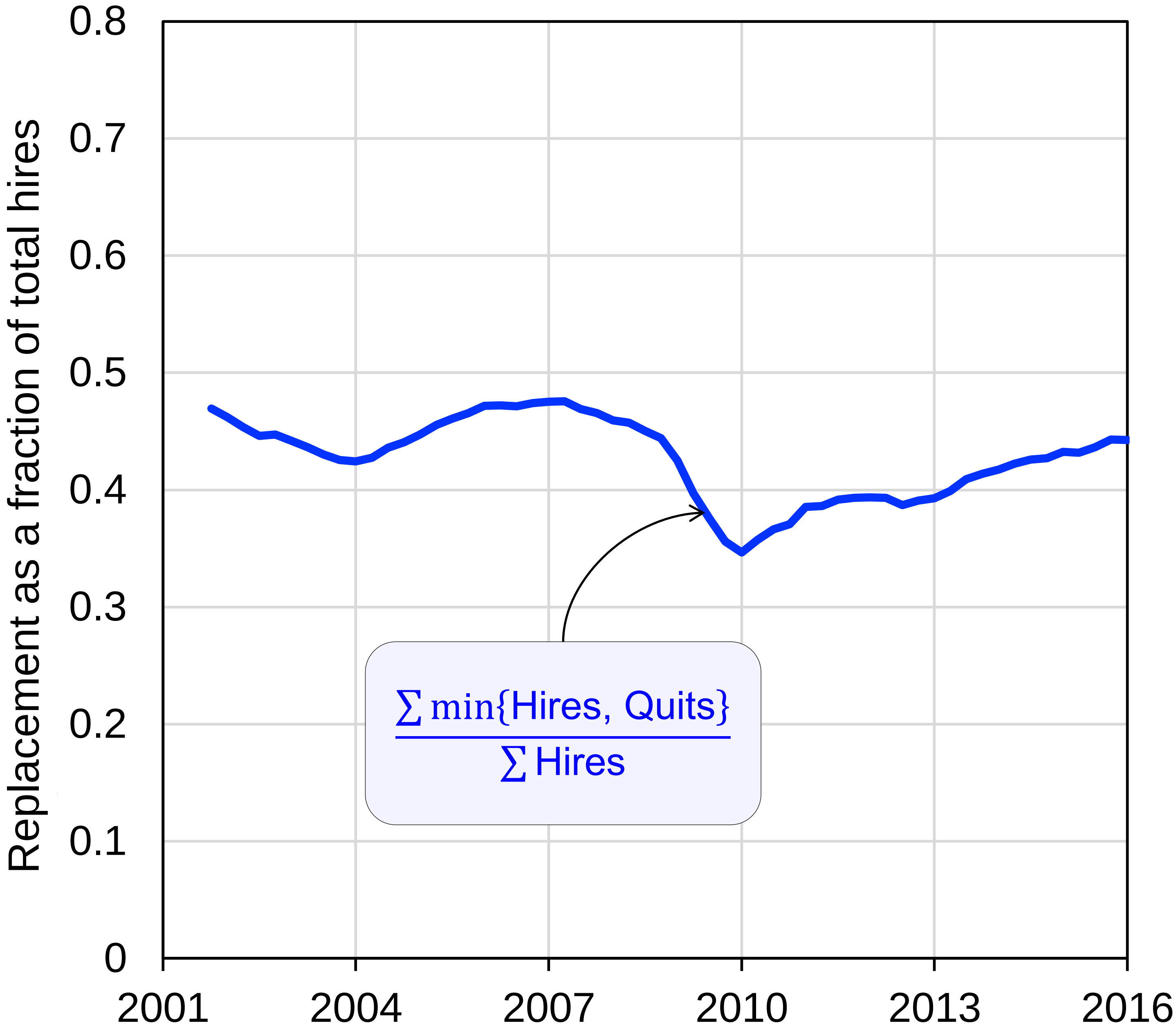

Replacement as a fraction of total hires, JOLTS

Lessons from the data

Firms have **reference levels** of employment to which they return routinely.

Many short-run adjustments appear to be **returns** to reference level.

Suggests role of **replacement hiring**.

Could this matter?

Towards a model

Stylized facts $\Rightarrow$ model with three ingredients:

1. Multi-worker firms.

   To map theory to data.

2. On-the-job search.

   To generate quits.

3. Persistent reference levels of employment.

   To generate replacement.

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“Firm Dynamics with On-the-Job Search”

(feat. Axel Gottfries)

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“Vacancy Chains”

Firm's problem

$$\Pi(n_{-1}, x) \equiv \max_{v,S}\{pxF(n)$$
$$-w(\cdot)n$$
$$-c(v)$$
$$+\beta\mathbb{E}[\Pi(n, x')|x]\}$$

subject to $\Delta n = q(\cdot)v - \delta(\cdot)n_{-1} - S$

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Multi-worker firms

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Multi-worker firms

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On-the-job search

Wages and turnover (w, q and δ)

Two challenges to wage determination:

1. Multi-worker firms. 2. Employees with outside offers.

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Use surplus sharing at margin with continual renegotiation.

[Stole/Zwiebel 96; Bruegemann et al. 16; Gottfries 18]

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Use surplus sharing at margin with continual renegotiation.

[Stole/Zwiebel 96; Bruegemann et al. 16; Gottfries 18]

$\Rightarrow$ Worker's surplus $\propto$ Firm's marginal surplus $\equiv J$.

$\Rightarrow$ J sufficient statistic for recruitment and retention:

$$q = q(J) \text{ and } \delta = \delta(J).$$

Conceptually and analytically simple. Efficient separations.

Matching

- Matching function, $M(U + s(L - U), V)$.

Fixed employed search intensity s.

Tightness $\theta = V/[U + s(L - U)]$.

On-the-job search

Vacancy contact rate $\chi(\theta) = M(1/\theta, 1)$.

Unemployed contact rate $\phi(\theta) = M(1, \theta)$.

Employed contact rate $s\phi(\theta)$.

CRS in matching

Turnover

- Recruitment rate

$$q(J) = \chi(\theta)[\upsilon + (1-\upsilon)\mathbb{J}_E(J)]$$

V contacts a searcher

υ are U Hire w.p. 1

$1-\upsilon$ are E Hire w.p. $\mathbb{J}_E(J)$

where $\mathbb{J}_E(J)$ is c.d.f. of Js among the *employed*.

Turnover

- Recruitment rate

$$q(J) = \chi(\theta)[v + (1 - v)\mathbb{J}_E(J)]$$

- Quit rate

$$\delta(J) = s\phi(\theta)[1 - \mathbb{J}_V(J)]$$

E searcher contacts V

Quits w.p. $1 - \mathbb{J}_V(J)$

where $\mathbb{J}_V(J)$ is c.d.f. of Js among *vacancies*.

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$$\Pi(n_{-1}, x) \equiv \max_{v,S}\{pxF(n)$$

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$$\Pi(n_{-1}, x) \equiv \max_{v,S}\{pxF(n)$$
$$-w\big(\mathbb{J}(J)\big)n$$
$$-c(v)$$
$$+\beta\mathbb{E}[\Pi(n, x')|x]\}$$

subject to $$\Delta n = q\big(\mathbb{J}(J)\big)v - \delta\big(\mathbb{J}(J)\big)n_{-1} - S$$

- Π a function of its derivative J, and distributions $\mathbb{J}$.
- And $\mathbb{J}$s are induced by $\{\Pi, J\}$ by aggregation.

Steady-state equilibrium

Given $\Omega = \{\theta, v, \mathbb{J}_V, \mathbb{J}_E; p\}$:

⇒ Firm labor demand: $n(n_{-1}, x; \Omega)$.

⇒ Agg. labor demand and U inflows: $N(\Omega)$, $S(\Omega)$.

⇒ Update $\Omega' = \{\theta', v', \mathbb{J}'_V, \mathbb{J}'_E; p\}$.

Steady-state equilibrium: $\Omega' = \Omega$.

The challenge

Distributions $\{\mathbb{J}_V, \mathbb{J}_E\}$ or, equivalently, turnover rates $\{\delta(\cdot), q(\cdot)\}$ part of state.

How to solve for them?

Some progress

- Set in continuous time.
- Isoelastic production, $F(n) = n^{\alpha}$.
- Idiosyncratic shocks, $dx/x = \mu dt + \sigma d\mathcal{W}$.

Wages

Unemployment outside option

$$w(n,x) =$$

$$\eta\left[px\alpha n^{\alpha-1} \qquad + \phi\int[1-\mathbb{J}_V(j)]dj\right] + (1-\eta)b$$

Wages

Infra-marginal surplus

Unemployment outside option

$$w(n,x) = \eta\left[pxan^{\alpha-1} - w_n n + \phi\int[1-\mathbb{J}_V(j)]dj\right] + (1-\eta)b$$

Wages

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$$\eta\left[px\alpha n^{\alpha-1} - w_n n + \phi\int[1-\mathbb{J}_V(j)]dj\right] + (1-\eta)b$$

$$-\eta s\phi\int_J[1-\mathbb{J}_V(j)]dj - \eta\frac{d(\delta n)}{dn}J$$

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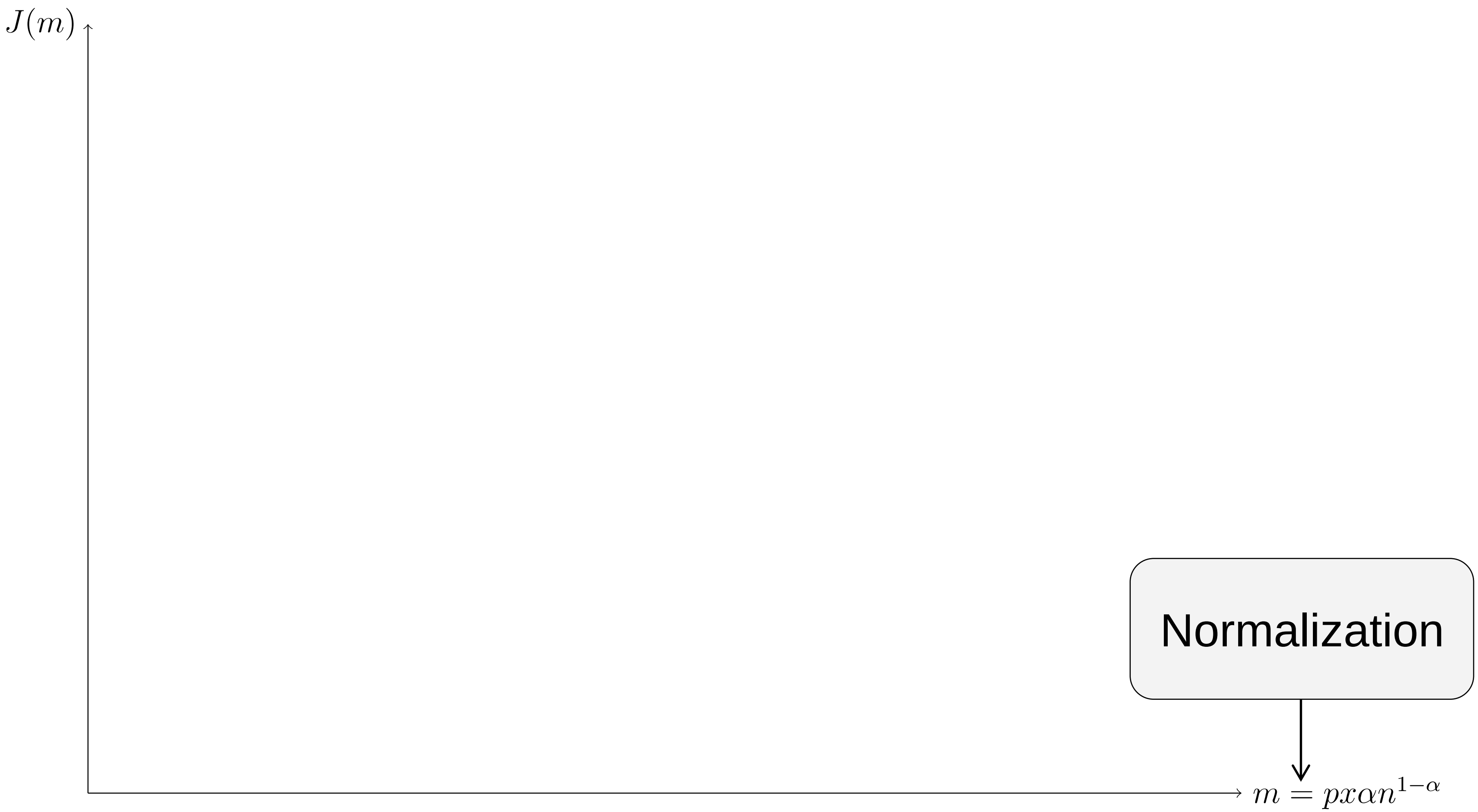
  Surplus, quit and recruitment rates: $J(m)$, $\delta(m)$, $q(m)$.
- Per-worker hiring cost, $c(h) = ch$.
- Job-to-job turnover from low m to high m.

  Suppose (for now) this also breaks ties.

Optimal labor demand



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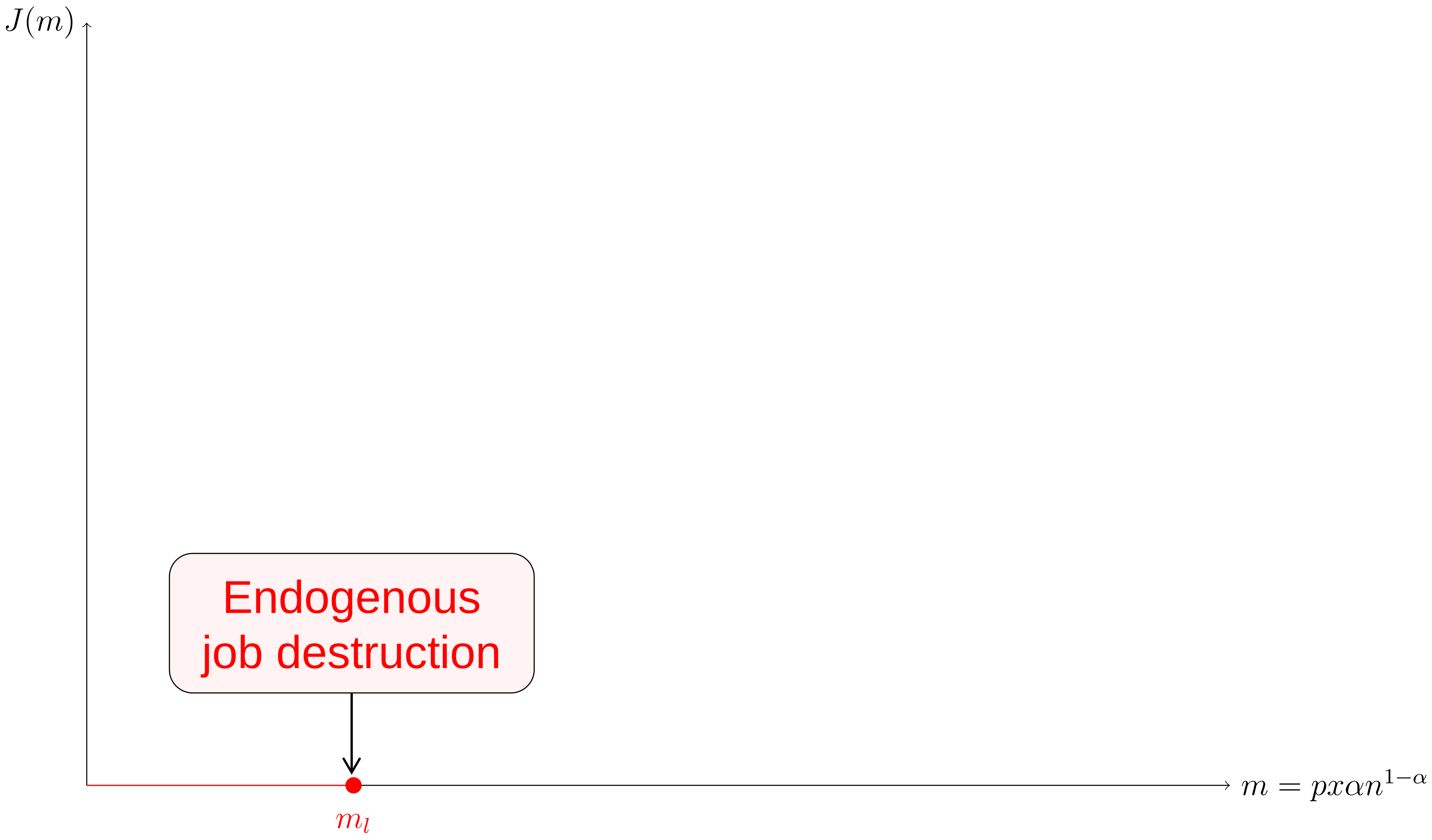

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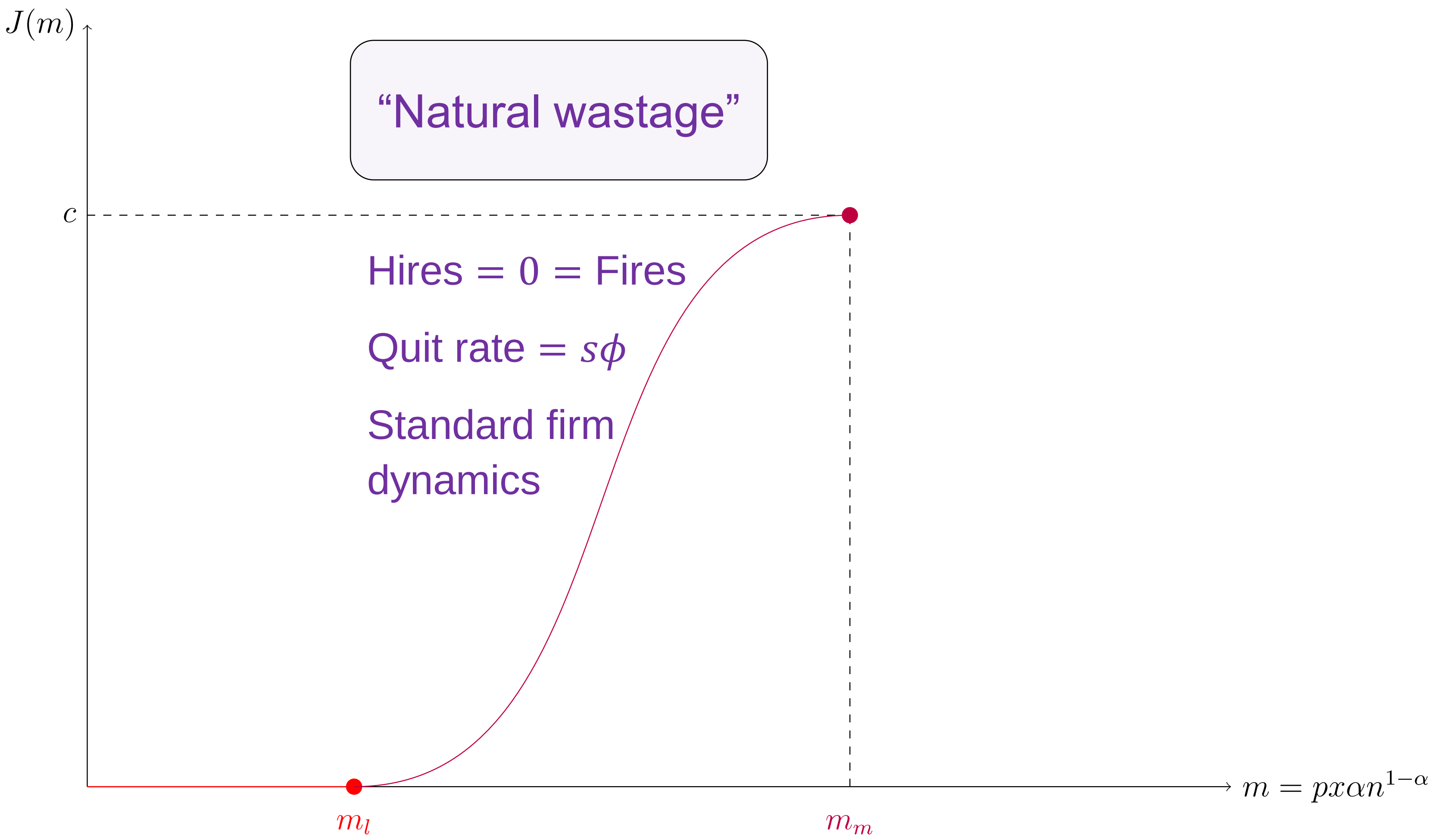

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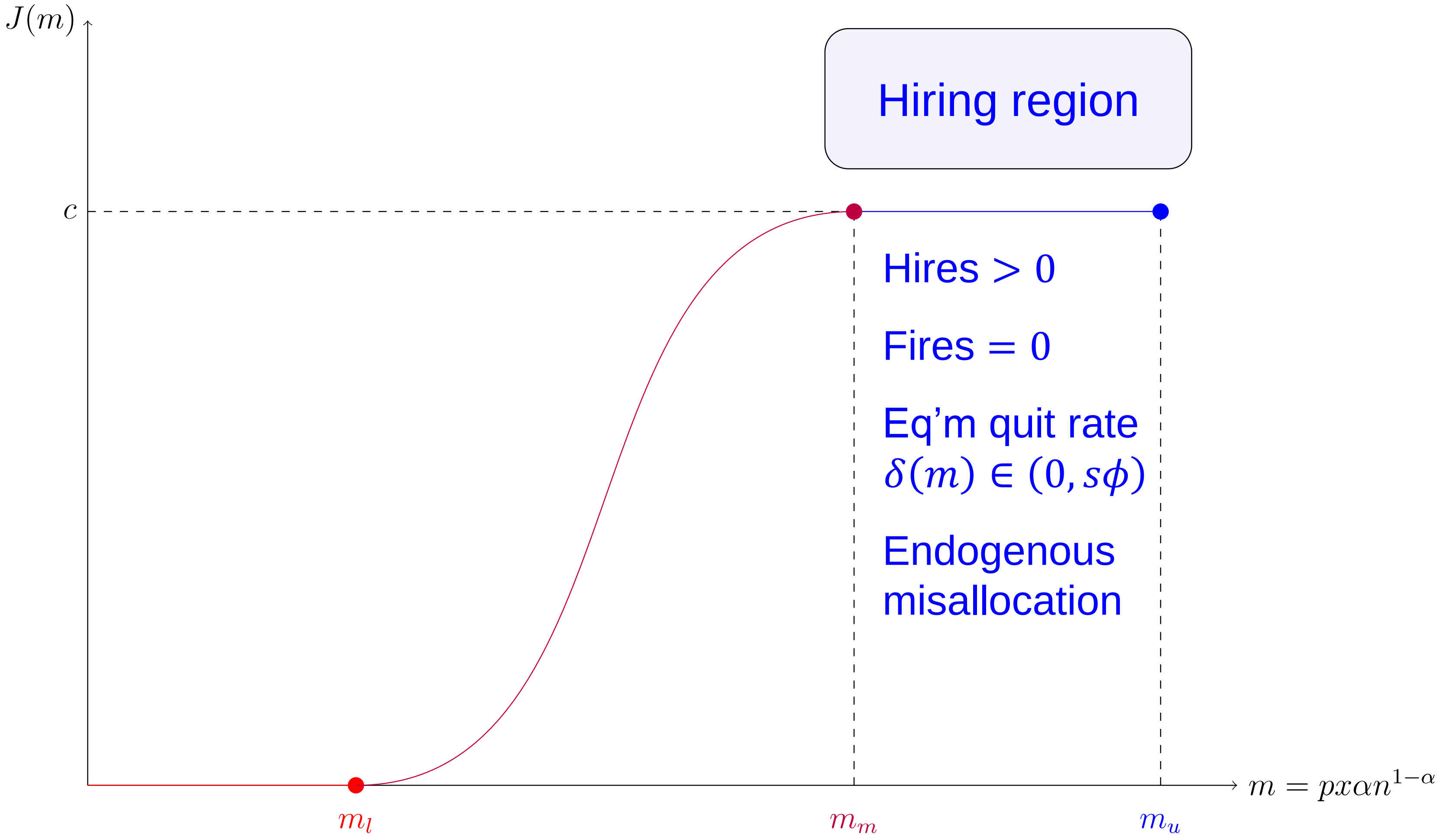

Solution for $\boldsymbol{\delta(m)}$

Bellman equation for firm's marginal surplus

$$rJ = m - \frac{\partial(wn)}{\partial n} - \frac{\partial(\delta nJ)}{\partial n} + \mu x J_x + \frac{1}{2}\sigma^2 x^2 J_{xx}$$

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In hiring region, $J(m) = c \Rightarrow w(m) = w_u$.

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$$rc = m - w_u - \frac{\partial(\delta n)}{\partial n} c$$

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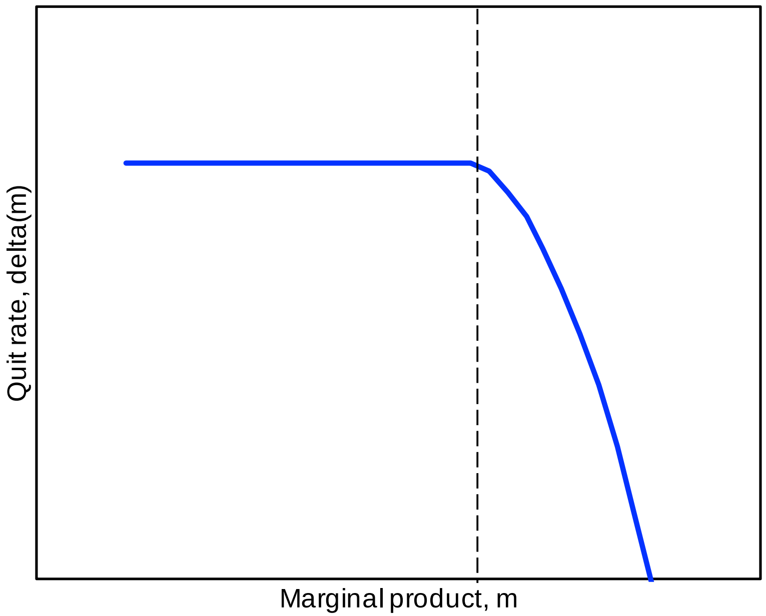
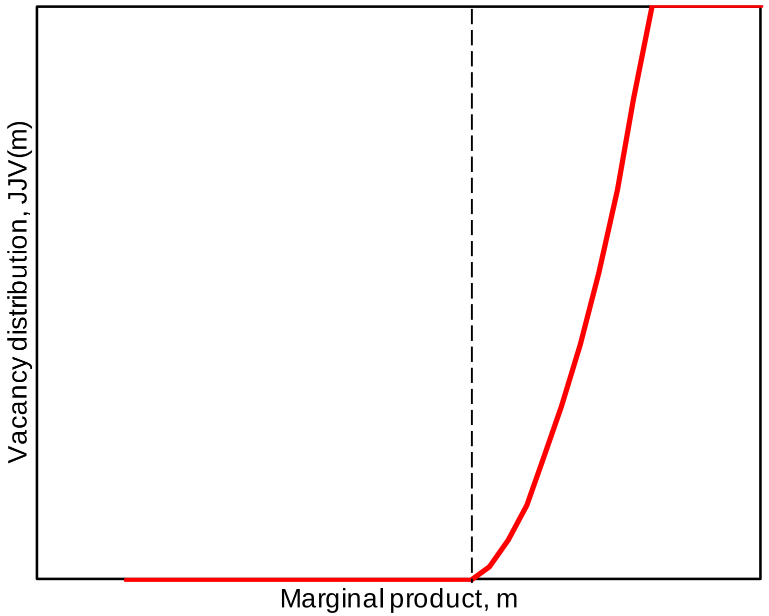
$$\delta(m) = -\delta_0 + \delta_1 m - \delta_2 m^{\frac{1}{1-\alpha}}.$$

Solution for $\boldsymbol{\delta(m)}$

$\delta(m)$



$\mathbb{J}_V(m)$



$$\delta(m) = -\delta_0 + \delta_1 m - \delta_2 m^{\frac{1}{1-\alpha}} = s\phi[1 - \mathbb{J}_V(m)]$$

Solution for $\delta(m)$: Some intuition

- Turnover is costly to the firm on the margin.
- Workers don't internalize these costs.
- Higher m allows firm to reduce turnover costs.
- Firms "under-hire"; but not to the same m.
- Optimal to deviate from any mass point in m.
- The result is endogenous misallocation.

Solution for $\boldsymbol{q(m)}$

Stochastic law of motion for marginal product m:

$$\frac{dm}{m} = \{\mu - (1-\alpha)[h(m) - \delta(m)]\}dt + \sigma d\mathcal{W}$$

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Endogenous mean reversion in m.

- $m \uparrow \Rightarrow$ net hiring rate $[h(m) - \delta(m)]$ rises $\Rightarrow m \downarrow$.

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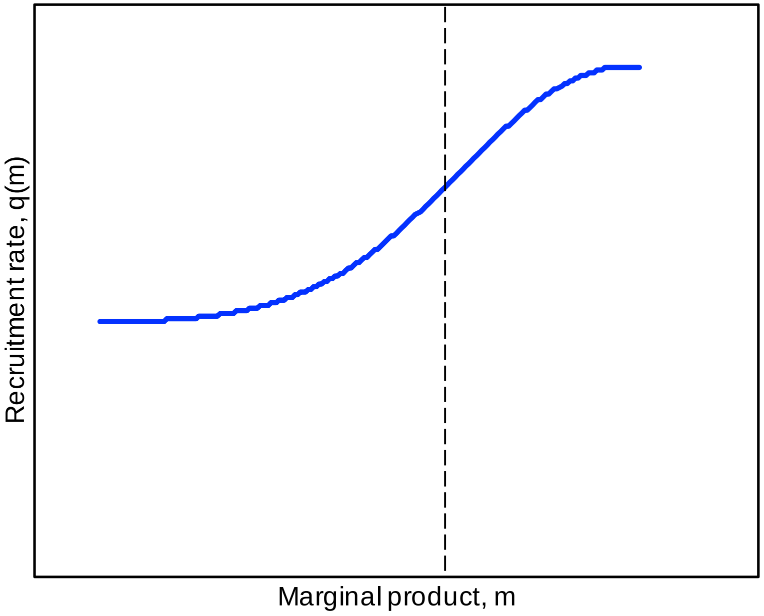
Fokker-Planck (Kolmogorov Forward) Equation $\Rightarrow$

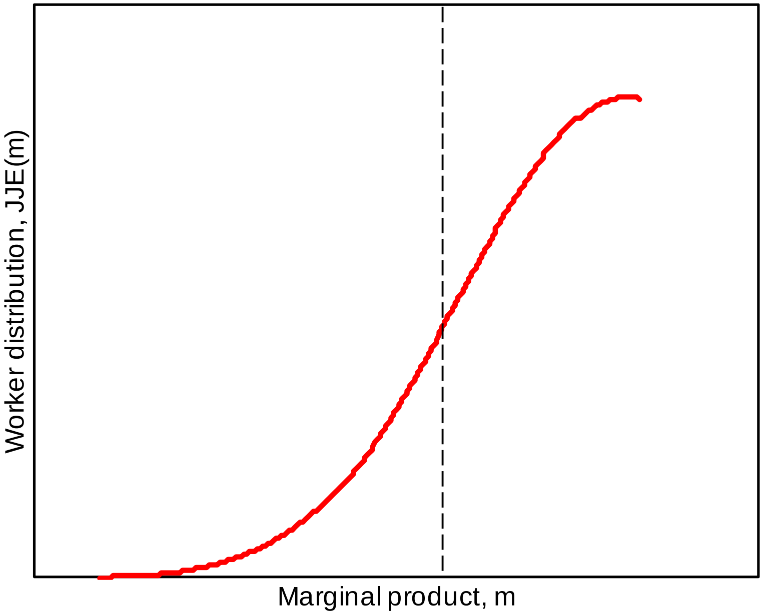
$$q(m) = q_0 \exp\left[q_1 \int^m \delta(\nu)/\nu \, d\nu\right].$$

Solution for $\boldsymbol{q(m)}$

$q(m)$



$\mathbb{J}_E(m)$



$$q(m) = q_0 \exp\left[q_1 \int^m \delta(\nu)/\nu \, d\nu\right] = \chi[\upsilon + (1-\upsilon)\mathbb{J}_E(m)]$$

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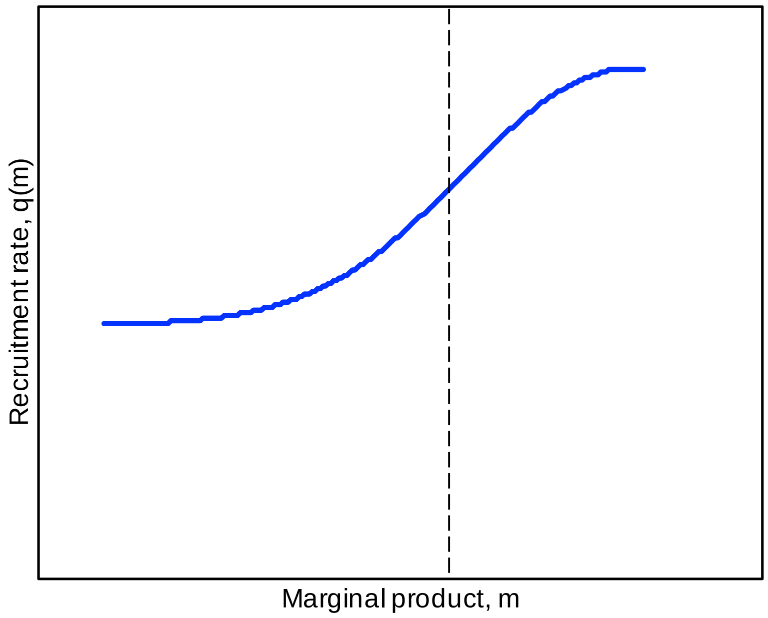

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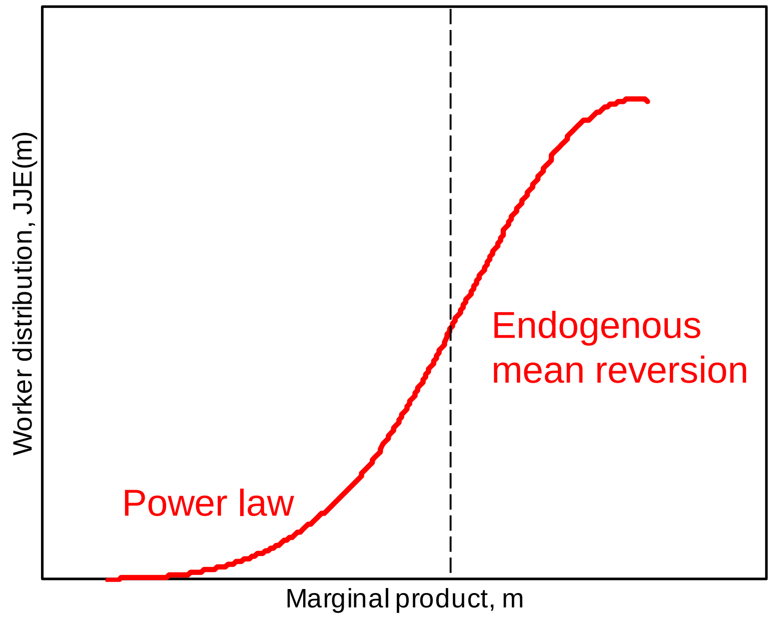


$$q(m) = q_0 \exp\left[q_1 \int^{m} \delta(\nu)/\nu \, d\nu\right] = \chi[\upsilon + (1-\upsilon)\mathbb{J}_E(m)]$$

Steady-state equilibrium

- Job creation curve (recall $n = (\alpha p x / m)^{\frac{1}{1-\alpha}}$):

$$N(\theta) = \mathbb{E}\left[(\alpha p x)^{\frac{1}{1-\alpha}}\right] / \mathbb{E}_{\mathbb{J}_E}\left[m^{\frac{1}{1-\alpha}}; \theta\right].$$

- Beveridge curve (flow balance):

$$N(\theta) = \frac{\phi(\theta)}{\lambda(\theta) + \phi(\theta)} L,$$

where $\lambda(\theta) \equiv \frac{1}{2} \frac{\sigma^2}{1-\alpha} m_l \mathbb{J}_E'(m_l; \theta)$ is E-to-U rate.

Lessons from the model

1. It is possible to solve for equilibrium distributions.

2. Wages and endogenous misallocation.

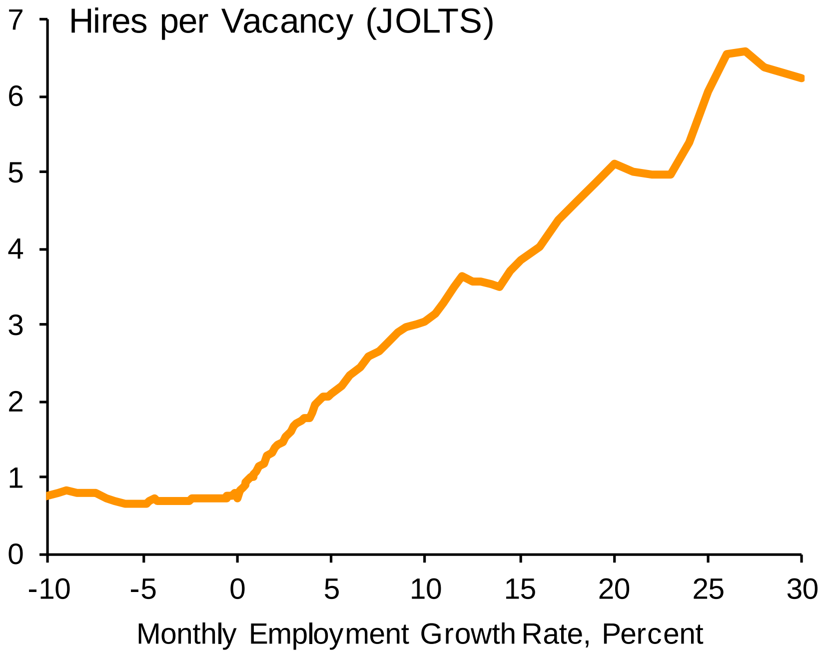
3. New perspectives on labor market competition.
   Endogenous mean reversion.

4. Establishment-level behavior of vacancies.

5. “Excess” firing as natural wastage falls in recession.

Employment growth vs. $q(m)$

Data



Davis, Faberman and Haltiwanger (2013):

Fast-growing firms have higher vacancy-filling rates. Why?

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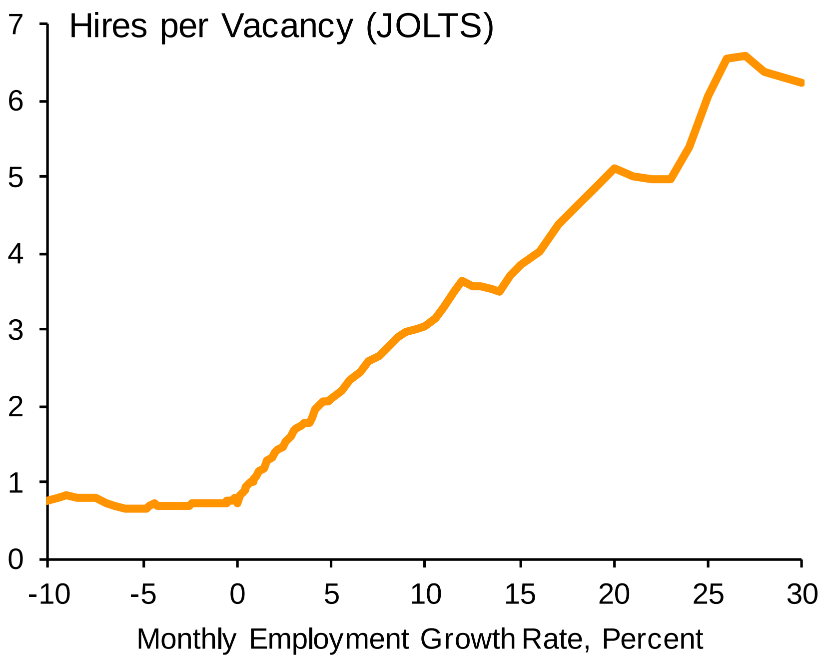
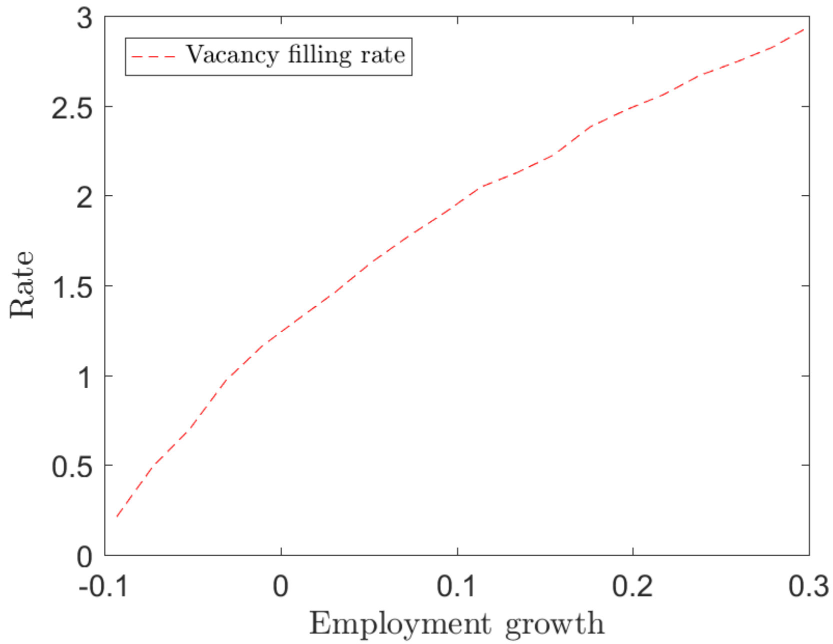
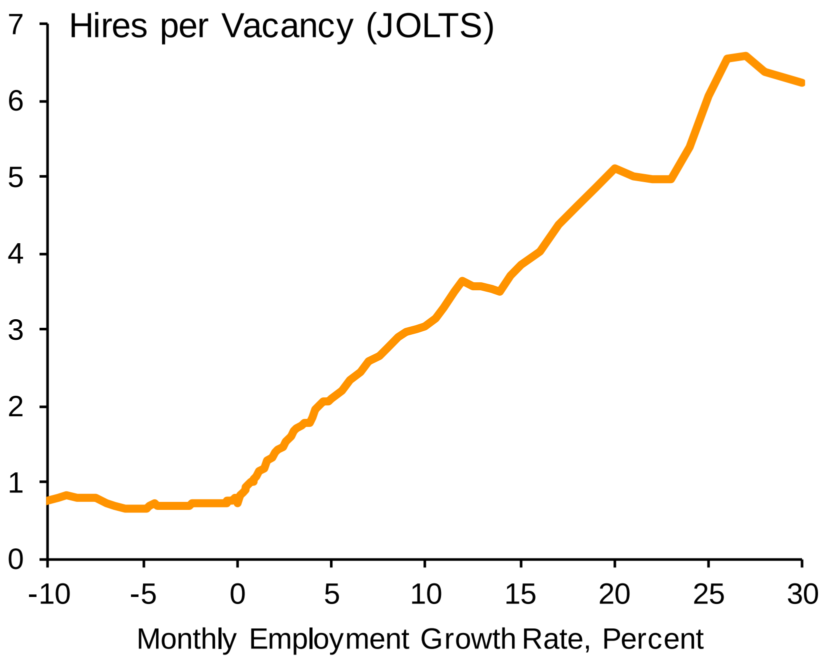


Model

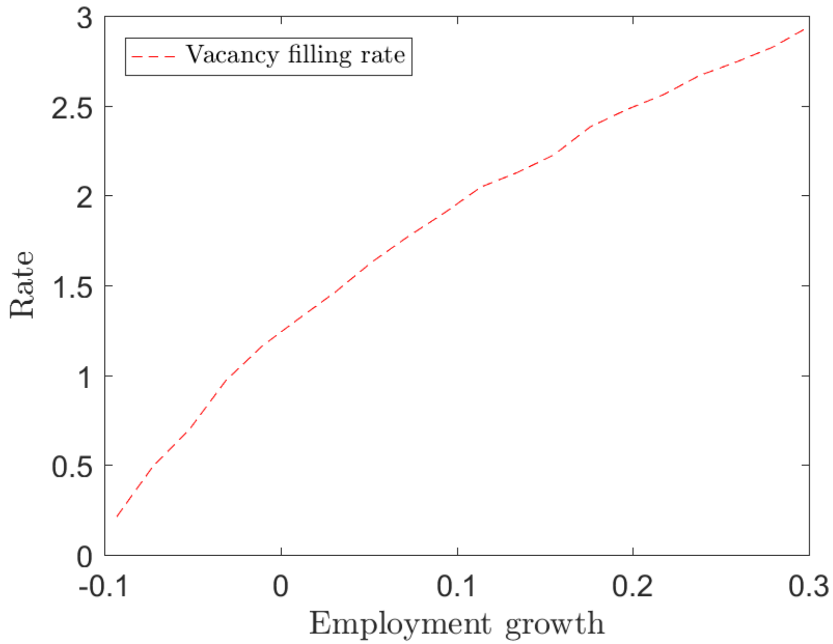


Employment growth vs. $q(m)$

Data



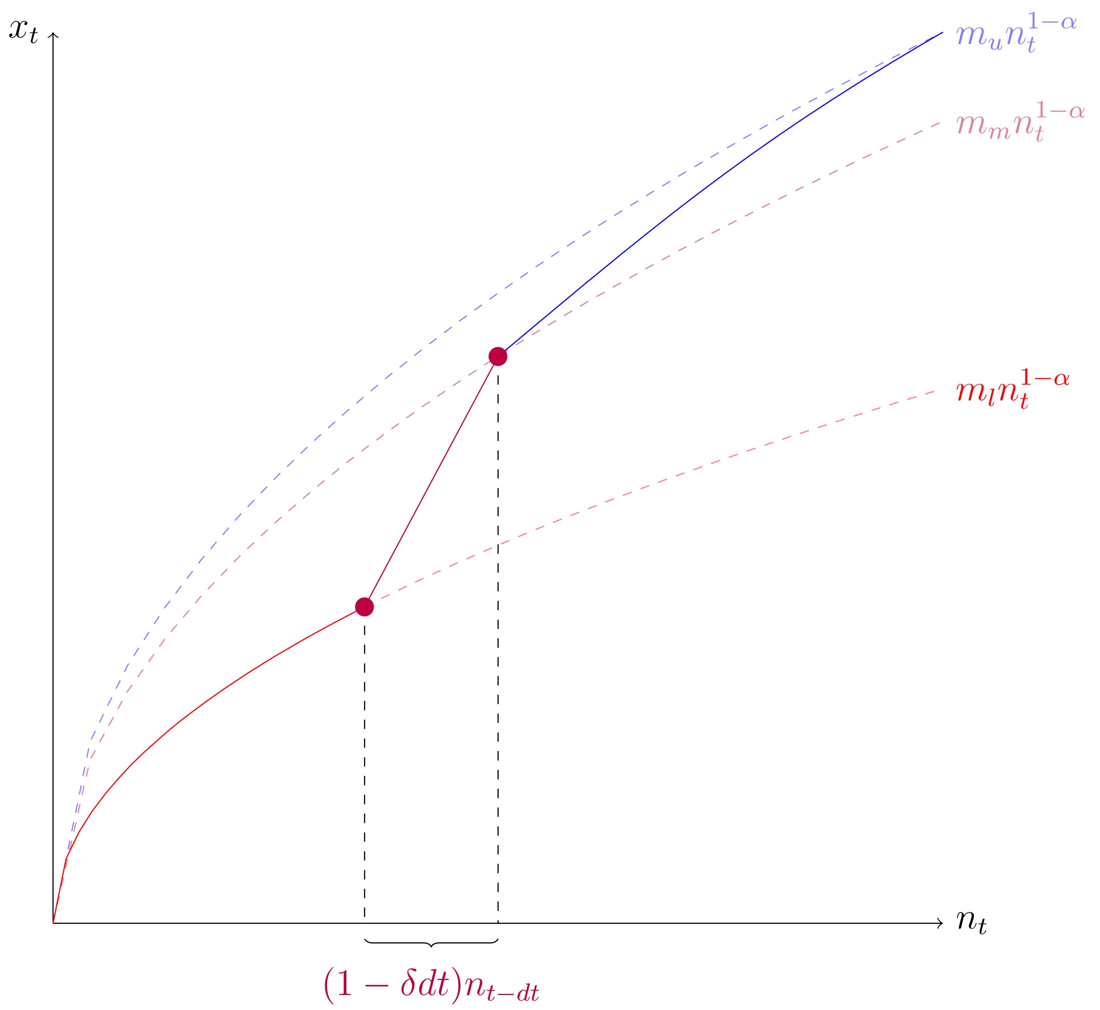
Model



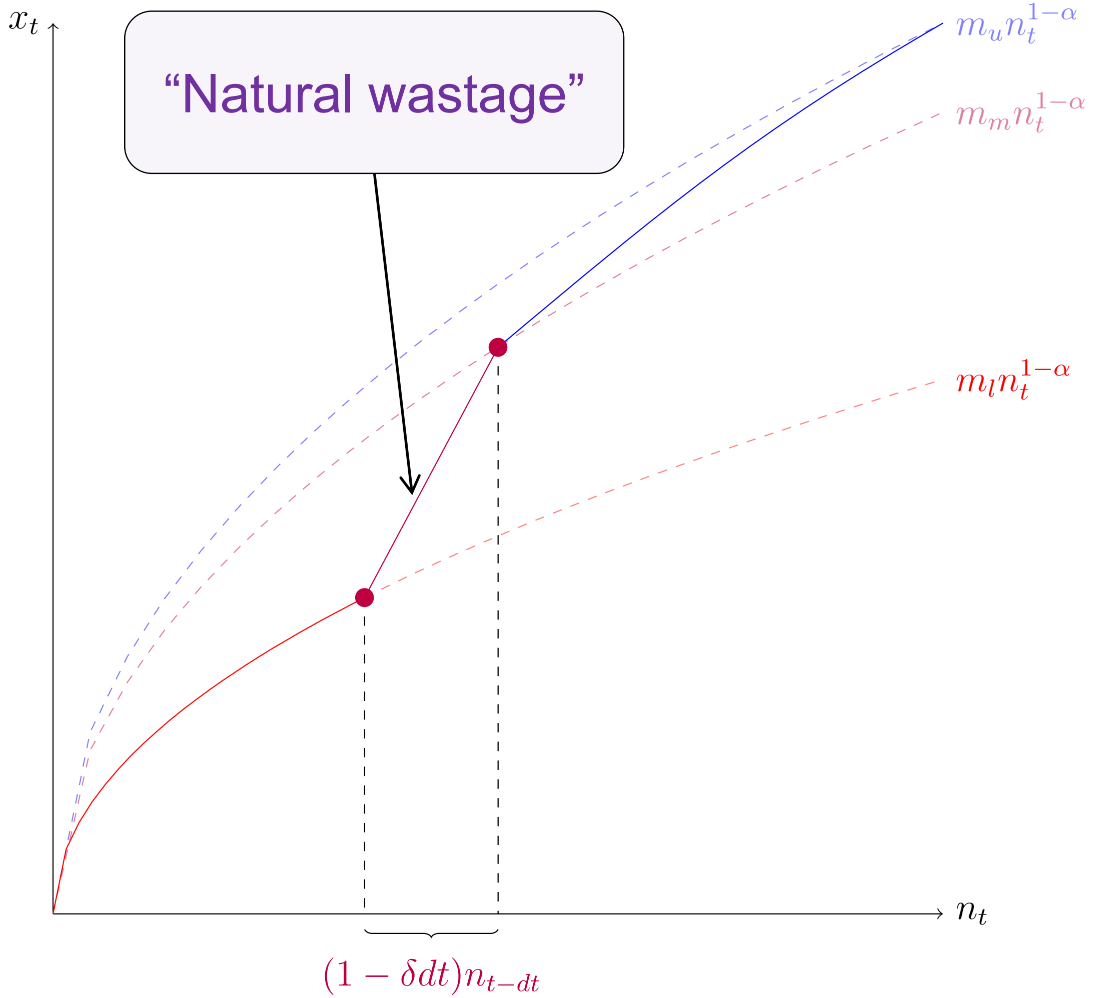
Fast-growing firms have large hiring rates, small quit rates

$\Rightarrow$ high marginal product, $m \Rightarrow$ high vacancy-filling rates

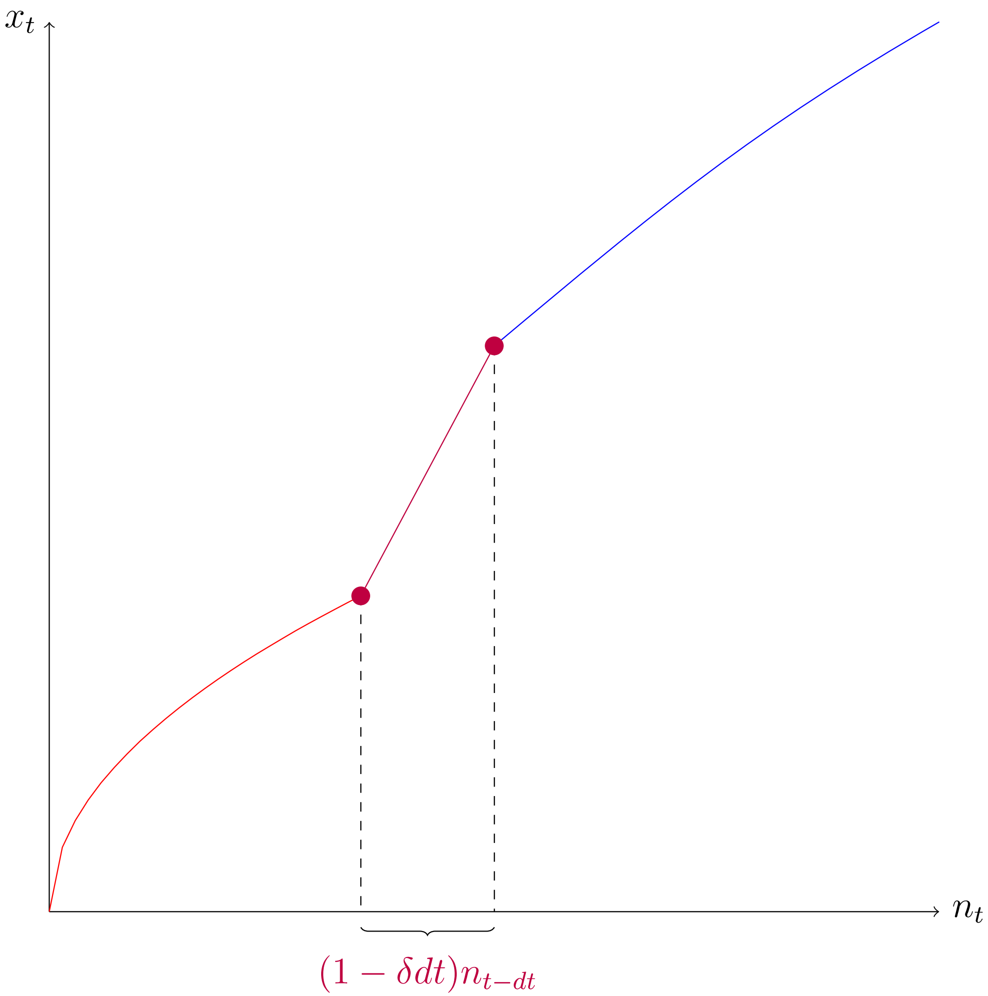
Natural wastage and job destruction



Natural wastage and job destruction



Natural wastage and job destruction



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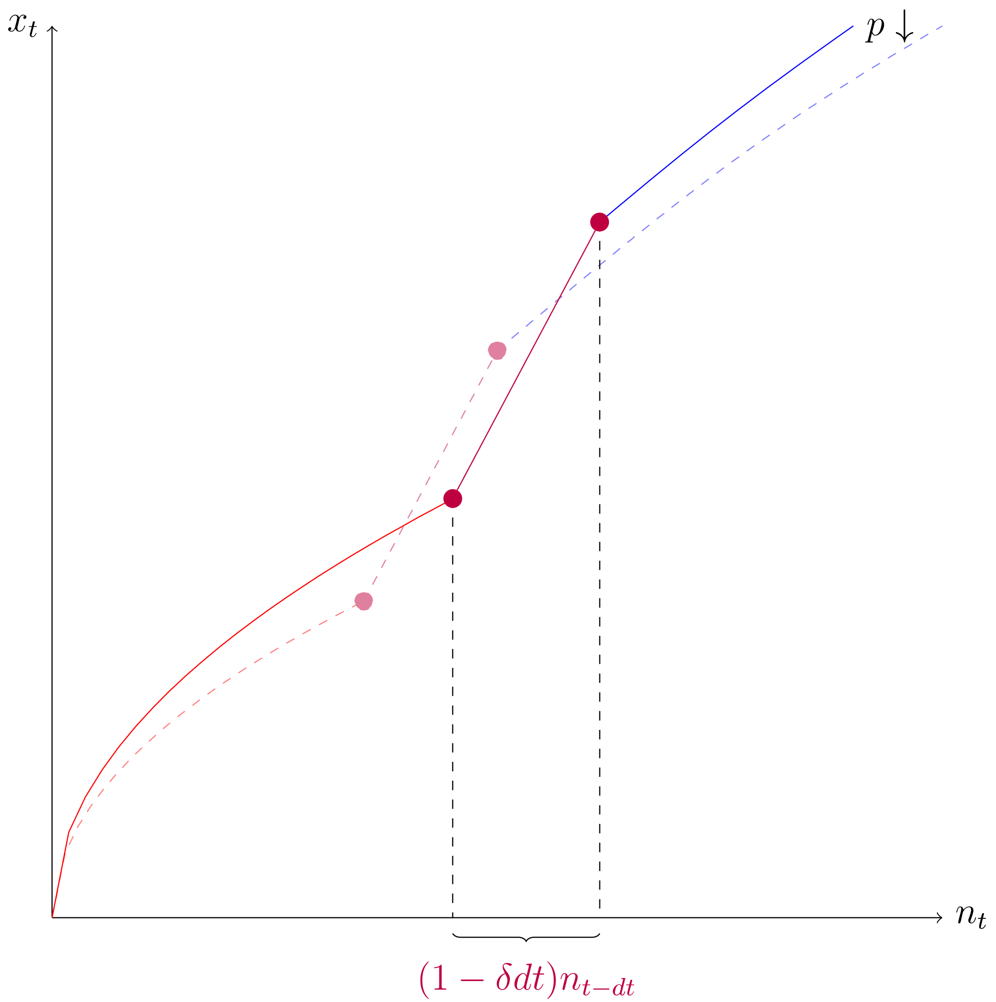
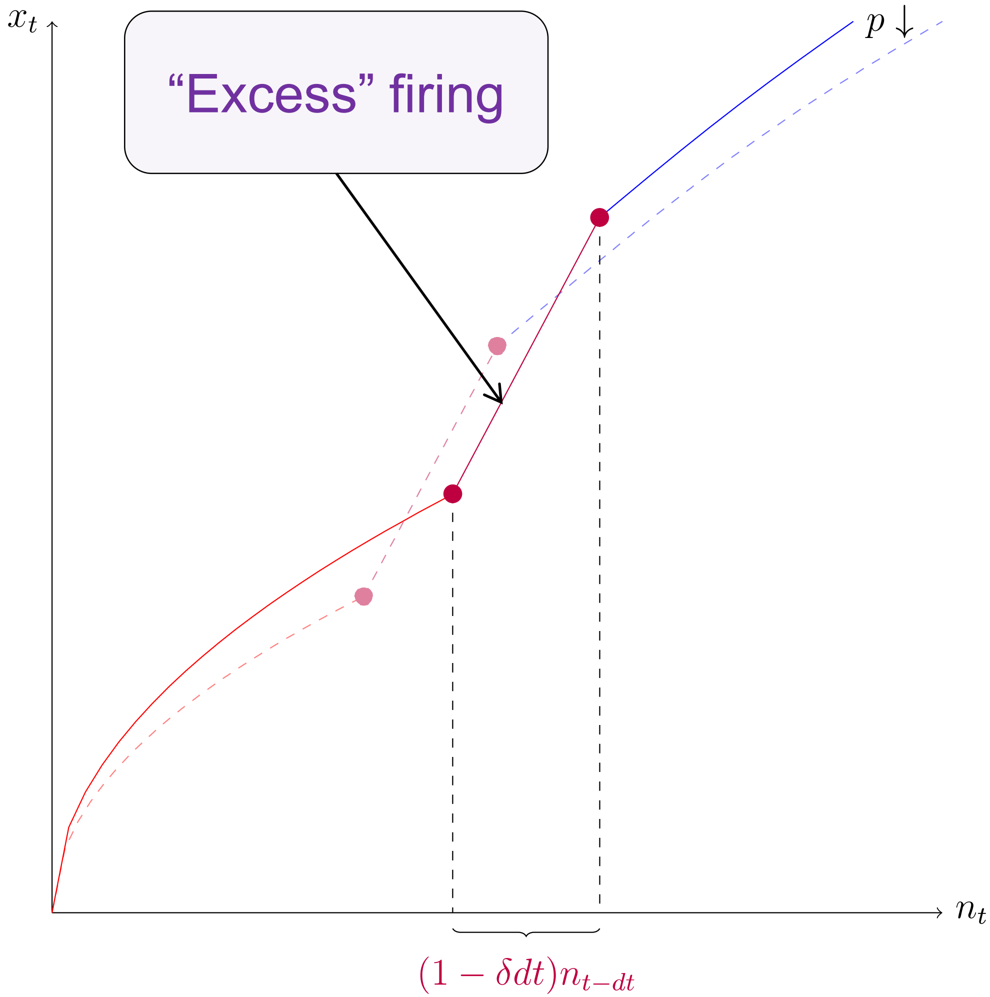
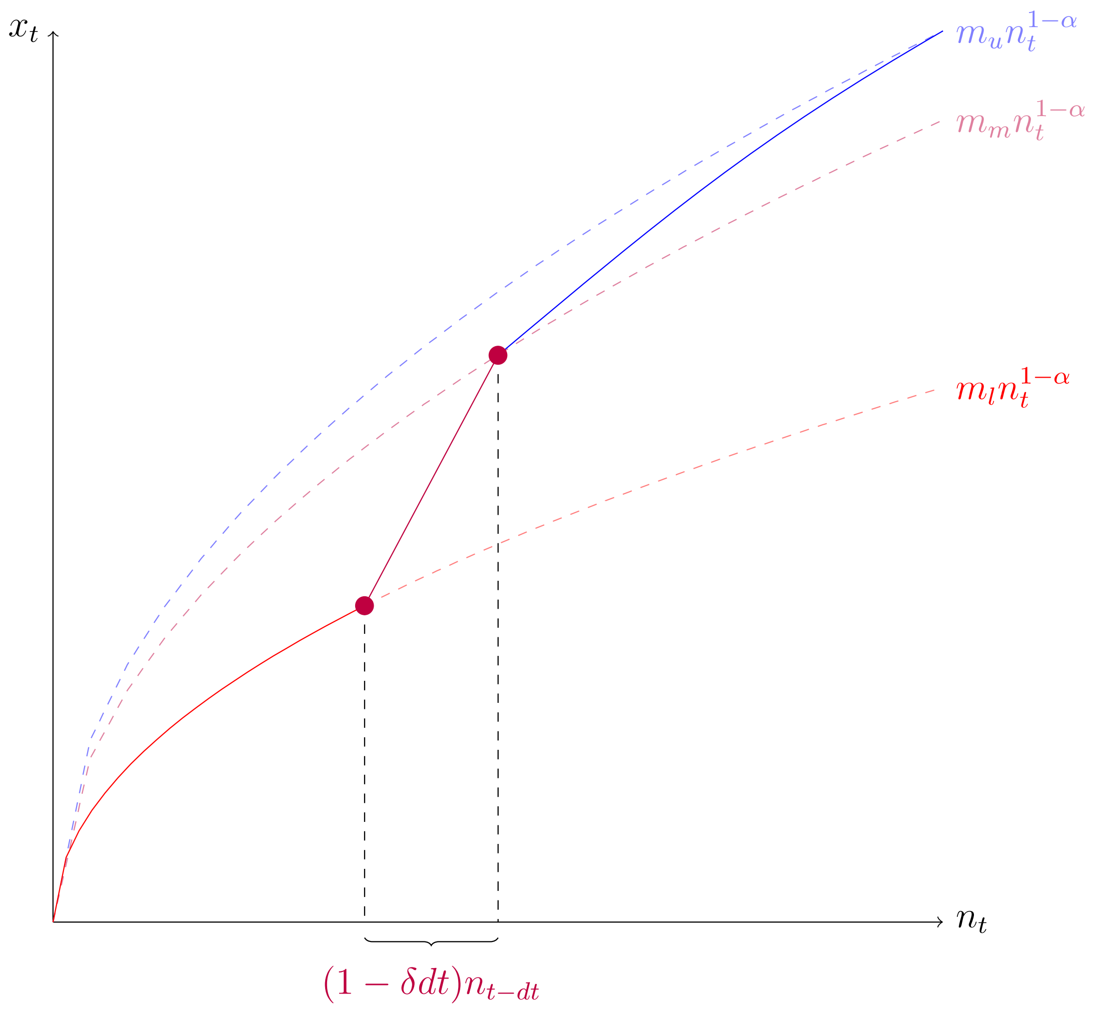


Natural wastage and job destruction



Looking ahead: Vacancy Chains

- Consider an aggregate expansion.
- Raises J for individual firm.
  More likely to post vacancies and grow.
- But raises J for all firms.
  Distributions of J shift to right; $q\downarrow$ and $\delta\uparrow$.
- If labor demand is inelastic, firms must post even more vacancies to reach desired employment.



Model so far: **Gross** inaction versus Data: **Net** inaction…

Towards a model

Stylized facts $\Rightarrow$ model with three ingredients:

1. Multi-worker firms.

   To map theory to data.

2. On-the-job search.

   To generate quits.

3. Persistent reference levels of employment.

   To generate replacement.

Towards a model

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Firm's problem

$$\Pi(k_{-1}, n_{-1}, x) \equiv \max_{v,S,k}\{pxF(n;k)$$

$$-w(\cdot)n$$

$$-c_v(v)$$

$$-c_k(\Delta k)$$

$$+\beta\mathbb{E}[\Pi(k,n,x')|x]\}$$

subject to $\Delta n = q(\cdot)v - \delta(\cdot)n_{-1} - S$

Firm's problem

$$\Pi(k_{-1}, n_{-1}, x) \equiv \max_{v,S,k} \{pxF(n;k)$$

Operating with $n < k$ costly…

$$-w(\cdot)n$$

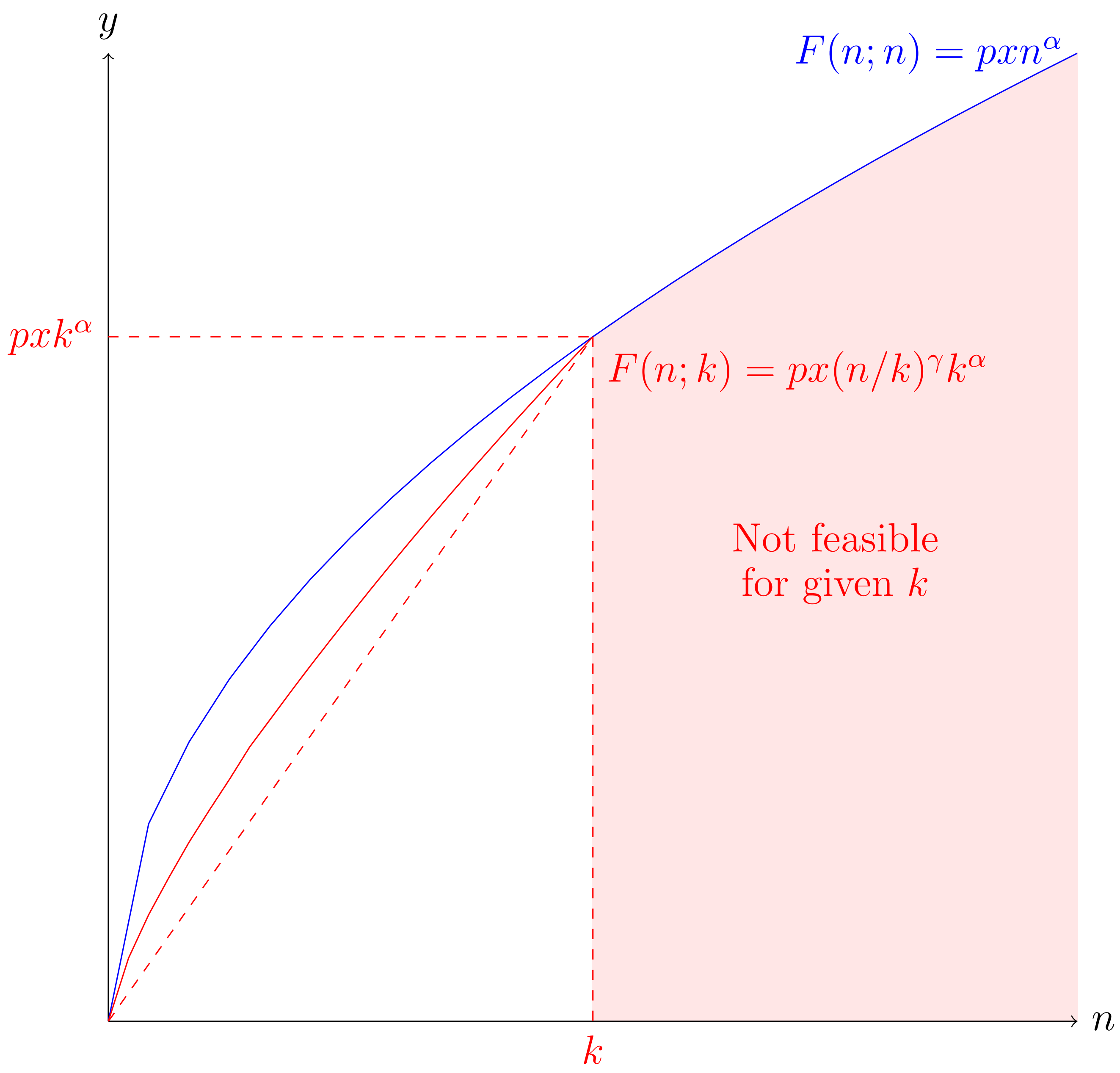
$$-c_v(v)$$

…and k (very) costly to adjust

$$-c_k(\Delta k)$$

$$+\beta\mathbb{E}[\Pi(k, n, x')|x]\}$$

subject to $\Delta n = q(\cdot)v - \delta(\cdot)n_{-1} - S$



Effects of reference employment k

Recall: What is a vacancy?

After several decades of BLS research:

> "A specific position exists and there is work available for that position..."

What is a "position"?

Connotes some sunk investment.

Recall: What is a vacancy?

After several decades of BLS research:

> "A specific position exists and there is work available for that position..."

What is a "position"?

Connotes some sunk investment.

In this model: k.

Firm's problem

$$\Pi(k_{-1}, n_{-1}, x) \equiv \max_{v,S,k}\{px\,(n/k)k^{\alpha}$$

$$-w(\cdot)n$$

$$-c_v(v)$$

$$-c_k(\Delta k)$$

$$+\beta\mathbb{E}[\Pi(k, n, x')|x]\}$$

subject to $\quad \Delta n = q(\cdot)v - \delta(\cdot)n_{-1} - S$

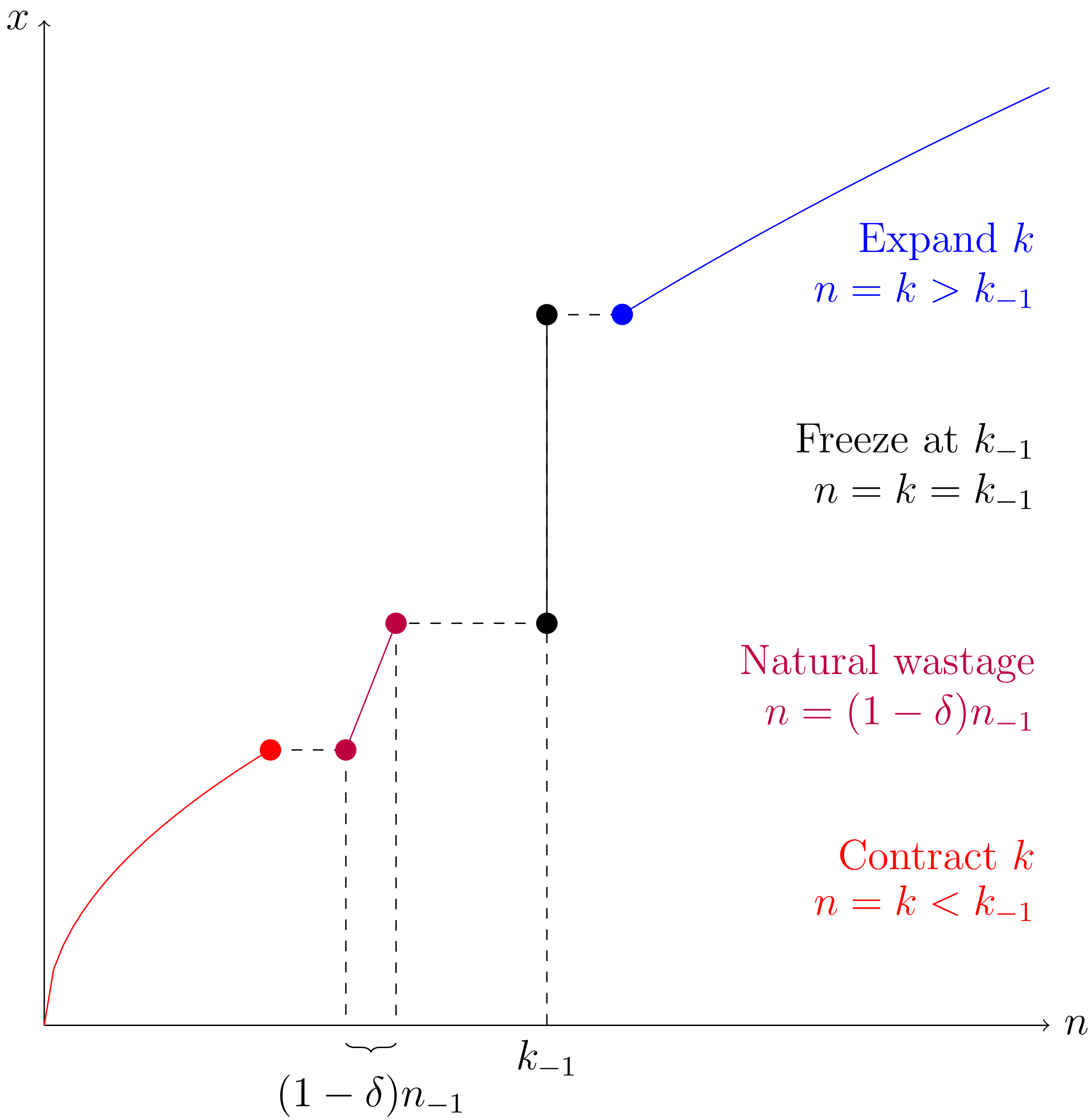
and $\quad n \leq k$

Firm's problem

$$\Pi(k_{-1}, n_{-1}, x) \equiv \max_{v,S,k}\{px\,(n/k)k^{\alpha}$$
$$-w(\cdot)n$$
$$-c_v(v)$$
$$-c_k\mathbb{I}[k \neq k_{-1}]$$
$$+\beta\mathbb{E}[\Pi(k, n, x')|x]\}$$

subject to $\Delta n = q(\cdot)v - \delta(\cdot)n_{-1} - S$

and $n \leq k$



Optimal labor demand policy

Calibration (preliminary)

Parameter	Meaning	Value	Reason
α	Returns to scale	0.64	Cooper et al. (2007, 2015)
β	Discount factor	0.987	Annual real interest rate = 0.05
ρ_x	Persistence of shocks	0.7	Abraham and White (2006)
σ_x	Std. dev. of shocks	0.187	Unemployment rate = 0.065
ϵ	Matching elasticity	0.67	Elasticity of job-finding rate w.r.t. V/U
η	Bargaining power	0.25	Elasticity of $\bar{w}$ w.r.t. $1-u$
s	Search intensity of employed	0.066	38 percent of hires from employment
c_v	Linear vacancy cost	2 weeks' wages	Manning (2011)
μ	Matching efficiency	0.23	Job-finding rate of unemployed = 0.28
b	Flow unemployment payoff	0.23	Average firm size = 16
C_k	Capacity adjustment cost	12.5% revenue	Four-quarter inaction rate = 0.41

Matching stylized facts

Moments	**Data**	**Model (with k)**
One-quarter inaction rate	0.55	0.55
Quits as share of employment (monthly)	0.017	0.014
Quit rate among nonadjusters (monthly)	0.011	0.012
Replacement hires as a share of total hires	0.45	0.32
Four-quarter inaction rate	0.41	0.46
E-to-E flows as a share of total hires	0.38	0.38
One-quarter k-inaction rate	—	0.84
Vacancy-filling rate (monthly)	0.74	0.72

Matching stylized facts

Moments	Data	Model (with k)	Model (no k)
One-quarter inaction rate	0.55	0.55	0
Quits as share of employment (monthly)	0.017	0.014	0.016
Quit rate among nonadjusters (monthly)	0.011	0.012	—
Replacement hires as a share of total hires	0.45	0.32	0.03
Four-quarter inaction rate	0.41	0.46	0
E-to-E flows as a share of total hires	0.38	0.38	0.44
One-quarter k-inaction rate	—	0.84	—
Vacancy-filling rate (monthly)	0.74	0.72	0.75

Comparative steady states

Moment	Data	Model (with $\boldsymbol{k}$)
$\Delta\ \ln$ vacancies / $\Delta\ \ln$ output per worker	10.1	7.8
$\Delta\ \ln$ unemployment / $\Delta\ \ln$ output per worker	-9.5	-7.8
$\Delta\ \ln$ job−finding rate / $\Delta\ \ln$ output per worker	5.9	3.8
$\Delta\ \ln$ inflow rate / $\Delta\ \ln$ output per worker	-3.8	-4.5
$\Delta\ \ln$ average wages / $\Delta\ \ln$ employment	≈1	1.13

Comparative steady states

Moment	Data	Model (with k)	Model (no k)
$\Delta \ln$ vacancies / $\Delta \ln$ output per worker	10.1	7.8	4.9
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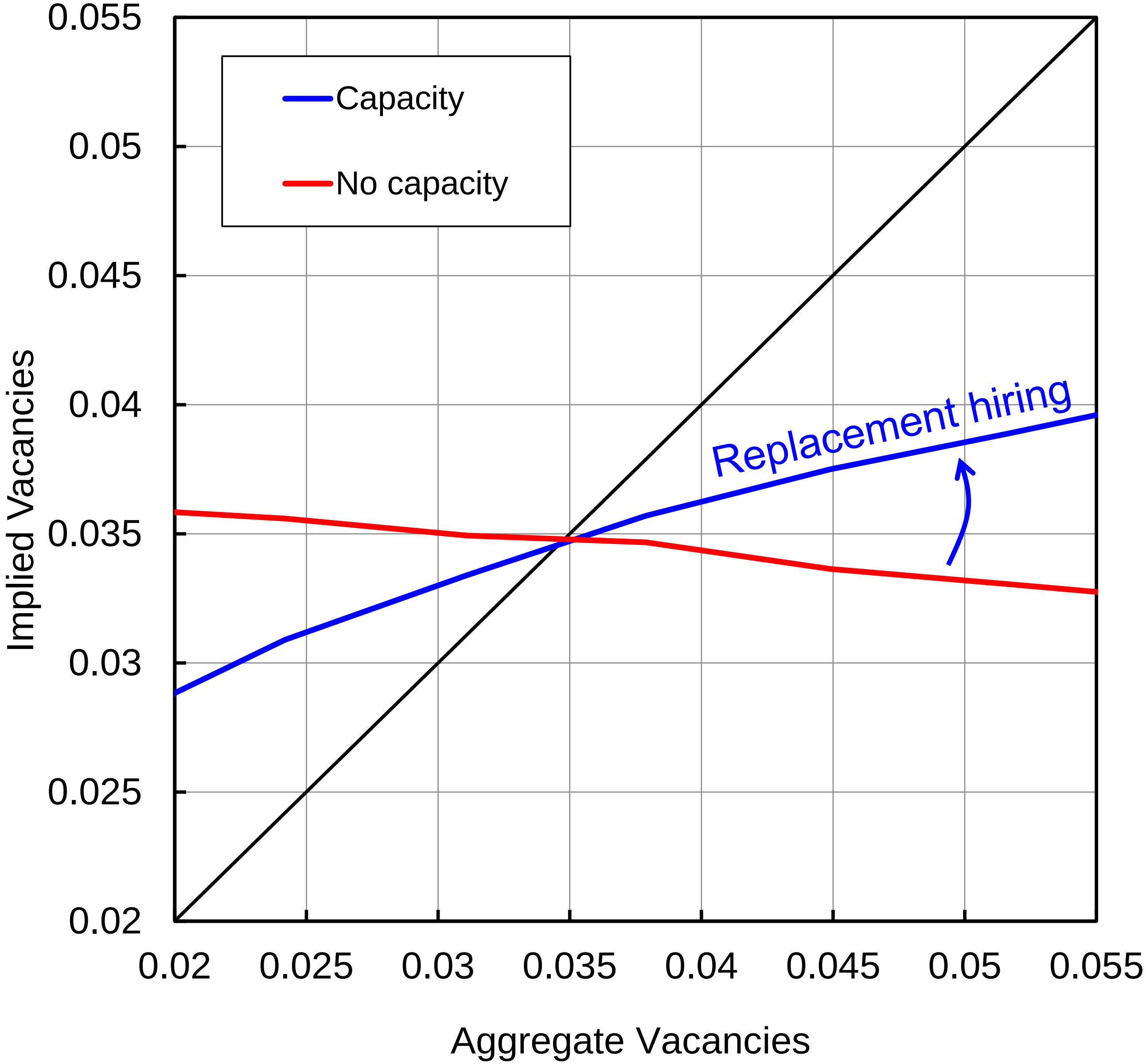
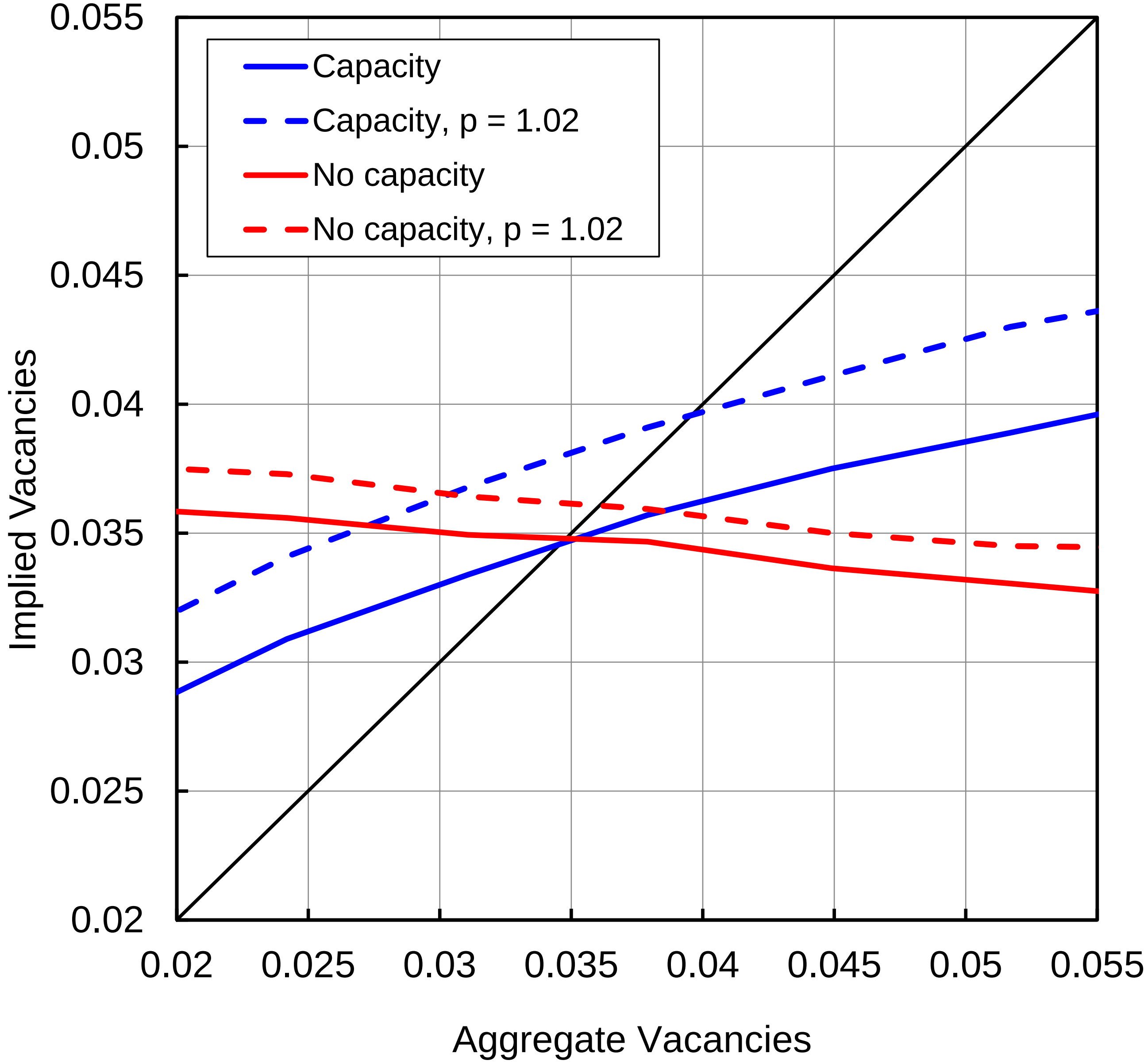
$\Delta \ln$ job−finding rate / $\Delta \ln$ output per worker	5.9	3.8	3.1
$\Delta \ln$ inflow rate / $\Delta \ln$ output per worker	-3.8	-4.5	-7.1
$\Delta \ln$ average wages / $\Delta \ln$ employment	≈1	1.13	1

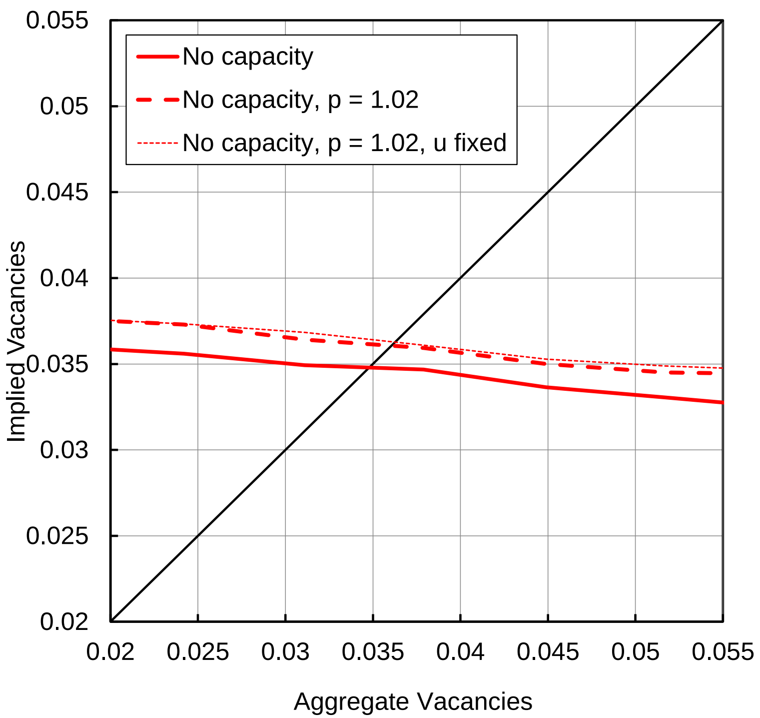


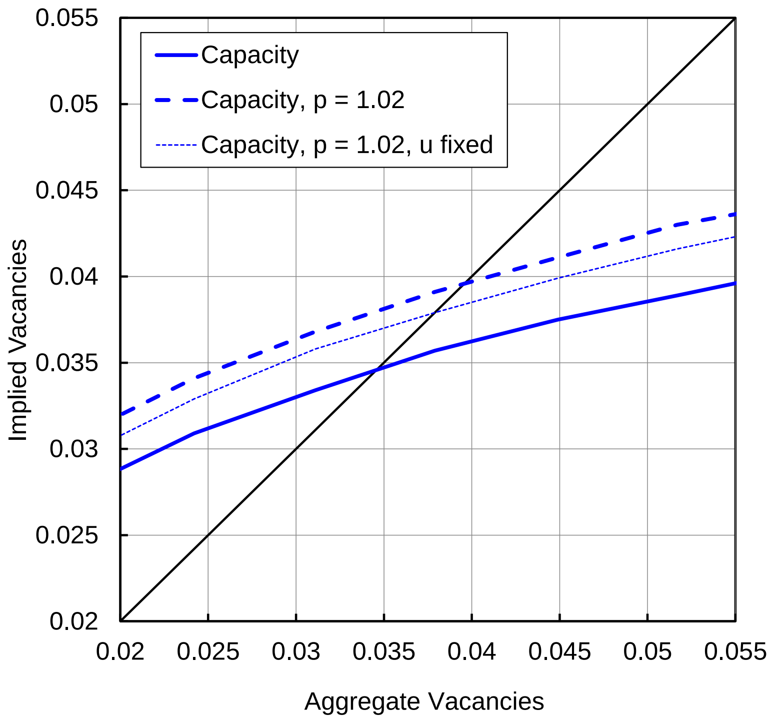
Replacement hiring ⇒ positive feedback in vacancy creation



Positive feedback amplifies aggregate responses

Adjustment of U reinforces response of V





$\Delta V | U \approx \Delta V$

No feedback

$\Delta V | U < \Delta V$

Positive feedback

Summary and where next?

- Replacement hiring pervasive.

- Nature of frictions:

  In the production structure.

- Induces vacancy chains:

  Positive feedback in vacancy creation.

  Amplifies aggregate labor market responses.

  Sluggish $\mathbb{J}$s $\Rightarrow$ Persistence in vacancy chains?

Extra slides

Five facts on replacement hiring

1. Inaction over **net** employment changes.

   Despite nontrivial quit rates.

2. Net inaction is inversely related to **quits**.

   At aggregate, industry, state, and establishment levels.

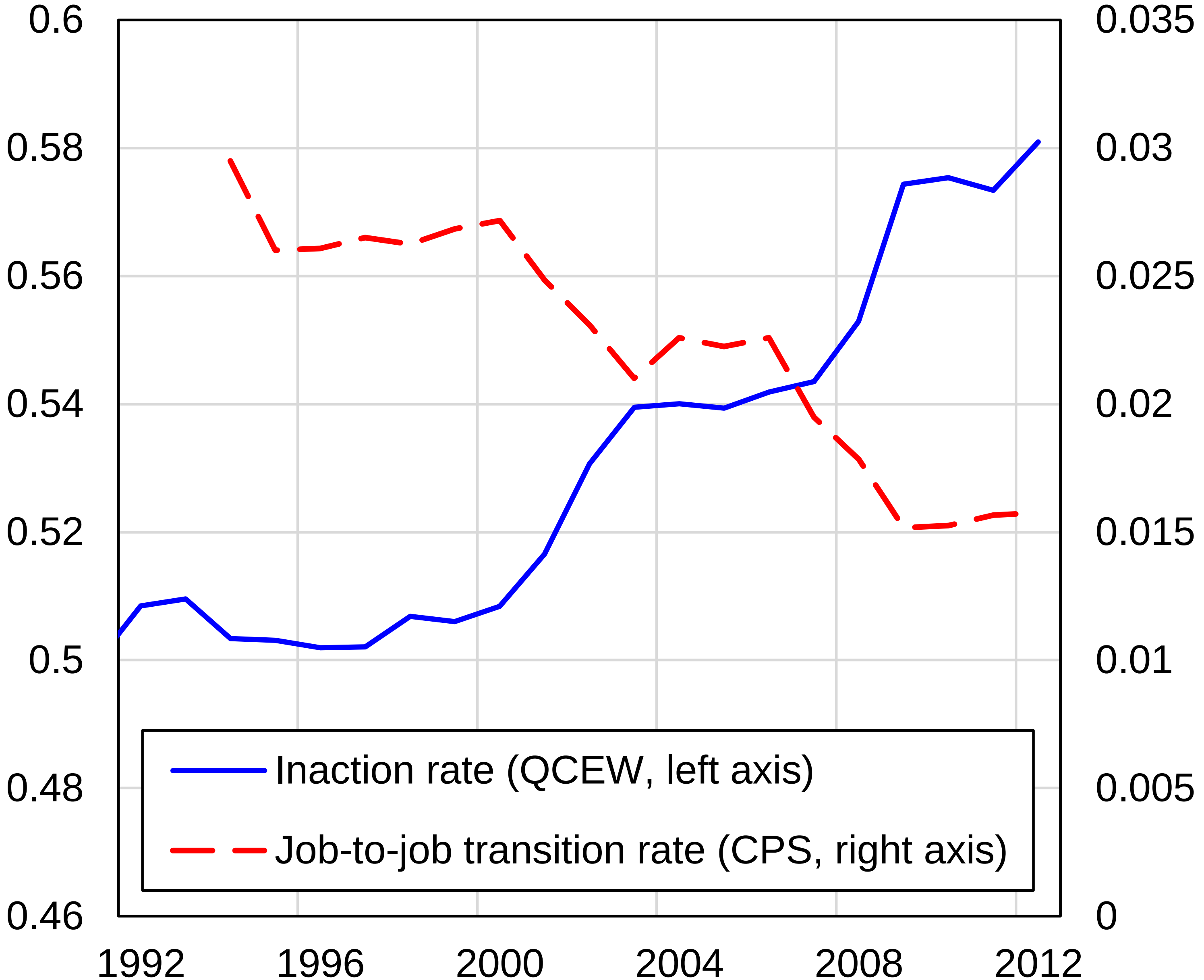
3. Slow **decay** of inaction by frequency of adj.

   Much slower than geometric decay.

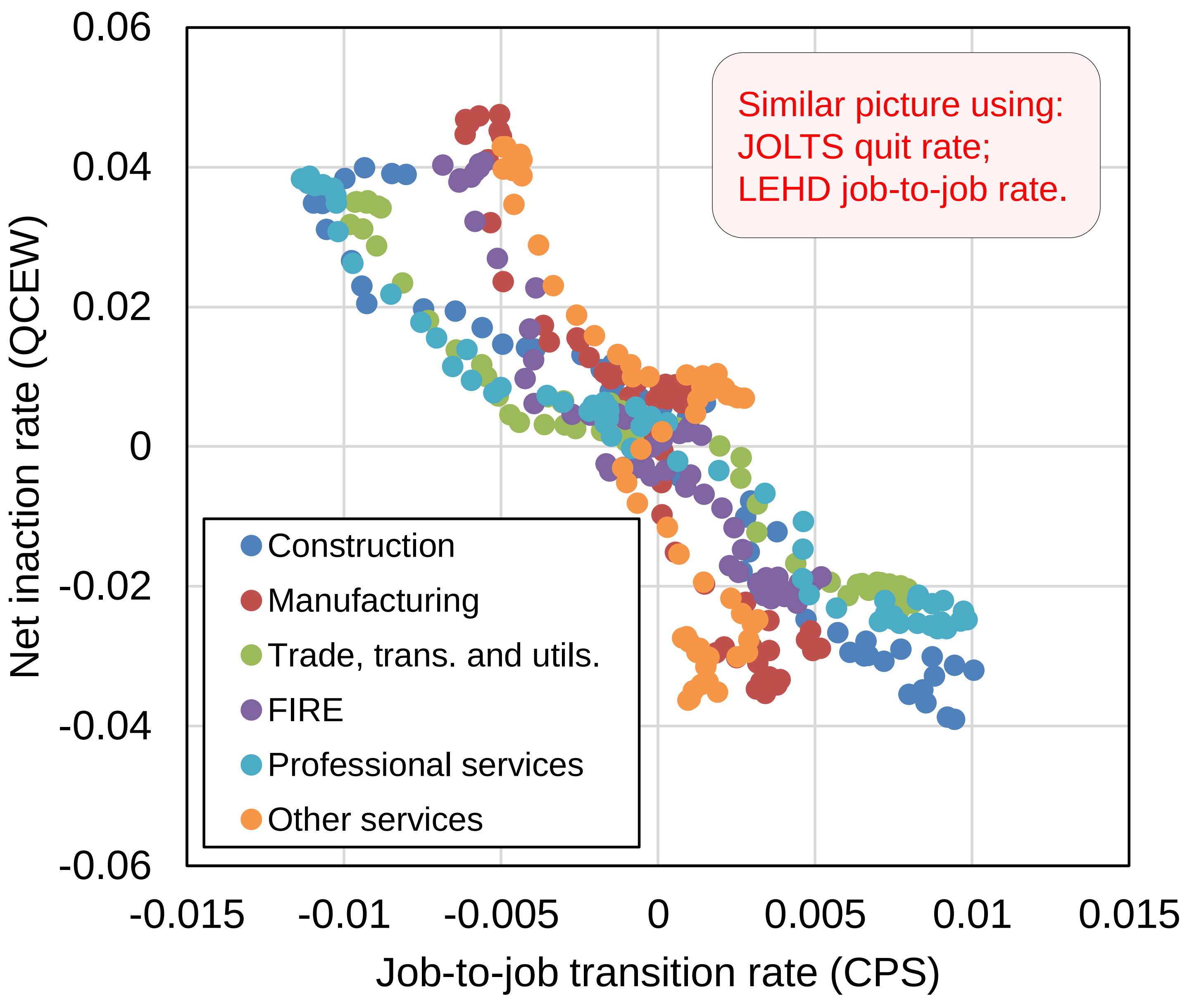
4. Large cumulative gross turnover in inactive estabs.

   Cumulative replacement is nontrivial.

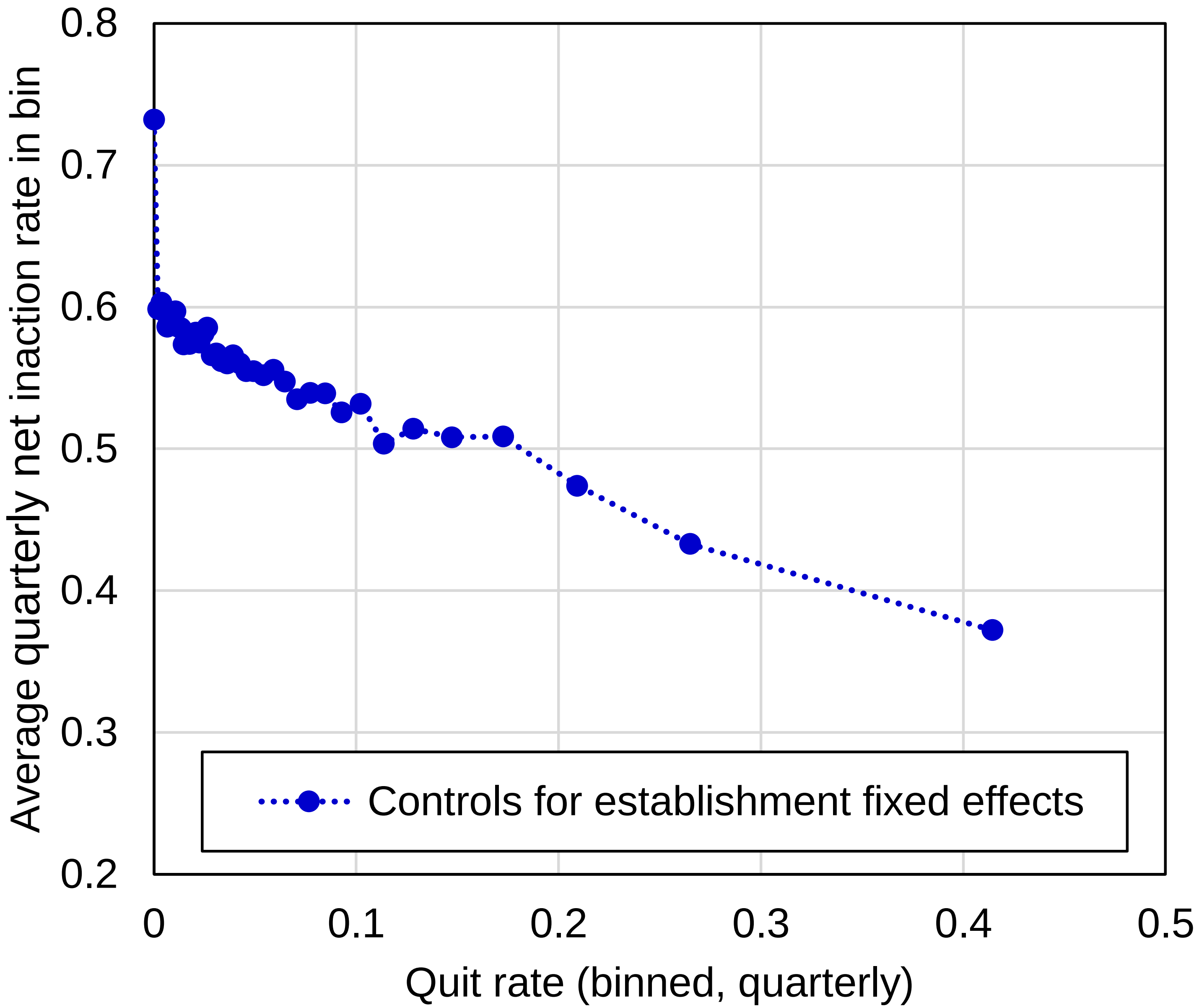
5. Replacement is a large share of total hires



Aggregate-level inaction and quits, QCEW and CPS



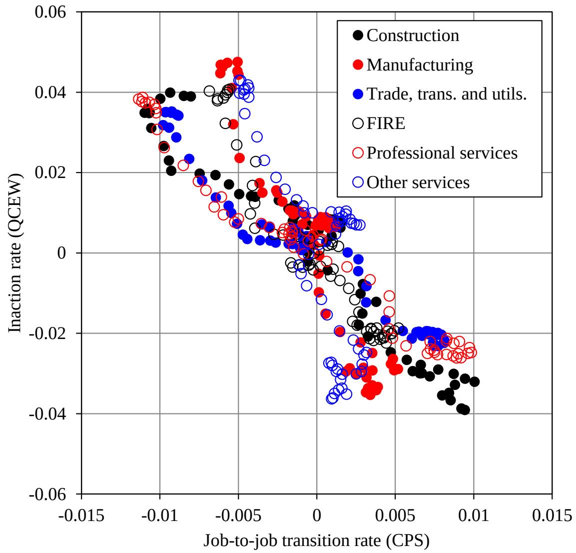
Industry-level inaction and quits, QCEW and CPS



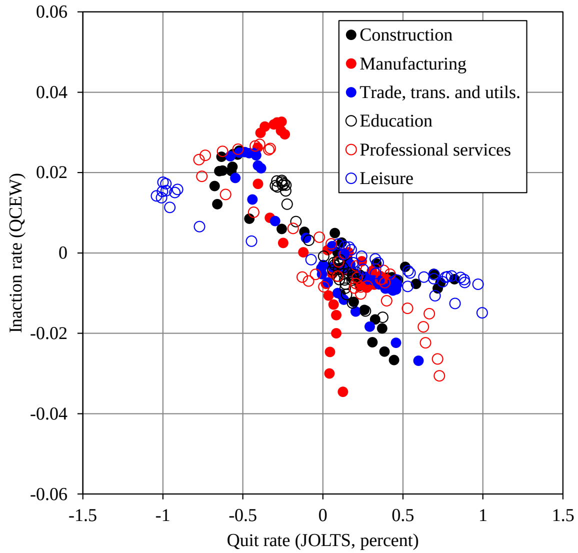
Establishment-level inaction and quits, JOLTS

Industry-level inaction vs. job-to-job rate

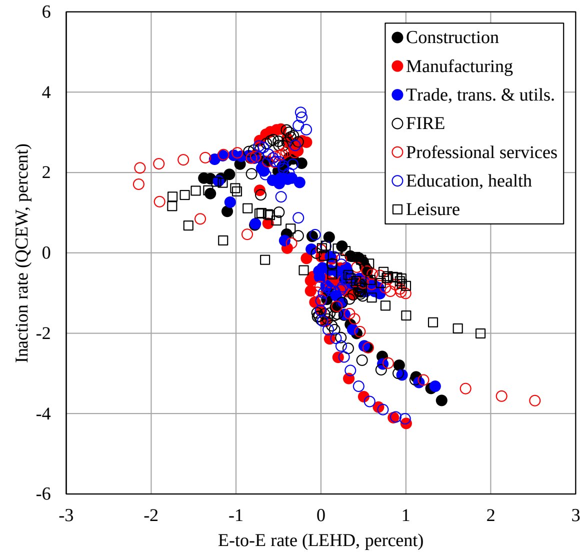
CPS (E-to-E rate), 1996-2011



JOLTS (Quit rate), 2001-2011

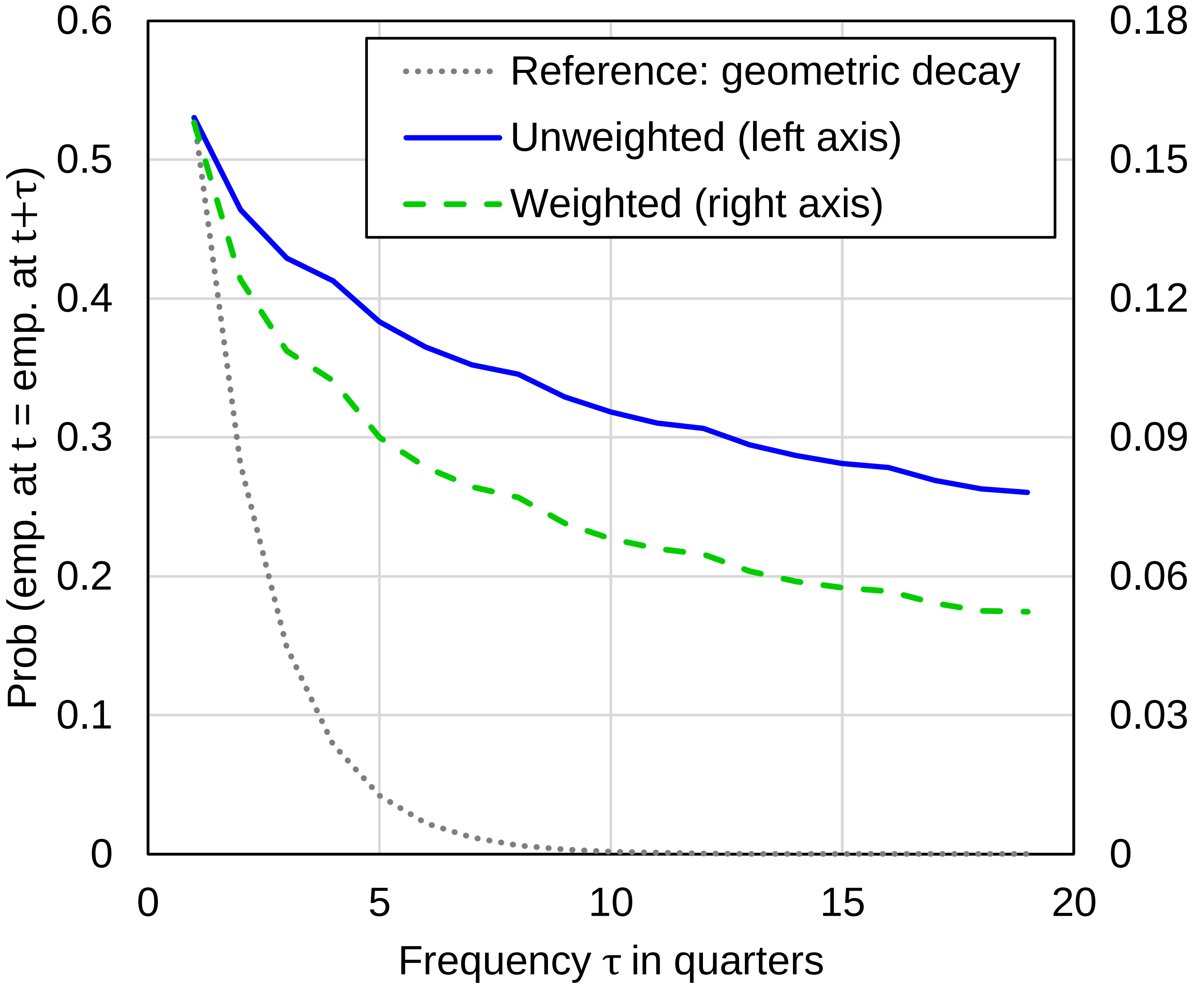


LEHD (E-to-E rate) 2001-2013



Three measures of (de-meaned) industry E-to-E indicators.

- Current Population Survey [Fallick and Fleischman 2004].
- Job Openings and Labor Turnover Survey [N.B. Quit rate].
- Longitudinal Employer-Household Data [Bjelland et al. 2011].



Slow decay of inaction, QCEW, employment weighted

Slow decay of inaction

- Not an artefact of seasonality.
  - Decay is slow between as well as within years.
  - Similar decay in high vs. low seasonal industries.

- Nor of mean reversion.
  - Mean reversion ⇒ return to *neighborhood* of n_t.
  - In data, return *precisely* to n_t, for example:

$$\Pr(n_t = n_{t+3}) > \mathbf{3} \times \Pr(n_t \in \{n_{t+3} \pm 1\})$$

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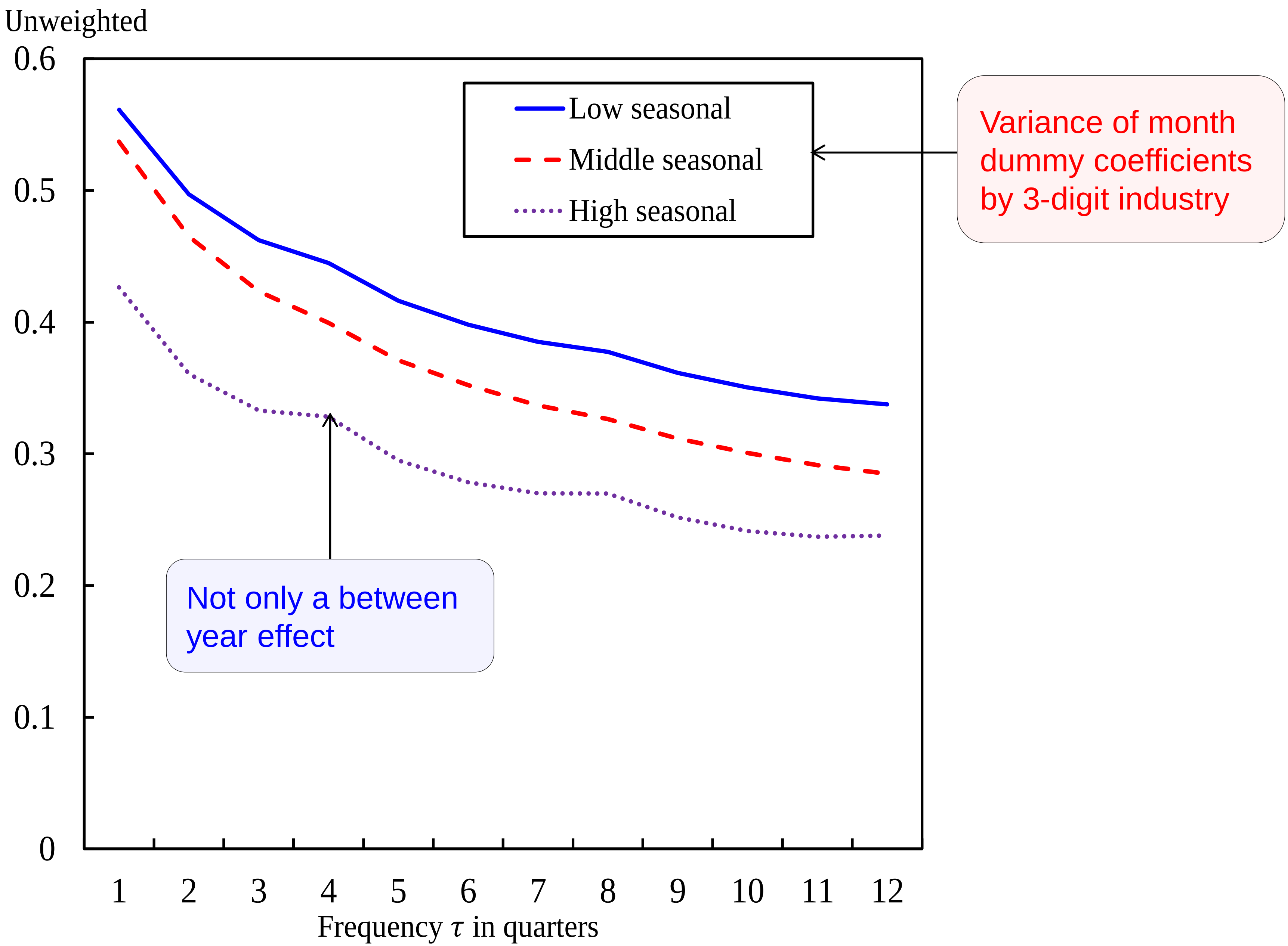
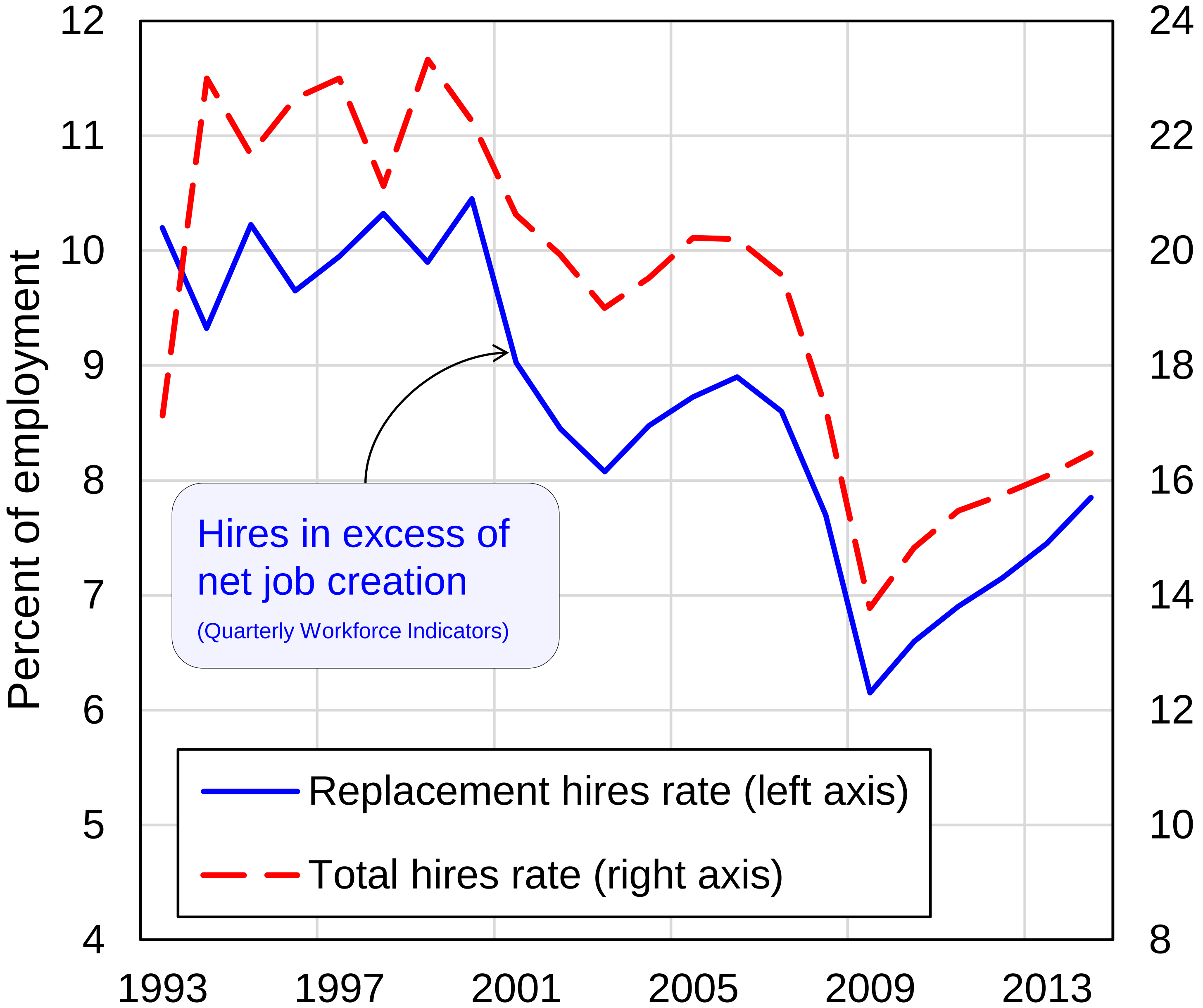


$\Pr(n_t = n_{t+\tau})$, QCEW, average over 1992-2014



Replacement and total hires, QWI

“A vacancy means that a current employee must do the work of a vacant position. This can cause a cascade effect causing others to have to fill in for their position, resulting in many ‘rusty’ people doing unfamiliar jobs and decreasing productivity.”

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~Corporate Strategic Resourcing

Why not Bertrand?

Not at all simple:

1. Within-firm wage distribution to keep track of.

   Multi-worker firms + heterogeneous histories of offers.

2. Bertrand paradox.

   Competing firms *know* which will prevail.

   ε-cost of competing $\Rightarrow$ losing firm withdraws.

   Moscarini (2005): linear surplus sharing obtains.

Why not directed search?

Directed search + free entry + complete contracts

$\Rightarrow$ recruitment and quit rates $\perp$ $\mathbb{J}$s. [Schaal (2015)]

But, we think this dependence is interesting:

1. Because it is. What happens in this case?

2. It is plausible that firms must know position in the J hierarchy to infer turnover.

3. Because $\mathbb{J}$s are slow-moving state variables; interesting propagation properties?

The value of the firm

$$r\Pi(n,x)dt$$

$$= \max_{h,dS}\left\{\left[pxn^{\alpha} - wn - ch + (h - \delta n)\Pi_n + \mu x\Pi_x + \frac{1}{2}\sigma^2 x^2 \Pi_{xx}\right]dt - \Pi_n dS\right\}$$

The value of the firm

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$$+\mu x\Pi_x + \frac{1}{2}\sigma^2 x^2 \Pi_{xx}\Big] dt - J dS\Big\}$$

The value of the firm

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$$\left.\left. +\mu x\Pi_x + \frac{1}{2}\sigma^2 x^2 \Pi_{xx}\right] dt - J dS\right\}$$

First-order conditions:

$$-c + J = 0 \text{ whenever } h > 0,$$

$$J = 0 \text{ whenever } dS > 0.$$

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$$r\Pi(n,x)dt$$

$$= \max_{h,dS}\Big\{\Big[pxn^{\alpha} - wn - J\delta n$$

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First-order conditions:

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BACK

Firm and worker value functions

$$r\Pi = \max_{h,dS}\left\{pxn^{\alpha} - wn - \delta nJ + \mu x\Pi_x + \frac{1}{2}\sigma^2 x^2 \Pi_{xx}\right\}$$

$$rJ = px\alpha n^{\alpha-1} - \frac{\partial(wn)}{\partial n} - \frac{\partial(\delta nJ)}{\partial n} + \mu xJ_x + \frac{1}{2}\sigma^2 x^2 J_{xx}$$

$$rW = w + s\phi\int_W [1 - \mathbb{W}_V(j)]dj - \delta nW_n + \mu xW_x + \frac{1}{2}\sigma^2 x^2 W_{xx}$$

$$rU = b + \phi\int [1 - \mathbb{W}_V(j)]dj$$

Firm and worker value functions

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Ignores infra-marginal effects

Firm and worker value functions

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Gains option value to OJS

Firm and worker value functions

$$rJ = px\alpha n^{\alpha-1} - \frac{\partial(wn)}{\partial n} - \frac{\partial(\delta n J)}{\partial n} + \mu x J_x + \frac{1}{2}\sigma^2 x^2 J_{xx}$$

$$rW = w + s\phi \int_W [1 - \mathbb{W}_V(j)]dj - \delta n W_n + \mu x W_x + \frac{1}{2}\sigma^2 x^2 W_{xx}$$

Ignores firms' turnover costs

BACK