Turbulent Business Cycles[1]

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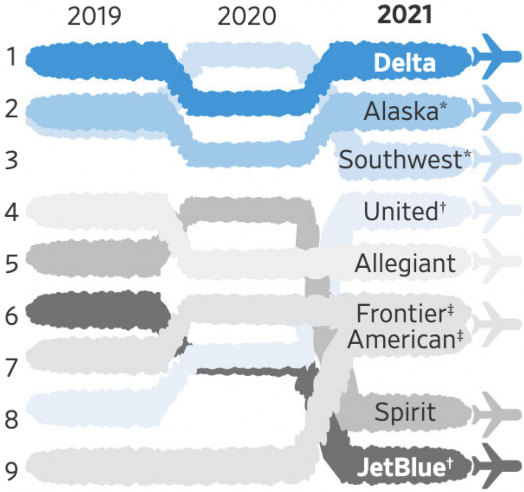
[1]The views expressed herein are those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of San Francisco or the Federal Reserve System.

Turbulent airline industry



*Tied in 2019 †Tied in 2020 ‡Tied in 2021
Sources: Anuvu; Transportation Department

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- Not studied here: What drives turbulence? (an important but separate issue, similar to "What drives TFP/Uncertainty?")

What's turbulence?

- Consider firm-level TFP process

$$z_{j,t+1} = \begin{cases} z_{j,t} & \text{with prob} \quad \rho_t, \\ \tilde{z} & \text{with prob} \quad 1-\rho_t, \end{cases}$$

where $\tilde{z} \sim \tilde{G}(z)$ is i.i.d.

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- Turbulence: measured as $1-\rho_t$
- Turbulence vs. micro uncertainty (mean-preserving spread)
  - Similarity: both raise conditional variance of productivity: $Var(z_{j,t+1}|z_{j,t}) = (1-\rho)^2 Var(\tilde{z})$
  - Difference: turbulence raises conditional mean of productivity for high-z firms and lowers it for low-z firms
  - Difference: turbulence preserves distribution: $G_{t+1}(z) = G_t(z)$

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- Absent measurement errors in firm productivity, ρ_t = Spearman rank correlation of productivity b/n t and t + 1

Challenges for measuring turbulence

- True productivity z (TFPQ) not observed. Observed productivity a (TFPR) contains measurement errors τ:

$$a_{j,t} = z_{j,t} + \tau_{j,t}$$

where $\tau \sim N(0, \sigma_t)$ is i.i.d. noise

- Observed productivity:

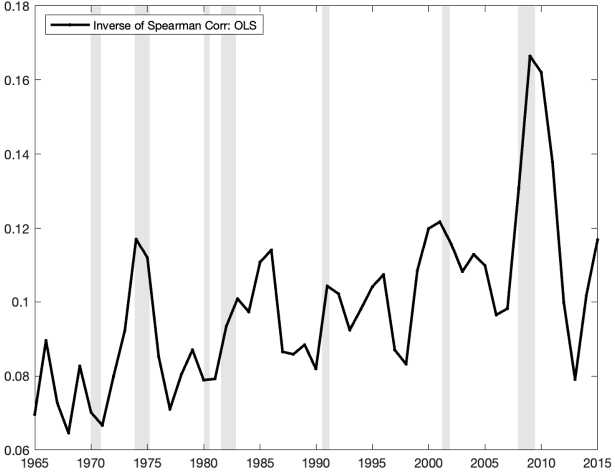
$$a_{j,t+1} = \begin{cases} a_{j,t} + \underbrace{\tau_{jt+1} - \tau_{jt}}_{\equiv e_{jt+1}} & \text{with prob} \quad \rho_t, \\ \tilde{z} + \tau_{j,t} & \text{with prob} \quad 1 - \rho_t, \end{cases}$$

- Potential biases in estimating turbulence:
  - Heteroskedasiticty: time-varying vol of τ could confound turbulence
  - Endogeneity bias: regression residuals $e_{j,t+1}$ correlated with $a_{j,t}$

Measuring turbulence

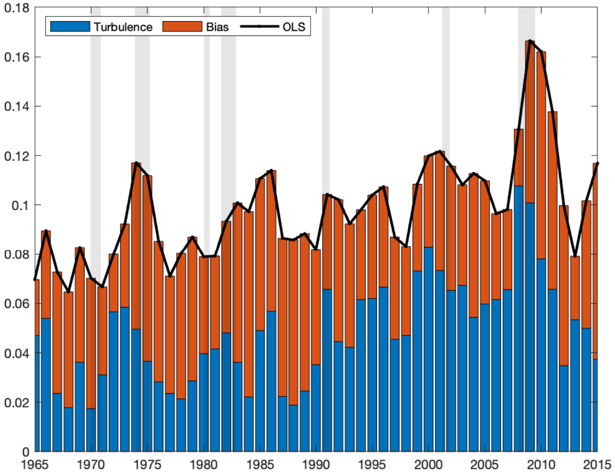
- Correcting heteroskedasticity using rank correlations
  - Rank distribution is time-invariant regardless of functional form of true productivity variance
  - Estimate ρ_t using Spearman rank correlation in a (instead of level of a)
- Mitigating endogeneity bias using IV approach (Arellano-Bond)
  - Use ranking of a_{t-1} and a_{t-2} as IV for ranking of a_t
  - Relevance: $corr(a_t, a_{t-1}) \neq 0$;
  - Exogeneity: $corr(\tau_t, a_{t-1}) = 0$

Churn in firm productivity ranking (OLS)

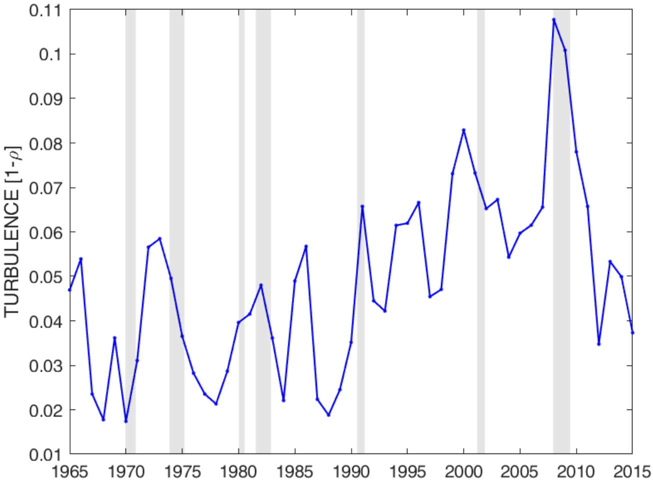


This figure plots the inverse of Spearman corr of firm TFP b/n year t and $t+1$ based on CRS tech $a_{ijt} = y_{ijt} - \alpha_{it} k_{ijt} - (1-\alpha_{it}) n_{ijt}$, calcualted using Compustat and NBER-CES data

Decomposition: churn in firm productivity ranking



Turbulence is countercyclical



Reallocation effects of turbulence

- Estimate baseline regression:

$$\Delta y_{jt} = \beta_0 + \beta_1 High\_TFP_{jt} + \beta_2 Turb_t * High\_TFP_{jt} + x_{jt} + \mu_j + \eta_t + \epsilon_{jt},$$

1. Δy_{jt}: YoY growth of employment, capital, value-added, or market value of firm j in year t
2. $High\_TFP_{jt} = 1$ if firm's TFP is above median *within its industry*
3. $Turb_t$: turbulence measured by $1 - \rho_t$
4. x_{jt}, μ_j and η_t: firm-year controls, firm- and year- fixed effects

- β_2: marginal effects of turbulence on high-productivity firms
  - If $\beta_2 < 0$: stronger adverse effects on high-productivity firms

Scatter

Turbulence has significant reallocation effects

Dep. Var.	Δn_{jt}	Δk_{jt}	Δy_{jt}	Δv_{jt}
	(1)	(2)	(3)	(4)
$High\_TFP_{jt}$	0.006	0.018**	0.094***	0.053***
	(0.006)	(0.007)	(0.006)	(0.008)
$Turb_t * High\_TFP_{jt}$	-0.945***	-0.969***	-1.220***	-0.940***
	(0.095)	(0.144)	(0.086)	(0.139)
Constant	0.052***	0.060***	0.034***	0.032***
	(0.002)	(0.003)	(0.004)	(0.002)
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	24,501	24,501	24,501	21,687

- One std increase in turbulence reduces high-productivity firm employment growth by about 6% and capital growth by 2.8%
- Reallocation effects: high-productivity firms → low-productivity firms

Robust reallocation effects of turbulence

- Controlling for effects from recessions
- Lagged high-TFP indicator
- Finer grouping of firms
- Sample with large industries (min 20 firms in each industry/year)
- Sample excluding large (top 5%) firms
- Decreasing returns technology

Financial frictions amply reallocation effects of turbulence

- Estimate the industry-level panel regression:

$$IQR_{it} = \beta_0 + \beta_1 High\_FF_{it} + \beta_2 Turb_t * High\_FF_{it} + \mu_i + \eta_t + \epsilon_{it},$$

1. IQR_{it}: Inter-quartile range (IQR) of employment (or capital) in industry i and year t;
2. $High\_FF_{it} = 1$ iff industry's financial friction (ff) measure above median
3. μ_i and η_t: industry and year fixed effects

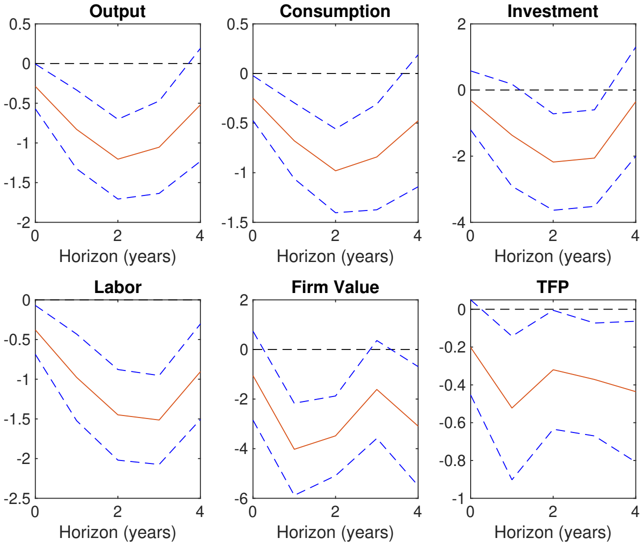
- β_2: marginal effects of turbulence on high financial friction industries
  - Low IQR of N and K indicates higher misallocation
  - If $\beta_2 < 0$: stronger reallocation effects for high-ff industries

Financial frictions significantly amplify reallocation

Dep. Var.	IQR of Employment		IQR of Capital	
	(1)	(2)	(3)	(4)
$High\_FF_{it}$	0.232***	0.271***	0.335***	0.385***
	(0.084)	(0.085)	(0.097)	(0.098)
$Turb_t * High\_FF_{it}$	-4.791***	-5.448***	-6.866***	-7.741***
	(1.548)	(1.566)	(1.792)	(1.810)
Constant	1.869***	1.895***	2.090***	2.122***
	(0.024)	(0.025)	(0.028)	(0.028)
Industry Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	3,647	3,552	3,647	3,552

- Column (2) and (4): lagged dummy $High\_FF_{it-1}$ replacing $High\_FF_{it}$

Turbulence is associated with synchronized recession



Summary of evidence

- Turbulence rises in recessions
- Increase in turbulence associated with
  1. reallocation from high- to low-productivity firms
  2. reallocation amplified by financial frictions
  3. synchronized and persistent declines in aggregate activity
- Turbulence is quantitatively important: one std increase in turbulence reduces real GDP by up to 1%

RBC model with turbulence shocks

- Heterogeneous firms facing idiosyncratic productivity with time-varying persistence
- Financial frictions: Firms finance working capital against equity value (Jermann-Quadrini 2012; Miao-Wang, 2018; Lian-Ma, 2021)

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- Heterogeneous firms facing idiosyncratic productivity with time-varying persistence
- Financial frictions: Firms finance working capital against equity value (Jermann-Quadrini 2012; Miao-Wang, 2018; Lian-Ma, 2021)
- Misallocation channel of turbulence
  - Turbulence ↑ ⇒ expected productivity of high-productivity firms ↓ ⇒ expected cash flow of high-productivity firms ↓ ⇒ equity value (Q_{jt}) of high-productivity firms ↓
  - Tightened borrowing constraints for high-productivity firms ⇒ reallocation toward low-productivity firms ⇒ TFP ↓ ⇒ synchronized recession in Y, C, I and N

Firms

- Production function: $y_{jt} = A_t z_{jt} k_{jt}^{\alpha} n_{jt}^{1-\alpha}$. '
- Idiosyncratic productivity z_{jt} follows process

$$z_{j,t+1} = \begin{cases} z_{jt} & \text{with prob} \quad \rho_t, \\ \tilde{z} & \text{with prob} \quad 1-\rho_t, \end{cases} \tag{1}$$

where $1-\rho_t$ is subject to turbulence shock.

- Bellman equation:

$$V_t(z_{jt}, \tau_{jt}) = \max_{k_{jt}, n_{jt}} \tau_{jt} y_{jt} - \underbrace{(R_t k_{jt} + W_t n_{jt})}_{W.C.} + \mathbb{E} \underbrace{M_{t+1}}_{SDF} V_{t+1}(z_{jt+1}, \tau_{jt+1})$$

s.t. working capital constraint *a la* Jermann & Quadrini (12), Miao & Wang (2018)

$$R_t k_{jt} + W_t n_{jt} \leq \theta \mathbb{E} M_{t+1} V_{t+1}(z_{jt+1}, \tau_{jt+1}) \equiv \theta Q_{jt} \tag{2}$$

where $\tau_{jt} \sim F(\tau)$: i.i.d. distortion (Hsieh-Klenow 2009; Buera-Shin 2013)

Firms

- At each productivity z_{jt}, firms are active iff $\tau_{jt} \geq \tau^*_{jt}$

$$\tau^*_{jt} = \frac{R_t^\alpha W_t^{1-\alpha}}{\alpha^\alpha (1-\alpha)^{1-\alpha} A_t z_{jt}} \tag{3}$$

  - τ^*_{jt} decreasing with z_{jt}
  - τ^*_{jt} increasing with R_t, W_t

- Labor demand

$$n_t(z_{jt}, \tau_{jt}) = \begin{cases} \frac{(1-\alpha)\theta Q_{jt}}{W_t}, & if \quad \tau_{jt} \geq \tau^*_{jt} \\ 0, & otherwise \end{cases} \tag{4}$$

- Capital demand

$$k_t(z_{jt}, \tau_{jt}) = \begin{cases} \frac{\alpha\theta Q_{jt}}{R_t}, & if \quad \tau_{jt} \geq \tau^*_{jt} \\ 0, & otherwise \end{cases} \tag{5}$$

- Model is easy to aggregate

Household optimization and market clearing

- Household's problem:

$$\max_{C_t, N_t, K_{t+1}} \mathbf{E} \sum_{t=0}^{\infty} \beta^t \left\{ \ln C_t - \psi \frac{N_t^{1+\gamma}}{1+\gamma} \right\} \tag{6}$$

  - s.t. budget constraint

$$C_t + K_{t+1} = (R_t + 1 - \delta) K_t + W_t N_t + D_t + T_t \tag{7}$$

- Factor market clearing (N_{jt}: labor to firms with z_{jt})

$$N_t = \sum_j \pi_j N_{jt} \equiv \sum_j \pi_j \frac{(1-\alpha)\theta Q_{jt}}{W_t} \left[1 - F(\tau_{jt}^*)\right] \tag{8}$$

$$K_t = \sum_j \pi_j K_{jt} \equiv \sum_j \pi_j \frac{\alpha\theta Q_{jt}}{R_t} \left[1 - F(\tau_{jt}^*)\right] \tag{9}$$

- Goods market clearing

$$Y_t = C_t + K_{t+1} - (1-\delta) K_t \tag{10}$$

PE channel: Misallocation effect of turbulence

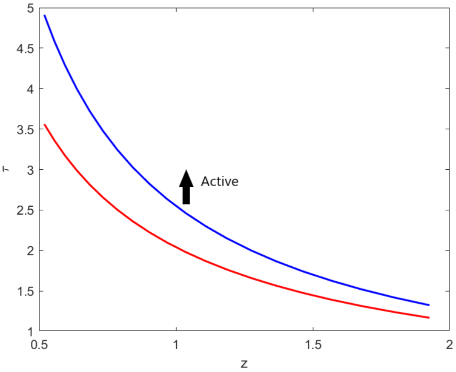
Proposition 1

Given the steady-state factor prices R and W, an increase in average turbulence reduces the share of labor/capital allocated to high-productivity firms.

$$1-\rho\uparrow \quad \rightarrow \quad \frac{N_{high}}{N_{low}}\downarrow$$

- $$\frac{N_{high}}{N_{low}} =$$
- Intuition: Given R and W, turbulence (1-ρ) reduces equity value of high-z firms, reallocating K and N to low-z firms.

GE Channel

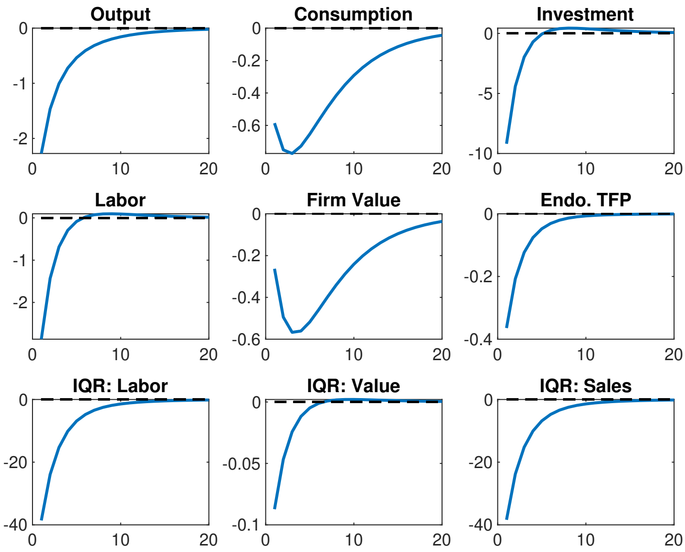


- At each productivity z_{jt}, firms are active iff $\tau_{jt} \geq \tau^*_{jt}$

$$\tau^*_{jt} = \frac{R_t^\alpha W_t^{1-\alpha}}{\alpha^\alpha (1-\alpha)^{1-\alpha} A_t z_{jt}} \tag{11}$$

- GE channel: W_t, R_t ↓ ⇒ threshold curve ↓ and flatter
  ⇒ disproportionately more low-productivity firms turn active

Macro and reallocation effects of turbulence



Counterfactual: Role of financial frictions

- Baseline:

$$V = \max_{k_{jt}, n_{jt}} \tau_{jt} y_{jt} - W.C. + \mathbb{E} M_{t+1} [\rho_t \bar{V}_{j,t+1} + (1-\rho_t) \sum_{i=1}^{J} \pi_i \bar{V}_{i,t+1}]$$

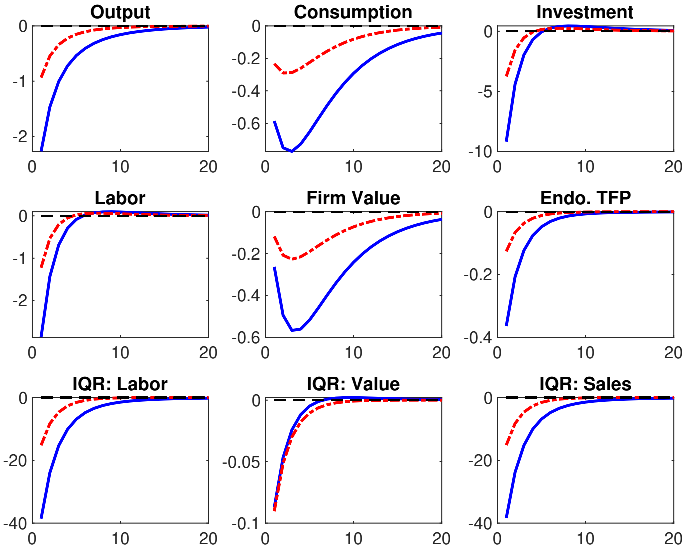
$$W.C. \leq \theta E_t M_{t+1} [\rho_t \bar{V}_{j,t+1} + (1-\rho_t) \sum_{i=1}^{J} \pi_i \bar{V}_{i,t+1}] \quad (12)$$

- Counterfactual: 'quasi-fixed' borrowing constraint

$$V = \max_{k_{jt}, n_{jt}} \tau_{jt} y_{jt} - W.C. + \mathbb{E} M_{t+1} [\rho_t \bar{V}_{j,t+1} + (1-\rho_t) \sum_{i=1}^{J} \pi_i \bar{V}_{i,t+1}]$$

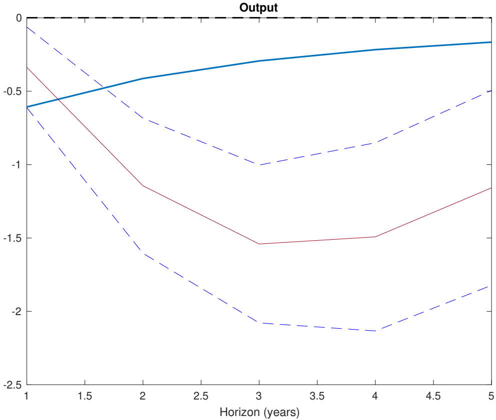
$$W.C. \leq \theta E_t M_{t+1} [\rho_t \bar{V}_j^{ss} + (1-\rho_t) \sum_{i=1}^{J} \pi_i \bar{V}_i^{ss}] \quad (13)$$

Financial frictions important for amplifying turbulence



Impulse responses to a one-std turbulence shock:
Baseline vs. Counterfactual (with quasi-fixed borrowing limit)

IRF to turbulence shock: Model vs. data



Impulse responses of aggregate output to a one-std turbulence shock:

Data vs. Model (with annual calibration)

Two types of policy interventions

- Policy I: Subsidy

$$V_t(z_{jt}, \tau_{jt}) = \max_{k_{jt}, n_{jt}} \tau_{jt} y_{jt} - \underbrace{(1 - \omega_{1t})(R_t k_{jt} + W_t n_{jt})}_{W.C.} + EV \ldots$$

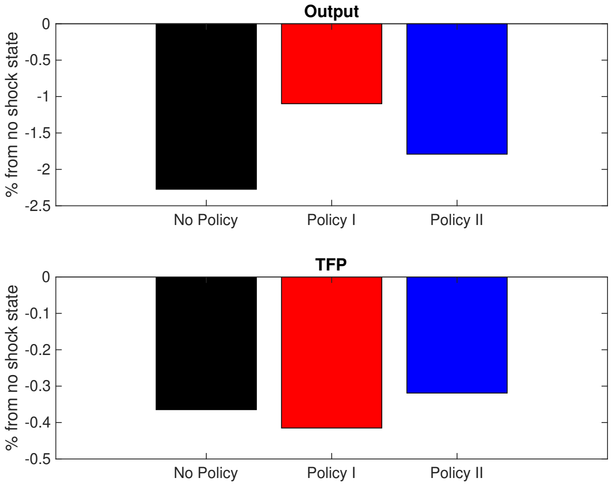
$$s.t. \quad (1 - \omega_{1t})(R_t k_{jt} + W_t n_{jt}) \leq \theta B_{jt} \tag{14}$$

- Policy II: Credit easing

$$s.t. \quad R_t k_{jt} + W_t n_{jt} \leq \theta (1 + \omega_{2t}) B_{jt} \tag{15}$$

- Both policies incur resource costs (gov't inefficiency); both financed by lump-sum taxes
- Policy interventions triggered by turbulence shock, with same persistence as shock

Stabilizing effects of policy interventions



- Both policies effective for stabilizing output fluctuations
- Borrowing subsidy exacerbates misallocation; credit easing improves it

Takeaway points

- Turbulence is countercyclical, rising sharply in recessions
- Turbulence different from micro-level uncertainty:
  - Turbulence changes both conditional mean and vol of firm productivity
- Micro-level turbulence can have important macro effects through reallocation
  - Financial frictions amplify reallocation effects