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.

Background

- Turbulence rises in recession
  - Product churn (Aghion, el al 2021; Bernard and Okubo 2016)
  - Productivity ranking churn (Bloom, et al 2018)
- This paper:
  1. Documents evidence of macro and reallocation effects of turbulence
  2. Studies transmission mechanism
  3. Evaluates alternative policy interventions

What's turbulence?

- Firm-level TFP follows the process

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

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

- Time-varying turbulence: $1-\rho_t$
  - $\rho_t = 1$: permanent shock
  - $\rho_t = 0$: i.i.d. shock
  - $1-\rho_t \uparrow \Rightarrow$ high-(low-) productivity firm less likely to remain productive (unproductive) $\Rightarrow$ turbulence $\uparrow$

- Time-invariant cross-sectional distribution of z
  - $Pr(z_t = z_j) = \pi_j \rightarrow Pr(z_{t+1} = z_j) = \rho_t \pi_j + (1-\rho_t)\pi_j = \pi_j$

Countercyclical turbulence

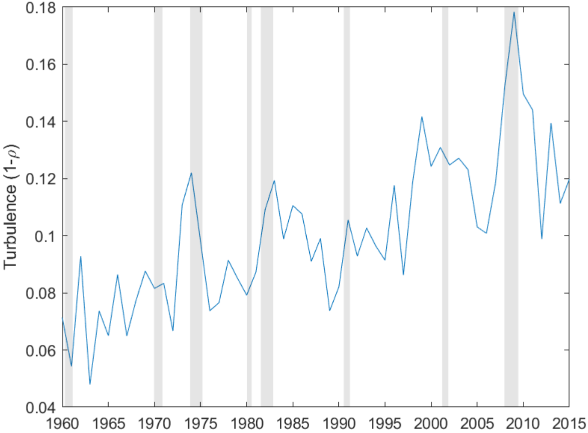


Figure: Measured turbulence is countercyclical details

Turbulence generates recession and reallocation

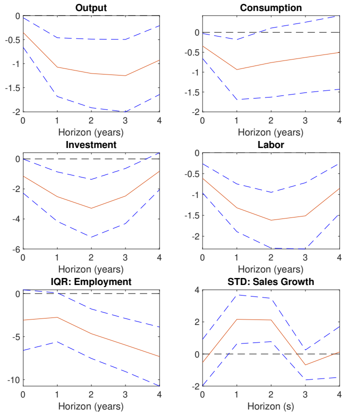


Figure: One standard deviation turbulence shock reduces real GDP by at least 0.5%: turbulence quantitatively important details

Reallocation effects of turbulence

Dep. Var.	Employment growth		Capital growth	
	(1)	(2)	(3)	(4)
$Turb_t * High\_TFP_{jt}$	-0.313***	-0.098**	-0.228***	-0.216***
	(0.046)	(0.039)	(0.055)	(0.055)
constant	0.061***	0.059***	0.071***	0.071***
	(0.002)	(0.002)	(.002)	(.002)
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	25,955	24,288	25,955	24,288

- $High\_TFP_{jt} = 1$ iff firm TFP above median;
- Column (2): lagged dummy $High\_TFP_{jt-1}$ replacing $High\_TFP_{jt}$

details

Summary of evidence

- Turbulence rises in recessions
- Increase in turbulence associated with
  1. declines in aggregate TFP and firm value,
  2. synchronized and persistent declines in aggregate activity,
  3. reallocation from high- to low-productivity firms, and
  4. reallocation effects working through financial frictions details
- Turbulence is quantitatively important: one std increase in turbulence reduces real GDP by 0.5%

RBC model: overview

- Heterogeneous firms
  - productive firm: turbulence $\uparrow \rightarrow$ future profit $\downarrow$ more
- Working capital constraint
  - borrow against firm value (equity) to finance N and K
  - firm value: discounted future profit
  - productive firm: borrow $\downarrow \rightarrow$ N & K share $\downarrow$ (misallocation)
- Misallocation channel of turbulence
  - turbulence $\uparrow \rightarrow$ misallocation $\uparrow \rightarrow$ TFP $\downarrow \rightarrow$ Y $\downarrow$
  - synchronized declines: C, I, N $\downarrow$

Firms [1]

- CRS technology, renting capital (k_{jt}) and labor (n_{jt})

$$y_{jt} = A_t z_{jt} k_{jt}^{\alpha} n_{jt}^{1-\alpha} \tag{2}$$

- z_{jt}: idiosyncratic prod. subject to turbulence shock to ρ_t

$$z_{j,t+1} = \begin{cases} z_{jt} & \text{with prob} \quad \rho_t, \\ \tilde{z} & \text{with prob} \quad 1-\rho_t, \end{cases} \tag{3}$$

- Bellman equation:

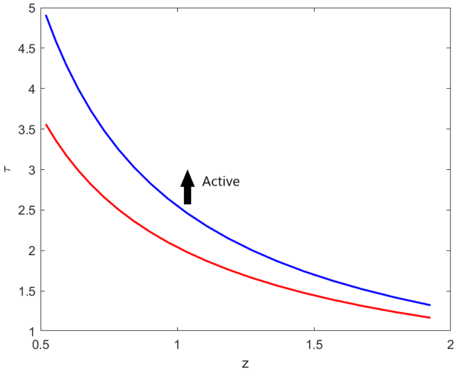
$$V_t(z_{jt}, \tau_{jt}) = \max_{k_{jt}, n_{jt}} \tau_{jt} A_t z_{jt} k_{jt}^{\alpha} n_{jt}^{1-\alpha} - R_t k_{jt} - W_t n_{jt} + \mathbb{E} M_{t+1} V_{t+1}(z_{jt+1}, \tau_{jt+1})$$

s.t. working capital constraints

$$R_t k_{jt} - W_t n_{jt} \leq \theta \mathbb{E} M_{t+1} V_{t+1}(z_{jt+1}, \tau_{jt+1}) \equiv \theta B_{jt} \tag{4}$$

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

Production decisions



- Active firms: $\{\tau, z\}$ above threshold curve $\tau_t^* \propto \frac{R_t^\alpha W_t^{1-\alpha}}{A_t z_t}$ details
- Higher average turbulence (lower $\bar{\rho}$): high z firms less likely to remain productive, lowering wages and shifting down threshold curve

Equilibrium

- Household's problem:

$$\max_{C_t, N_t, K_{t+1}} \mathrm{E} \sum_{t=0}^{\infty} \beta^t \left\{ \ln C_t - \psi \frac{N_t^{1+\gamma}}{1+\gamma} \right\} \tag{5}$$

  - s.t. budget constraint

$$C_t + K_{t+1} = (R_t + 1 - \delta) K_t + W_t N_t + D_t + T_t \tag{6}$$

- Factor market clearing

$$N_t = \sum_j \pi_j n_{jt} \equiv \sum_j \pi_j \frac{(1-\alpha)\theta B_{jt}}{W_t} \left[1 - F(\tau_{jt}^*) \right] \tag{7}$$

$$K_t = \sum_j \pi_j k_{jt} \equiv \sum_j \pi_j \frac{\alpha \theta B_{jt}}{R_t} \left[1 - F(\tau_{jt}^*) \right] \tag{8}$$

- Goods market clearing

$$Y_t = C_t + K_{t+1} - (1-\delta) K_t \tag{9}$$

IRF: turbulence shock

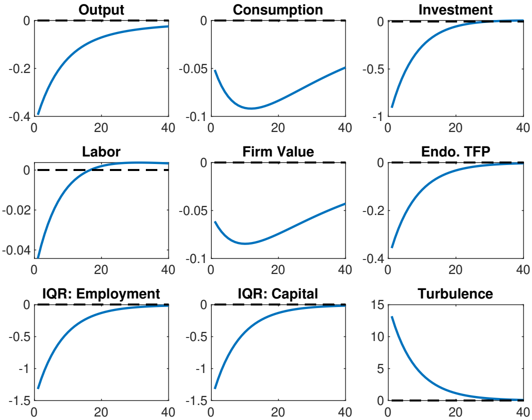


Figure: Impulse responses to one std turbulence shock

calibration

Counterfactual: turbulence shock

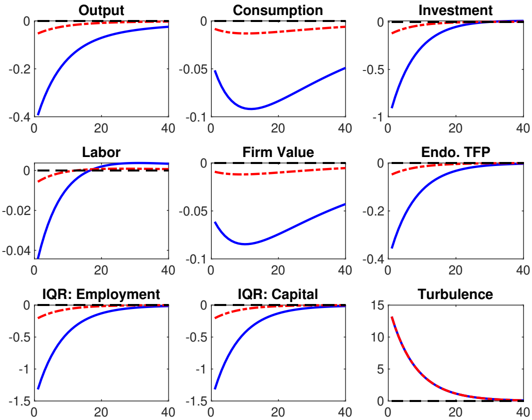


Figure: Counterfactual: "Quasi-fixed" borrowing limit (red lines)

$$R_t k_{jt} + W_t n_{jt} \leq \theta E_t M_{t+1}[\rho_t \bar{V}_j^{ss} + (1-\rho_t)\sum_{i=1}^{J} \pi_i \bar{V}_i^{ss}]$$

Turbulence vs micro-level uncertainty shock

- Uncertainty shock:

$$\ln(\sigma_{\tau,t}) = (1-\rho_\sigma)\ln(\sigma_\tau) + \rho_\sigma \ln(\sigma_{\tau,t-1}) + \sigma_\sigma \varepsilon_t^\sigma,$$

- Similar to uncertainty, turbulence increases conditional vol of productivity
  - conditional variance of z_{jt+1}

$$var(z_{jt+1}) = (1-\rho_t)^2 var(\tilde{z}) \tag{10}$$

  - strictly decreasing in ρ_t for all j
- Different from uncertainty, turbulence preserves ex ante productivity distribution

$$\begin{aligned} G_{t+1}(z) &= Pr(z_{t+1} \leq z) \\ &= Pr(z_t \leq z)\rho_t + Pr(\tilde{z} \leq z)(1-\rho_t) \\ &= G_t(z)\rho_t + \tilde{G}(z)(1-\rho_t) = G_t(z) \end{aligned}$$

IRF: uncertainty shock

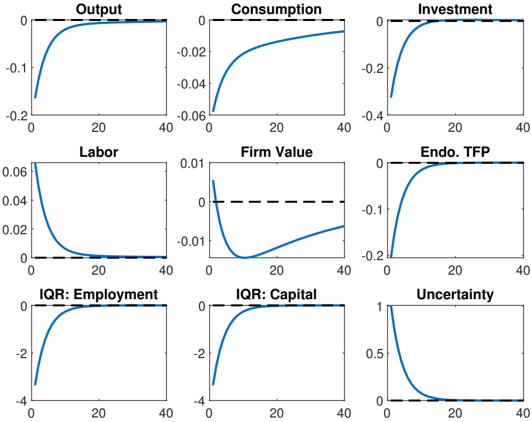


Figure: Impulse responses to micro uncertainty shock $\sigma_{\tau t}$

Uncertainty expands right tail of τ distribution, raising average subsidy for active firms and increasing labor demand

Model vs data

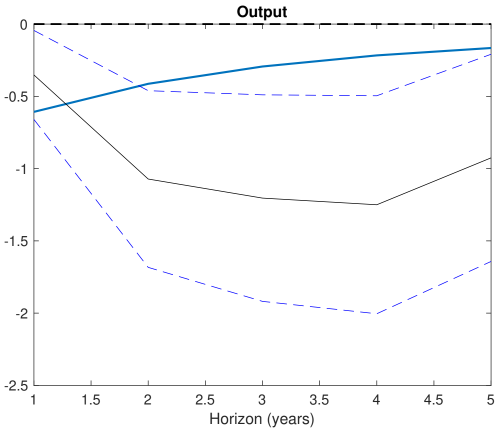


Figure: Impulse response to turbulence shock: Model vs. data

One std turbulence shock reduces aggregate output about 0.5%, both in annual model (blue line) and in data (black line)

Two types of policy interventions

- Policy I: Borrowing subsidy

$$s.t. \quad (1 - \omega_{1t})(R_t k_{jt} + W_t n_{jt}) \leq \theta B_{jt} \tag{11}$$

- Policy II: Credit easing

$$s.t. \quad R_t k_{jt} + W_t n_{jt} \leq \theta(1 + \omega_{2t}) B_{jt} \tag{12}$$

- 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

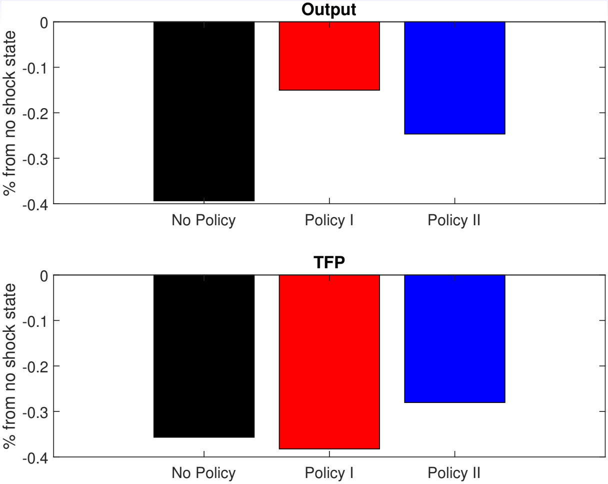


Figure: Stabilizing effects of policy interventions

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

Conclusion

- Firm-level evidence shows that countercyclical turbulence has important macro and reallocation effects
    - Financial frictions are important in reallocation effects
- RBC model with firm heterogeneity and financial frictions highlights reallocation channel for transmitting turbulence over business cycles
- Credit policies can stabilize turbulence-drive recessions, but implications for reallocation depend on policy
    - Borrowing subsidies amplify misallocation whereas credit easing mitigates it.

THANK YOU !

Measuring turbulence

- Construct firm-level TFP following literature (Syverson, 2004; Foster, et al 2008), using data from Compustat and NBER-CES (1958-2016)

$$tfp_{ijt} = y_{ijt} - \alpha_{it} k_{ijt} - (1 - \alpha_{it}) n_{ijt} \tag{13}$$

- Calculate Spearman rank correlation of firm-level TFP between year t and $t+1 \Rightarrow \rho_t$
- Turbulence measured by $1 - \rho_t$

back

Macro effects of turbulence

- Local projections (Jorda, 2005)

$$x_{t+h} - x_{t-1} = \beta_0^h + \beta_1^h turb_t + \beta_2^h turb_{t-1} + \beta_3^h dx_{t-1} + \epsilon_{t+h}, \tag{14}$$

- x_t denotes macro variable of interest (log level of GDP, C, I, H, IQR_n, and IQR_k); $turb_t$ denotes turbulence in log units ($log(1-\rho_t)$)
- β_1^h measures IRFs to turbulence shock at horizon h (years)
- Sample: Annual time series from 1958 to 2015

back

Reallocation effects of turbulence [1]

- Estimate the regression:

$$x_{jt} = \beta_0 + \beta_1 Turb_t * High\_TFP_{jt} + \mu_j + \eta_t + \epsilon_{jt}, \qquad (15)$$

1. x_{jt}: growth of N (or K) in firm j at year t;
2. $Turb_t$: turbulence at year t;
3. $High\_TFP_{jt}$: binary dummy of high TFP firms ($>$ median)
4. Robustness: quartile dummies replacing binary dummy

- β_1: additional effects of turbulence on high-productivity firms
  - $\beta_1 < 0$: high-productivity firms more sensitive to turbulence

back

Reallocation effects of turbulence: robustness

Dep. Var.	Employment growth		Capital growth	
	(1)	(2)	(3)	(4)
$Turb_t * z_{2,jt}$	-0.186***	-0.061	-0.182***	-0.127***
	(0.054)	(0.044)	(0.052)	(0.049)
$Turb_t * z_{3,jt}$	-0.338***	-0.098*	-0.283***	-0.256***
	(0.064)	(0.047)	(0.072)	(0.070)
$Turb_t * z_{4,jt}$	-0.658***	-0.242***	-0.512***	-0.412***
	(0.093)	(0.062)	(0.092)	(0.084)
constant	0.076***	0.055***	0.085***	0.081***
	(0.005)	(0.003)	(0.005)	(0.005)
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	24,288	24,288	24,288	24,288

- $z_{2,jt} = 1$, $z_{3,jt} = 1$, $z_{4,jt} = 1$ when firm j's TFP ranking is in 50th, 75th and 100th quartile;
- Column (2): lagged dummy $z_{2,jt-1}, z_{3,jt-1}, z_{4,jt-1}$ replacing $z_{2,jt}, z_{3,jt}, z_{4,jt}$

back

Reallocation effects: role of financial friction

Dep. Var.	IQR of Employment		IQR of Capital	
	(1)	(2)	(3)	(4)
$High\_FF_{it}$	0.682**	0.435	0.962**	0.724*
	(0.315)	(0.340)	(0.368)	(0.406)
$Turb_t * High\_FF_{it}$	-5.789**	-3.805	-8.151**	-6.256*
	(2.863)	(3.055)	(3.397)	(3.634)
constant	2.008***	2.036***	2.15***	2.174***
	(0.043)	(0.045)	(0.040)	(0.043)
Industry Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	2,505	2,421	2,505	2,421

- $High\_FF_{it} = 1$ if industry i's external financing dependence is above the median.
- Column (2): lagged dummy $High\_FF_{it-1}$ replacing $High\_FF_{it}$

back

Firms [2]

- At each productivity z_{jt}, firms are active iff $\tau_{jt} \geq \tau_{jt}^*$
- Break-even threshold

$$\tau_{jt}^* = \frac{R_t^\alpha W_t^{1-\alpha}}{\alpha^\alpha (1-\alpha)^{1-\alpha} A_t z_{jt}} \tag{16}$$

- Labor demand

$$n_t(z_{jt}, \tau_{jt}) = \begin{cases} \frac{(1-\alpha)\theta B_{jt}}{W_t}, & if \quad \tau_{jt} \geq \tau_{jt}^* \\ 0, & otherwise \end{cases} \tag{17}$$

- Capital demand

$$k_t(z_{jt}, \tau_{jt}) = \begin{cases} \frac{\alpha\theta B_{jt}}{R_t}, & if \quad \tau_{jt} \geq \tau_{jt}^* \\ 0, & otherwise \end{cases} \tag{18}$$

back

Misallocation effect of turbulence in steady state

Proposition 1

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

$$\frac{\partial \eta_{ji}}{\partial \bar{\rho}} > 0,$$

where $\eta_{ji} \equiv \frac{N_j}{N_i}$ denotes relative labor hours allocated to firms with $z_j > z_i$.

- Higher turbulence reduces expected value of high-productivity firms, tightening their credit constraints and reallocating N to low-productivity firms

Calibration [1]

- Turbulence shock $1 - \rho_t$
  - Calibrated based on Spearman correlation of firm-level TFP in annual data 1960-2015, converted to quarterly
  - TFP in data is revenue based, corres. to $TFP_{jt} = z_{jt}\tau_{jt}$ in model
  - τ_{jt} is i.i.d. $\Rightarrow$ Spearman correlation of true productivity z_{jt} same as that of TFP_{jt}
- Idiosyncratic production distortion τ_{jt}
  - Average dispersion $\sigma_\tau = 0.6$ to match IQR of employment (17) in 1960-2015 data
  - Mean value of normalized such that $\mathbb{E}\tau_{jt} = 1$
- Calibrate process for z_{jt} based on $tfp_{jt} = \log(z_{jt}) + \log(\tau_{jt})$
  - Measured TFP has std $\sigma_{tfp} = 0.607$
  - $\log(z_{jt})$ and $\log(\tau_{jt})$ independent $\Rightarrow \sigma_z = \sqrt{\sigma^2_{tfp} - \sigma^2_\tau} = 0.05$

Calibration [2]

	Parameter Description	Value	Target
β	Discount factor	0.99	Annual real rate of 4% per year
α	Capital share	0.34	Ave. cost share of capital
δ	Capital depreciation rate	0.025	Annual depreciation rate of 10%
γ	Inverse Frisch elasticity	5	Frisch elasticity of 0.2
θ	Loan to value ratio	0.35	Working K to equity (Compustat)
$\bar{\rho}$	Ave persistence	0.974	Compustat and NBER-CES
ρ_ρ	AR(1) of turbulence	0.882	Compustat and NBER-CES
σ_ρ	std of turbulence shock	0.124	Compustat and NBER-CES
μ_τ	Average distortion	-0.18	Compustat and NBER-CES
σ_τ	std of distortion	0.60	Compustat and NBER-CES
σ_z	std of firm-level TFP	0.05	Compustat and NBER-CES

back

IRF: TFP shock

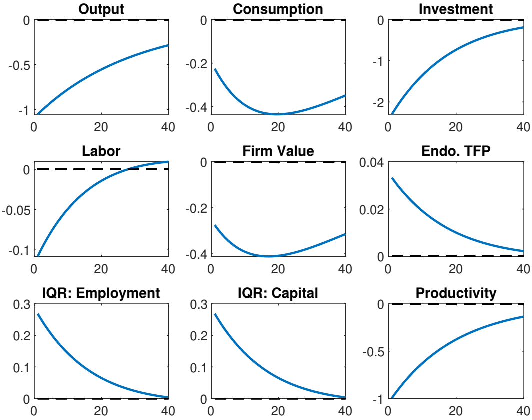


Figure: Impulse responses to negative aggregate TFP shock.

1. Decline in TFP shrinks set of active firms; 2. Lower prod. firms more likely to go inactive, improving allocation efficiency (cleansing effect)