TURBULENT BUSINESS CYCLES
ONLINE APPENDIX

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Abstract. This online appendix provides robustness analysis of the main results reported in the paper by Dong et al. (2023).

Appendix A. Robustness of empirical results

This appendix presents some robustness checks on the empirical measurement of turbulence, the macroeconomic and reallocation effects of turbulence.

A.1. **Measures of turbulence.** Our measure of turbulence is robust to alternative measures of value added, capital input, and labor input. It is also robust to the data samples used.

In our benchmark empirical specification, we construct firm-level TFP based on firm-level value added and capital and labor inputs. We measure value added using firm-level sales and the average share of intermediate inputs at the 6 digit industry level, where the intermediate input share is the ratio of costs of materials to total value of shipments. We measure capital input using the real book value of a firm and labor input using the number of employees. We also focus on the sample that contains firms with 25+ years of observations (Sample 2).

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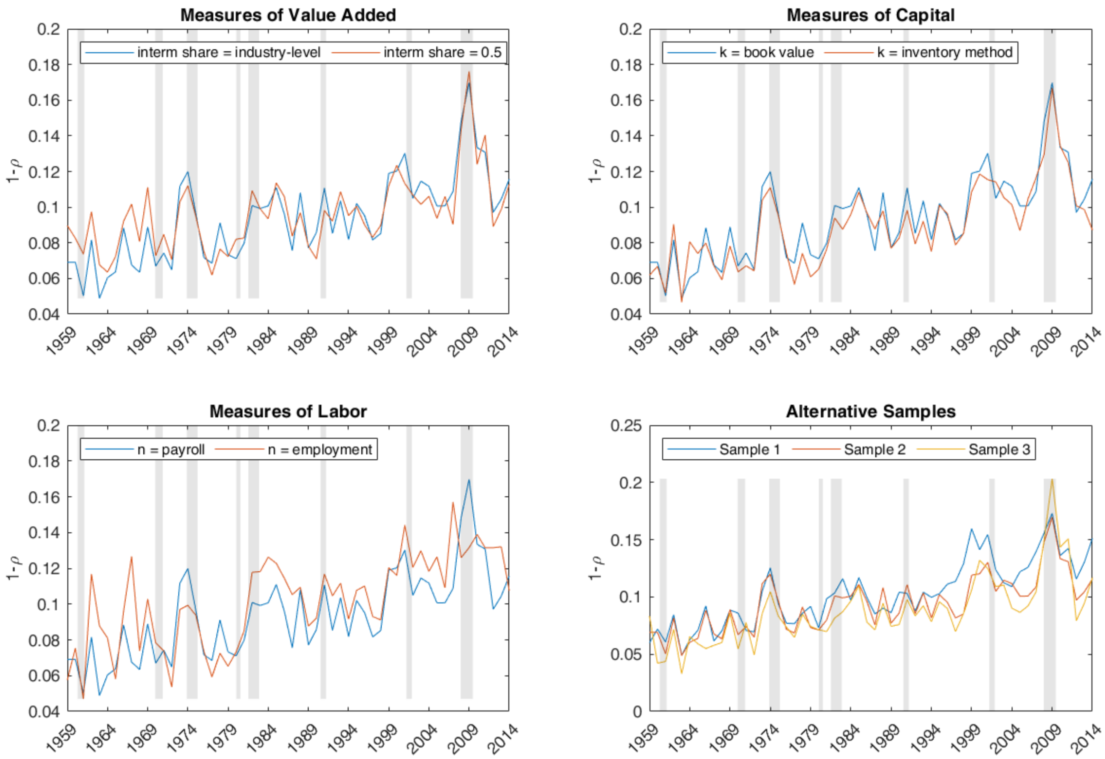

FIGURE A1. Robustness of Turbulence Measure

Figure A1 shows that the turbulence measure is robust to alternative measurements of value added, capital and labor inputs, and alternative samples.

The upper left panel of the figure compares the benchmark measure of turbulence (blue line) and the alternative measure using a different measure of value added (red line). In particular, we follow the approach in David et al. (2016) and David and Venkateswaran (2019), and construct value added by assuming a constant intermediate input share of 0.5 for all firms. These two alternative measures of turbulence are highly correlated, with a correlation coefficient of 0.7806. We have also considered another approach to constructing firm-level value added by subtracting the costs of goods sold from reported sales in Compustat (not shown in the figure). The resulting turbulence measure is also highly correlated with our benchmark measure, with a correlation coefficient of 0.7583.

The upper right panel of Figure A1 shows that the measure of turbulence is robust to alternative approaches to measuring capital. Here, instead of using the real book value of firms, we measure capital input using a perpetual inventory method. Specifically, we first fix the initial real value of capital using $PPEGT$ in the first year of our sample. We then construct a measure of net investment using $PPENT_{it} - PPENT_{it-1}$, deflated by industry-specific investment deflators. Finally we iterate forward the law of motion of the capital stock by adding real net investment to the capital stock in the previous period. With this alternative measure of capital, we obtain a turbulence series (red line) that is highly correlated with the benchmark series (blue line), with a correlation coefficient of 0.8650.

The measure of turbulence is also robust to alternative approaches to measuring labor input, as shown in the lower left panel of Figure A1. Here, instead of measuring labor input by a firm's total payroll, we measure labor input by the number of employees. The turbulence series under this alternative measure of labor input (red line) is highly correlated with the benchmark series (blue line), with a correlation coefficient of 0.7428.

Finally, the lower right panel of the figure shows that the turbulence measure is robust to alternative data samples.

A.2. **Reallocation effects of turbulence.** The reallocation effects of turbulence are robust to alternative high-TFP indicators, alternative samples, and including controls of the potential reallocation effects of recessions.

Our baseline regression estimates the effects of turbulence on firms with different levels of TFP, based on current-year firm-level TFP ranking. It is possible that a firm's employment, capital or sales growth might affect its contemporaneous TFP ranking. To mitigate this concern, we construct an alternative indicator of high-productivity firms based on their TFP rankings with a one-year lag. We re-estimate the responses of firm growth to turbulence shocks for firms with different levels of productivity. Table A.1, with the lagged high-TFP indicator, turbulence reduces growth for high-productivity firms relative to low-productivity firms, similar to the results obtained under the benchmark specification.

To examine the robustness of the reallocation effects of turbulence, we also consider an alternative specification in which we sort firm-level TFP into four quartiles and we replace the dummy $High\_TFP_{jt}$ in the baseline specification by the dummy indicators of the top three quartiles of the productivity distribution (denoted by $z_{2,j,t}$, $z_{3,j,t}$, and $z_{4,j,t}$) (Table A.2). Implicitly, we treat the firms in the first quartile ($z_{1,j,t}$) of the productivity distribution (i.e., firms with the lowest productivity levels) as the reference group. An increase in turbulence is associated with larger declines in employment, capital, sales and market value growth for firms with higher productivity. These reallocation effects are both statistically significant and economically important.

Our results are also robust to alternative sample selections. Table A.3 shows the estimation results from an alternative sample that includes only large industries, i.e., those with at least 20 firms in each industry and each year.

Our benchmark empirical results suggest that financial frictions are important for amplifying the reallocation effects of turbulence. However, it is plausible that sufficiently large firms

Table A.1. Impact of turbulence on firms with different productivity: Lagged high-TFP indicators

Dep. Var.	Δn_{jt}	Δk_{jt}	Δy_{jt}	Δv_{jt}
	(1)	(2)	(3)	(4)
$High\_TFP_{jt-1}$	0.133***	0.125***	0.093***	0.162***
	(0.012)	(0.013)	(0.012)	(0.022)
$Turb_t * High\_TFP_{jt-1}$	-1.180***	-1.046***	-1.616***	-1.703***
	(0.104)	(0.170)	(0.091)	(0.182)
$constant$	0.021***	0.033***	0.080***	0.043***
	(0.003)	(0.004)	(0.005)	(0.005)
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	23,802	23,802	23,802	22,377

Note: This table shows the regression of firm-level employment, capital expenditure, sales or firm value growth on the measured turbulence ($Turb$) for firms with different levels of TFP (lagged). The dummy $High\_TFP_{jt-1}$ equals one if firm j's TFP at year $t-1$ is above the median and zero otherwise. All regressions use the pseudo panel of Compustat firms that appear for at least 25 years from 1958 to 2015. The standard errors shown in the parentheses are clustered by industries. The stars denote the p-values: $^{*}\, p < 0.1$; $^{**}\, p < 0.05$; $^{***}\, p < 0.01$.

are not as financially constrained as small and medium-sized firms. Including large firms in our sample can thus potentially bias the results against finding important reallocation effects of turbulence. This is indeed the case, as we find using a subsample that excludes the top 5% of firms based on their asset sizes. As shown in Table A.4, excluding the large firms from our sample delivers stronger reallocation effect of turbulence.

Since turbulence is countercyclical, the reallocation effects estimated from our benchmark specification might reflect the general impact of recessions instead of that of turbulence. To address this concern, we consider a regression that controls for the direct reallocation effects of recessions. In particular, we add an interaction term between NBER recession year dummy ($NBER_t$) and our high TFP indicator in the regression. As shown in Table A.5, the reallocation effect of turbulence shock remains significant after controlling for the reallocation effect of recessions.

TABLE A.2. Impact of turbulence on firms with different productivity: Finer grouping of firm TFP levels

Dep. Var.	Δn_{jt}	Δk_{jt}	Δy_{jt}	Δv_{jt}
	(1)	(2)	(3)	(4)
$z_{2,jt}$	0.131***	0.105***	0.087***	0.145***
	(0.008)	(0.015)	(0.011)	(0.014)
$z_{3,jt}$	0.137***	0.116***	0.053***	0.195***
	(0.010)	(0.011)	(0.012)	(0.027)
$z_{4,jt}$	0.176***	0.164***	0.047*	0.121***
	(0.024)	(0.019)	(0.025)	(0.031)
$Turb_t * z_{2,jt}$	-1.273***	-1.126***	-1.481***	-1.461***
	(0.102)	(0.202)	(0.116)	(0.161)
$Turb_t * z_{3,jt}$	-1.219***	-1.102***	-1.498***	-2.045***
	(0.110)	(0.216)	(0.096)	(0.268)
$Turb_t * z_{4,jt}$	-1.395***	-1.257***	-1.787***	-1.230***
	(0.156)	(0.185)	(0.120)	(0.226)
Constant	0.016**	0.035***	0.117***	0.040***
	(0.007)	(0.010)	(0.011)	(0.007)
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	25,481	25,481	25,481	23,541

Note: This table shows the regression of firm-level employment, capital expenditure, sales and value growth on the measured turbulence ($Turb$) for firms with different levels of TFP. We sort the Compustat firms into four quartiles based on their TFP levels. The dummy variables $z_{2,jt}$, $z_{3,jt}$, and $z_{4,jt}$ indicate whether a firm j's TFP is in the second, third, or fourth quartile in year t. All regressions use the pseudo panel of Compustat firms that appear for at least 25 years from 1958 to 2015. The standard errors shown in the parentheses are clustered by industries. The stars denote the p-values: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

A.3. **Importance of financial frictions for the reallocation effects of turbulence.** To examine the robustness of the impact of financial friction on reallocation effects of turbulence, we also consider an alternative specification in which we sort industry-level external

TABLE A.3. Impact of turbulence on firms with different productivity: Sample with large industries

Dep. Var.	Δn_{jt}	Δk_{jt}	Δy_{jt}	Δv_{jt}
	(1)	(2)	(3)	(4)
$High\_TFP_{jt}$	0.036***	0.055***	0.151***	0.100***
	(0.008)	(0.009)	(0.006)	(0.020)
$Turb_t * High\_TFP_{jt}$	-0.863***	-0.969***	-1.241***	-0.790***
	(0.062)	(0.143)	(0.088)	(0.193)
$constant$	0.056***	0.067***	0.038***	0.029***
	(0.002)	(0.003)	(0.004)	(0.002)
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	25,481	25,481	25,481	23,541

Note: This table shows the estimation results from the empirical specification that regresses firm-level variables (including the growth rates of employment, capital expenditure, sales, and firm value) on the measured turbulence ($Turb$) for firms with different levels of TFP. The dummy $High\_TFP_{jt}$ equals one if firm j's TFP is above the median within its industry and zero otherwise. All regressions use the pseudo panel of Compustat firms that appear for at least 25 years from 1958 to 2015, in industries with at least 20 firms in each year (sample 3). The standard errors shown in the parentheses are clustered by industry. The stars denote the p-values: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

finance dependence into four quartiles and we replace the dummy $High\_FF_{it}$ in the baseline specification by the dummy indicators of the top three quartiles of the financial friction distribution (denoted by $FF_{2,it}$, $FF_{3,it}$, and $FF_{4,it}$) (Table A.6). Implicitly, we treat the industry in the first quartile ($FF_{1,it}$) of the external finance dependence distribution (i.e., industries with the lowest external finance dependence) as the reference group. An increase in turbulence is associated with larger declines in interquartile range of employment and capital for industries with higher external finance dependence. These effects are both statistically significant and economically important.

A.4. **Macroeconomic effects of uncertainty.** We now examine the macroeconomic effects of uncertainty shock. We follow Bloom et al. (2018) to construct uncertainty as IQR

TABLE A.4. Impact of turbulence on firms with different productivity: Sample excluding large firms

Dep. Var.	Δn_{jt}	Δk_{jt}	Δy_{jt}	Δv_{jt}
	(1)	(2)	(3)	(4)
$High\_TFP_{jt}$	0.132***	0.122***	0.092***	0.159***
	(0.012)	(0.012)	(0.011)	(0.024)
$Turb_t * High\_TFP_{jt}$	-1.093***	-0.933***	-1.507***	-1.554***
	(0.099)	(0.158)	(0.083)	(0.182)
constant	0.021***	0.031***	0.078***	0.042***
	(0.003)	(0.004)	(0.005)	(0.005)
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	22,059	22,059	22,059	20,721

Note: This table shows the estimation results from the empirical specification that regresses firm-level variables (including the growth rates of employment, capital expenditure, sales, and firm value) on the measured turbulence ($Turb$) for firms with different levels of TFP. The dummy $High\_TFP_{jt}$ equals one if firm j's TFP is above the median within its industry and zero otherwise. All regressions use the pseudo panel of Compustat firms that appear for at least 25 years from 1958 to 2015, excluding firms with asset sizes at the top 5% in each year. The standard errors shown in the parentheses are clustered by industry. The stars denote the p-values: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

of micro-TFP shocks, which is consistent with our model specification[1]. For this purpose, we estimate the impulse responses of several key macroeconomic variables to an uncertainty shock using the local projection regression

$$x_{t+h} - x_{t-1} = \beta_0^h + \beta_1^h \sigma_t + \beta_2^h \sigma_{t-1} + \beta_3^h (x_{t-1} - x_{t-2}) + \epsilon_{t+h} \quad h = 0, 1, 2, 3, 4. \tag{A1}$$

The dependent variable $x_{t+h} - x_{t-1}$ denotes the cumulative changes in the log-level of the variable of interest from year $t-1$ to year $t+h$, where h denotes the projection horizons

[1]To measure uncertainty, we first estimate TFP shocks (e_{jt}) as the residual from the first-order autoregression after controlling for firm- and year- fixed effects: $\log(TFP_{jt}) = \rho \log(TFP_{jt-1}) + \mu_j + \lambda_t + e_{jt}$. We define microeconomic uncertainty in period t as the cross-sectional dispersion (IQR) of TFP shocks in period t+1.

TABLE A.5. Impact of turbulence on firms with different productivity: Control for recession effects

Dep. Var.	Δn_{jt}	Δk_{jt}	Δy_{jt}	Δv_{jt}
	(1)	(2)	(3)	(4)
$High\_TFP_{jt}$	0.067***	0.087***	0.159***	0.152***
	(0.009)	(0.013)	(0.008)	(0.023)
$Turb_t * High\_TFP_{jt}$	-1.022***	-1.201***	-1.154***	-1.030***
	(0.086)	(0.180)	(0.118)	(0.225)
$NBER_t * High\_TFP_{jt}$	-0.039***	0.004	-0.059***	-0.089***
	(0.009)	(0.008)	(0.010)	(0.016)
$constant$	0.053***	0.061***	0.035***	0.025***
	(0.002)	(0.002)	(0.003)	(0.003)
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	18,740	18,740	18,740	17,604

Note: This table shows the estimation results from the empirical specification that regresses firm-level variables (including the growth rates of employment, capital expenditure, sales, and firm value) on the measured turbulence ($Turb$) for firms with different levels of TFP. The dummy $High\_TFP_{jt}$ equals one if firm j's TFP is above the median within its industry and zero otherwise. The dummy $NBER_t$ equals one if year t contains a recession that lasts for at least 60 days based on the NBER recession dates. All regressions use the pseudo panel of Compustat firms that appear for at least 25 years from 1958 to 2015. The standard errors shown in the parentheses are clustered by industry. The stars denote the p-values: $^{*} p < 0.1$; $^{**} p < 0.05$; $^{***} p < 0.01$.

(number of years). The list of dependent variables includes the macroeconomic times series of per capita real consumption, investment, private output (i.e., the sum of consumption and investment), and hours worked, manufacture TFP and interquartile range of sales growth constructed from the firm-level and industry-level data. The independent variable $sigma_t$ denotes the log-level of uncertainty in year t. In estimating the local projections, we control for lagged uncertainty ($sigma_{t-1}$) and the lagged growth rate of the dependent variable ($x_{t-1} - x_{t-2}$). The term ϵ_{t+h} is the regression residual. The parameter β_1^h measures the impulse responses of the macroeconomic variables to an uncertainty shock at horizon h.

Table A.6. Reallocation effects of turbulence: sensitivity to financial friction

Dep. Var.	IQR of Employment	IQR of Capital
	(1)	(2)
$FF_{2,it}$	0.268	0.328
	(0.352)	(0.386)
$FF_{3,it}$	0.435	0.630
	(0.358)	(0.453)
$FF_{4,it}$	1.252***	1.571***
	(0.372)	(0.447)
$Turb_t * FF_{2,it}$	-4.197	-5.102
	(3.373)	(3.788)
$Turb_t * FF_{3,it}$	-4.811	-6.787
	(3.780)	(4.613)
$Turb_t * FF_{4,it}$	-13.142***	-16.655***
	(3.506)	(4.215)
constant	1.910***	2.136***
	(0.073)	(0.085)
Industry Fixed Effect	Yes	Yes
Year Fixed Effect	Yes	Yes
Observations	3,647	3,647

Note: This table shows the regression of inter-quartile range of employment (or capital) on the measured turbulence ($Turb$) for industries with different levels of external finance dependence. We sort the NAICS four-digit industries into four quartiles based on their external finance dependence. The dummy variables $FF_{2,it}$, $FF_{3,it}$, and $FF_{4,it}$ indicate whether a industry i's KZ index is in the second, third, or fourth quartile in year t. All regressions use the pseudo panel of Compustat firms that appear for at least 25 years from 1958 to 2015. The standard errors shown in the parentheses are clustered by industries. The stars denote the p-values: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Figure A2 plots the estimated impulse responses of the macroeconomic variables to a one-standard-deviation uncertainty shock for horizons up to five years[2]. The shock leads

[2] Our measured annual series of (logged) uncertainty has a first-order autocorrelation of 0.631 and a standard deviation of 0.1530, implying a standard deviation of the innovation of 0.1187.

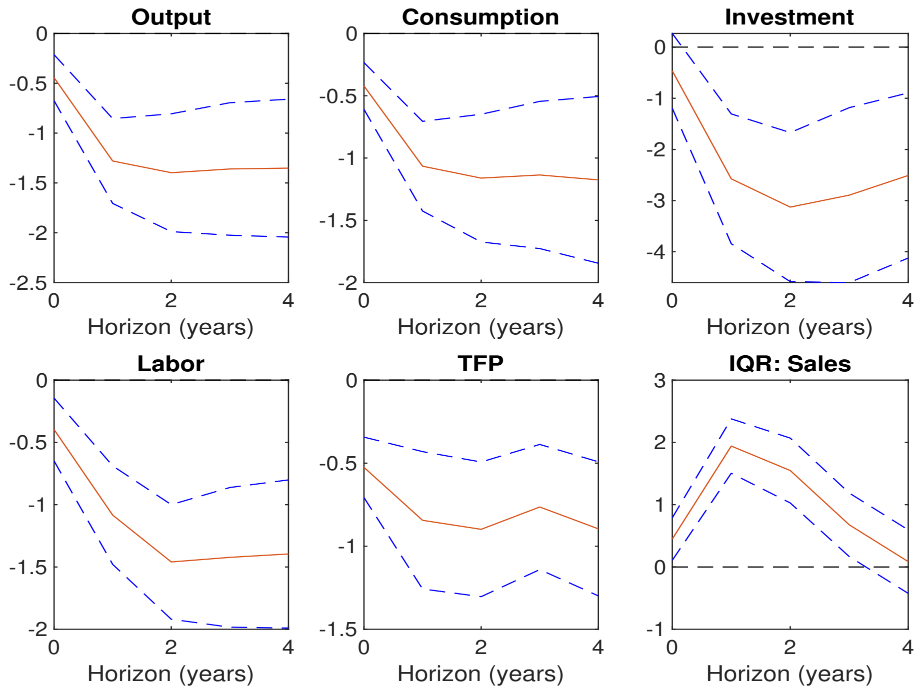

FIGURE A2. Estimated impulse response of macroeconomic variables to an uncertainty shock

Note: This figure shows the impulse responses of macroeconomic variables to a one-standard-deviation (11.87%) increase in the log-level of uncertainty from the local projections model (A1). The solid lines show the point estimates of the impulse responses. The blue dashed lines show the 68% confidence intervals.
Source: BEA, Compustat, NBER-CES, and authors' calculations.

to a recession with synchronized and persistent declines in aggregate output, consumption, investment, and hours worked. It also leads to a decline in manufacturing TFP and a rise in dispersion of sales growth. These macroeconomic effects of uncertainty are consistent with predictions from our calibrated model.

A.5. **Additional results from the calibrated model.** We now report some additional results from the calibrated theoretical model.

A.5.1. *Reallocation effects of a turbulence shock.* Figure A3 shows that turbulence has heterogeneous effects on firms at different productivity levels. As discussed in the text, turbulence reduces aggregate TFP and leads to a recession. Thus, aggregate factor demand declines, reducing wages and capital rents. At any given productivity level, the decline in the factor prices lowers the threshold level of subsidy for active production. Thus, the mass of producers at all levels of productivity increases, although the mass of high productivity firms

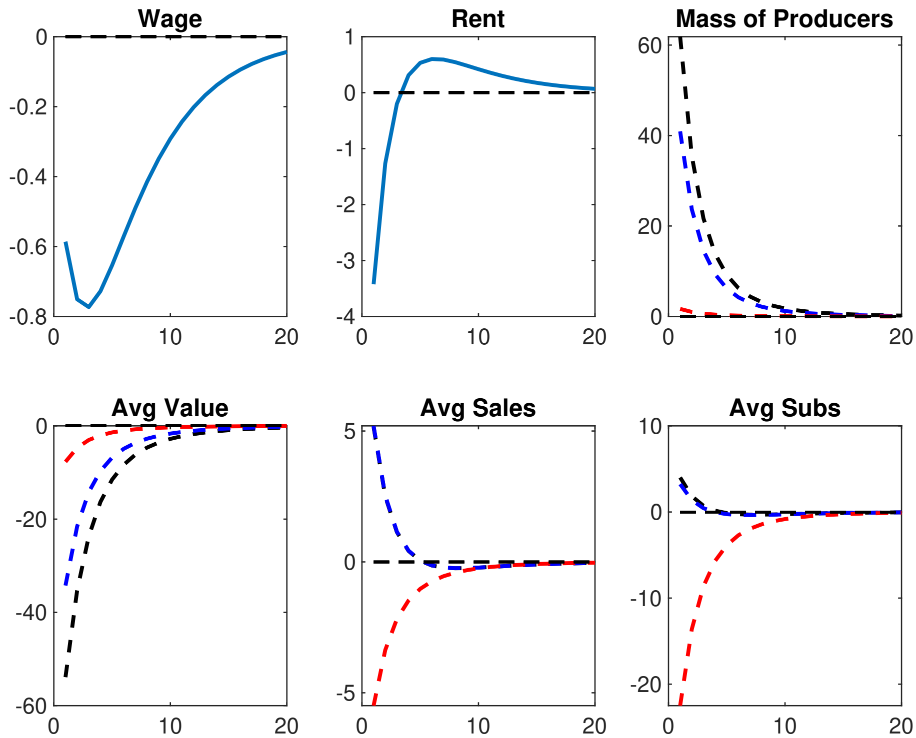

FIGURE A3. Reallocation effects of a turbulence shock

This figure shows the impulse responses to a turbulence shock in the benchmark model. The black, blue and red dashed lines represent, respectively, the responses of firms at the 25, 50 and 100 percentiles of the productivity distribution. The horizontal axis shows the periods (years) after the impact of the shock. The vertical axis measures percent deviations from the stochastic steady-state in response to a one-standard-deviation shock to turbulence.

increases less because the shock that reshuffles productivity implies that higher-productivity firms are less likely to remain productive. Since all firms face the same factor prices, firms with lower productivity require higher subsidies to stay active. Therefore, average sales of active low-productivity firms increase relative to those of high-productivity firms, exacerbating misallocation.

A.5.2. *Reallocation effects of a micro-level uncertainty shock.* An uncertainty shock measured by a mean-preserving spread of the production subsidies (i.e., an increase in $\sigma_{\tau,t}$) expands the tails of the subsidy distribution. At each level of productivity z_{jt}, a firm would be active in production if and only if its actual subsidy exceeds the threshold level τ^*_{jt}. Since firms with subsidies below τ^*_{jt} stay inactive, uncertainty affects production decisions only through the expansion of the right tail of the subsidy distribution. At any given factor prices, the threshold τ^*_{jt} decreases with z_{jt}. Thus, high-productivity firms face a lower

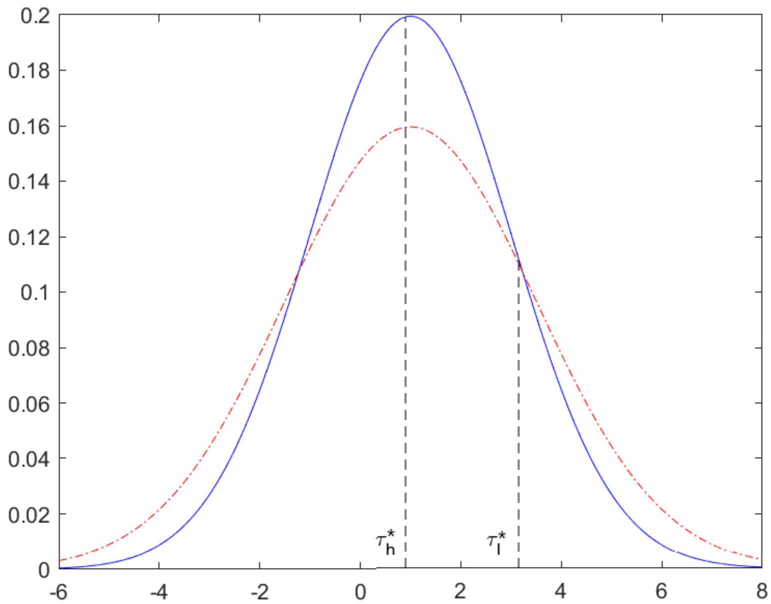

FIGURE A4. Uncertainty and the distribution of active firms

This figure illustrates how an increase in micro-level uncertainty affects the mass of active firms in the benchmark model. The blue solid and red dashed curves represents the distribution of i.i.d. shock τ in the steady state and after a mean-preserving spread shock. τ_h^* and τ_l^* denote the thresholds of active production for high-productivity and low-productivity firms, respectively.

threshold than low-productivity firms. A right-tail expansion of the subsidy distribution will therefore increase the relative mass of low-productivity firms (relative to high-productivity firms).

This is illustrated in Figure A4. To highlight our point, the figure shows a symmetric distribution, with the threshold for high-productivity firms (τ_h^*) normalized to be the mean of the distribution. The mass of high-productivity firms in this example is 1/2, both before and after the uncertainty shock (because the shock is a mean-preserving spread). Since the threshold for low-productivity firms (τ_l^*) lies to the right of τ_h^*, the increase in uncertainty raises the relative mass of low-productivity firms (upper right panel in Figure A5). This reallocation effect reduces aggregate TFP, leading to a decline in wages and rents, as shown in the impulse responses in Figure A5. Since all firms face the same wages and rents, which are now lower than in the steady-state, the declines in wages and rents reduce the relative mass of high-productivity firm even further.

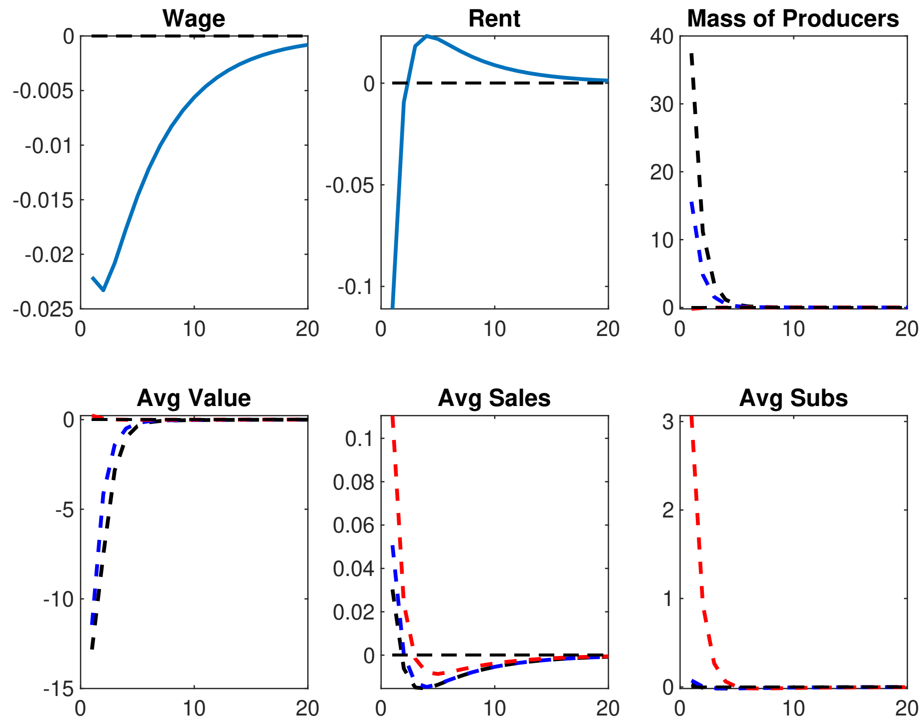

FIGURE A5. Reallocation effects of an uncertainty shock

This figure shows the impulse responses to an uncertainty shock in the benchmark model. The black, blue and red dashed lines represent the responses of firms at the 25, 50, and 100 percentile of the productivity distribution. The horizontal axis shows the periods (years) after the impact of the shock. The vertical axis measures percent deviations from the stochastic steady-state in response to a one-standard-deviation shock to uncertainty.

Given the size of the right-tail expansion of subsidies, the average subsidy received by each active, low-productivity firm declines relative to that by high-productivity firms. Thus, average sales of active high-productivity firms (inclusive of subsidies) increase relative to those of low-productivity firms, raising the cross-sectional dispersion of average sales, as shown in Figure A5. Through changes in the distribution of average subsidies to active firms, the increase in uncertainty also leads to larger reductions in the average market value of low-productivity firms than that of high-productivity firms.

A.5.3. *Reallocation effects of a TFP shock.* Figure A6 shows that a negative TFP shock has heterogeneous impacts on firms at different levels of productivity. The shock reduces aggregate labor and capital demand, lowering wages and capital rents. A decline in aggregate TFP raises the threshold of active production for firms at each level of productivity, shrinking the set of active firms, although this effect is partly mitigated by the decline in factor prices.

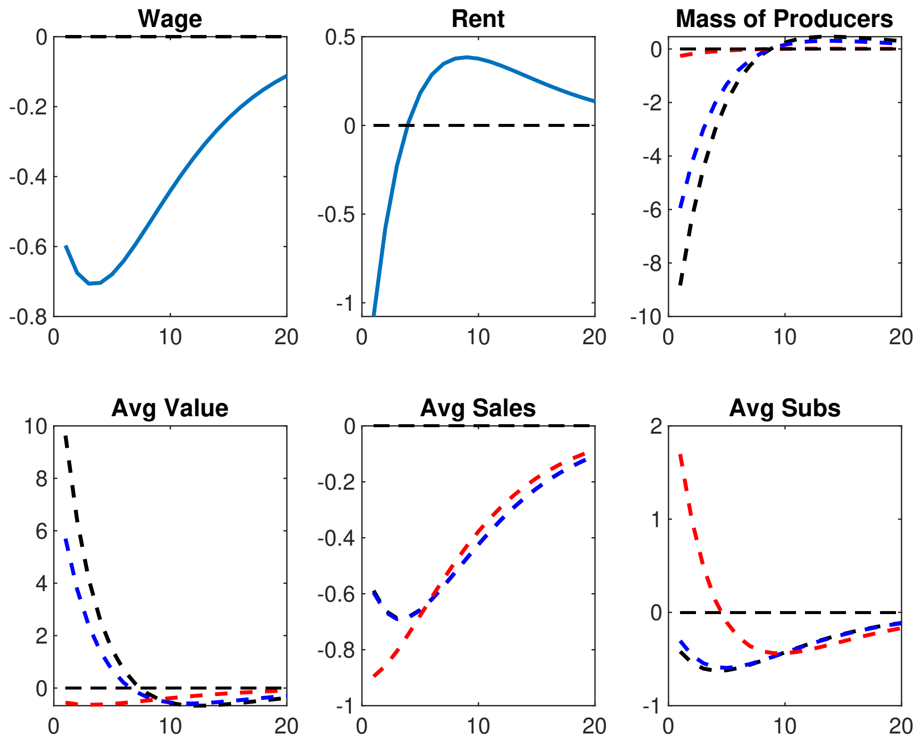

FIGURE A6. Reallocation effects of a TFP shock

This figure shows the impulse responses to a TFP shock in the benchmark model. The black, blue and red dashed lines represent the responses of firms at the 25, 50, and 100 percentile of the productivity distribution. The horizontal axis shows the periods (years) after the impact of the shock. The vertical axis measures percent deviations from the stochastic steady-state in response to a one-standard-deviation shock to TFP.

Since labor and capital are perfectly mobile across firms, all firms face the same wages and capital rents. A decline in aggregate TFP would therefore force more low-productivity firms into the inactive regions than high-productivity firms. The shock reduces the average sales of all active firms, and average sales decline more for firms with higher productivity because, among active firms, lower-productivity firms need to be compensated by higher average subsidies for them to remain active.

A.5.4. *Macroeconomic effects of turbulence: Benchmark model vs. data.* In the text, we show that an annual version of the benchmark calibrated model generates empirically plausible impulse responses of aggregate output to a turbulence shock. Here, we compare the impulse responses of other macro variables to a turbulence shock from the model against those estimated from the data.

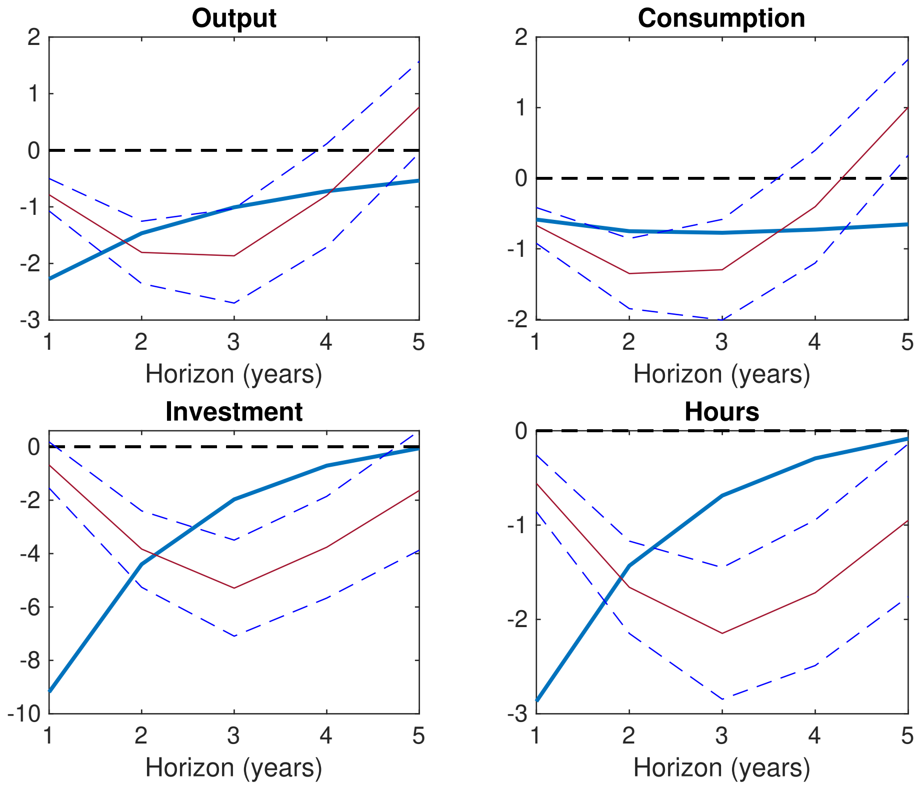

FIGURE A7. Impulse responses of macroeconomic variables to a turbulence shock: Benchmark model vs. data

Note: This figure shows the impulse responses of aggregate output, consumption, investment, and labor hours to a one-standard-deviation shock to turbulence in the data (the red solid line) and in the calibrated annual version of the model (the blue solid line). The dashed lines show the 68% confidence band around the empirical estimates of the impulse responses. The horizontal axis shows the years after the impact of the shock. The vertical axis shows the percent deviations of output in the model from its steady-state level and the percentage changes in output in the data relative to its pre-shock level.

Figure A7 compares the impulse response of output, consumption, investment and hours worked to a one-standard-deviation turbulence shock in the model (blue lines) vs. those in the data (red lines). The responses of output, investment, and labor hours are close to those in the data. However, under the calibrated intertemporal elasticity of substitution (log utility in consumption) and absence of real friction such as habit persistence and investment adjustment costs, the model does not reproduce the observed persistent, hump-shaped responses of the macroeconomic variables following a turbulence shock.

Appendix B. Decreasing Returns to Scale

Now we consider an alternative version of RBC model with decreasing returns to scale (DRS) and show that a turbulence shock has similar reallocation and macroeconomic effects as in the benchmark model with a constant returns technology.

B.1. **The model.**

The model economy is populated by a continuum of infinitely lived households with measure one, whose preference is characterized by the same utility function as in the benchmark model:

$$\mathbf{E}\sum_{t=0}^{\infty}\beta^t\left\{\ln C_t-\psi\frac{N_t^{1+\gamma}}{1+\gamma}\right\}, \tag{A2}$$

All markets are perfectly competitive. The household takes all prices as given and maximizes the utility in Eq. (A2) subject to a budget constraint

$$C_t+I_t=R_tK_t+W_tN_t+D_t-T_t, \tag{A3}$$

where K_{t+1} denotes the end-of-period capital stock, R_t denotes the capital rental rate, W_t denotes the real wage rate, D_t denotes the dividend income from firms, and T_t denotes a lump-sum tax paid to the government.

Household's decision rules are characterized by the following equations:

$$\psi N_t^{\gamma}=\frac{1}{C_t}W_t \tag{A4}$$

$$\frac{1}{C_t}=\beta E_t\frac{1}{C_{t+1}}\left(R_{t+1}+(1-\delta)\right) \tag{A5}$$

There is a continuum of intermediate good firms, each endowed with a constant-returns technology that produces an intermediate good using capital and labor as inputs. Firms face idiosyncratic productivity shocks drawn at the beginning of each period, before hiring inputs. The production function for an individual firm is given by

$$y_{jt}=A_tz_{jt}k_{jt}^{\alpha}n_{jt}^{1-\alpha}, \tag{A6}$$

where y_{jt} denotes the output produced by firm j in period t, and k_{jt} and n_{jt} denote the capital and labor inputs, respectively. The term A_t and z_{jt} denote aggregate and idiosyncratic productivity shocks respectively, which are assumed to follow the same stochastic processes as in the benchmark model.

Intermediate goods producers sell competitive monopolistic goods to a final good producer with production function as

$$Y_t=\left(\int_j[y_{jt}]^{\frac{\nu-1}{\nu}}dj\right)^{\frac{\nu}{\nu-1}}, \tag{A7}$$

from which we can derive demand function for each intermediate good as

$$p_{jt}=Y_t^{\frac{1}{\nu}}y_{jt}^{-\frac{1}{\nu}} \tag{A8}$$

Firms rely on external financing of their working capital, and face idiosyncratic production distortions (denoted by τ_{jt}). The firms' optimizing problem is characterized by the Bellman equation

$$V_t(z_{jt},\tau_{jt}) = \tau_{jt}p_{jt}y_{jt} - W_t n_{jt} - R_t k_{jt} + E_t M_{t+1} V_{t+1}(z_{jt+1},\tau_{jt+1}) \tag{A9}$$

subject to the working capital constraint

$$W_t n_{jt} + R_t k_{jt} \leq \theta E_t M_{t+1} V_{t+1}(z_{jt+1},\tau_{jt+1}) \equiv \theta B_{jt} \tag{A10}$$

Profit maximizing implies

$$k_{jt} = \frac{\alpha}{1-\alpha}\frac{W_t}{R_t} n_{jt}. \tag{A11}$$

It follows that there exists a threshold level of production subsidy τ^*_{jt} such that, if $\tau_{jt} \geq \tau^*_{jt}$, then a firm would be facing binding credit constraints in production. Otherwise, the firm would choose an interior optimal size. At the threshold level of subsidy, the optimal size of production coincides with level implied from binding constraint. The indifference condition determines the threshold level of subsidy, τ^*_{jt}:

$$\tau^*_{jt} = \left[\frac{\theta B_{jt}}{(\frac{\nu-1}{\nu})^{\nu}\left[(\frac{1-\alpha}{W_t})^{1-\alpha}(\frac{\alpha}{R_t})^{\alpha}\right]^{\nu-1}(A_t z_{jt})^{\nu-1} Y_t}\right]^{\frac{1}{\nu}}, \tag{A12}$$

The threshold τ^*_{jt} increases with the factor prices R_t and W_t and decreases with the productivity level z_{jt}. Thus, given the factor prices, the fraction of active firms is larger for firms with higher productivity. Idiosyncratic labor demand functions are:

$$n_t(z_{jt},\tau_{jt}) = \begin{cases} \frac{1-\alpha}{W_t}(\frac{\nu-1}{\nu})^{\nu} Y_t \tau^{\nu}_{jt}(A_t z_{jt})^{\nu-1}\left[(\frac{1-\alpha}{W_t})^{1-\alpha}(\frac{\alpha}{R_t})^{\alpha}\right]^{\nu-1}, & \text{if} \quad \tau_{jt} \leq \tau^*_{jt} \\ \frac{(1-\alpha)\theta B_{jt}}{W_t}, & otherwise \end{cases} \tag{A13}$$

Idiosyncratic capital demand functions are

$$k_t(z_{jt},\tau_{jt}) = \begin{cases} \frac{\alpha}{R_t}(\frac{\nu-1}{\nu})^{\nu} Y_t \tau^{\nu}_{jt}(A_t z_{jt})^{\nu-1}\left[(\frac{1-\alpha}{W_t})^{1-\alpha}(\frac{\alpha}{R_t})^{\alpha}\right]^{\nu-1}, & \text{if} \quad \tau_{jt} \leq \tau^*_{jt} \\ \frac{\alpha\theta B_{jt}}{R_t}, & otherwise \end{cases} \tag{A14}$$

Idiosyncratic output functions are

$$y_t(z_{jt},\tau_{jt}) = \begin{cases} Y_t(\frac{\nu-1}{\nu}\tau_{jt}A_t z_{jt})^{\nu}\left[(\frac{1-\alpha}{W_t})^{(1-\alpha)}(\frac{\alpha}{R_t})^{\alpha}\right]^{\nu}, & \text{if} \quad \tau_{jt} \leq \tau^*_{jt} \\ A_t z_{jt}\left[(\frac{1-\alpha}{W_t})^{1-\alpha}(\frac{\alpha}{R_t})^{\alpha}\right]\theta B_{jt}, & otherwise \end{cases} \tag{A15}$$

Since production subsidies are i.i.d. across time, the average value of a firm with productivity z_{jt} is given by

$$\begin{aligned}\bar{V}_{jt} &= \int V_t(z_{jt},\tau)dF(\tau) = \frac{1}{\nu-1}(\frac{\nu-1}{\nu})^{\nu} Y_t (A_t z_{jt})^{\nu-1}\left[(\frac{1-\alpha}{W_t})^{1-\alpha}(\frac{\alpha}{R_t})^{\alpha}\right]^{\nu-1}\int^{\tau^*_{jt}}\tau^{\nu}dF(\tau) \\ &+ Y_t^{\frac{1}{\nu}}(A_t z_{jt})^{\frac{\nu-1}{\nu}}\left[(\frac{1-\alpha}{W_t})^{1-\alpha}(\frac{\alpha}{R_t})^{\alpha} z_{jt}\right]^{\frac{\nu-1}{\nu}}(\theta B_{jt})^{\frac{\nu-1}{\nu}}\int_{\tau^*_{jt}}\tau dF(\tau) - \theta B_{jt}[1-F(\tau^*_{jt})] + B_{jt}\end{aligned} \tag{A16}$$

Given the stochastic process of $z_{j,t+1}$, we have

$$B_{jt} \equiv \beta \mathbb{E}_t \frac{C_t}{C_{t+1}}\left[\rho_t \bar{V}_{jt+1} + (1-\rho_t)\sum_{i=1}^{J}\pi_i \bar{V}_{it+1}\right] \tag{A17}$$

In a competitive equilibrium, markets for labor, capital, and final consumption goods all clear. Labor market clearing implies that

$$N_t = \sum_j \pi_j \left\{\frac{1-\alpha}{W_t}(\frac{\nu-1}{\nu})^{\nu} Y_t (A_t z_{jt})^{\nu-1}\left[(\frac{1-\alpha}{W_t})^{1-\alpha}(\frac{\alpha}{R_t})^{\alpha}\right]^{\nu-1}\int_0^{\tau^*_{jt}}\tau^{\nu}dF(\tau) + \frac{(1-\alpha)\theta B_{jt}}{W_t}[1-F(\tau^*_{jt})]\right\} \tag{A18}$$

Capital market clearing implies that

$$K_t = \sum_j \pi_j \left\{\frac{\alpha}{R_t}(\frac{\nu-1}{\nu})^{\nu} Y_t (A_t z_{jt})^{\nu-1}\left[(\frac{1-\alpha}{W_t})^{1-\alpha}(\frac{\alpha}{R_t})^{\alpha}\right]^{\nu-1}\int_0^{\tau^*_{jt}}\tau^{\nu}dF(\tau) + \frac{\alpha\theta B_{jt}}{R_t}[1-F(\tau^*_{jt})]\right\} \tag{A19}$$

Final good market clearing condition implies

$$Y_t = C_t + K_{t+1} - (1-\delta)K_t, \tag{A20}$$

where

$$y_{jt} = Y_t(\frac{\nu-1}{\nu}A_t z_{jt})^{\nu}\left[(\frac{1-\alpha}{W_t})^{(1-\alpha)}(\frac{\alpha}{R_t})^{\alpha}\right]^{\nu}\int_0^{\tau^*_{jt}}\tau^{\nu}dF(\tau) + A_t z_{jt}\left[(\frac{1-\alpha}{W_t})^{1-\alpha}(\frac{\alpha}{R_t})^{\alpha}\right]\theta B_{jt}[1-F(\tau^*_{jt})] \tag{A21}$$

Definition. A competitive equilibrium consists of the sequence of allocations $\{C_t, Y_t, N_t, K_t\}$ and the sequence of prices $\{W_t, R_t\}$ such that (i) taking all prices as given, the allocations solve the household's utility maximizing problem and the firms' profit maximizing problem; and (ii) markets for labor, capital, and goods all clear.

B.2. **Measured turbulence shock.** The methodology in estimation of turbulence can be easily extended to the decreasing return to scale (DRS) model. In specific, firm-level TFP is estimated from the following equation:

$$tfp_{ijt} = y_{ijt} - \frac{\nu-1}{\nu}\alpha_{it}k_{ijt} - \frac{\nu-1}{\nu}(1-\alpha_{it})n_{ijt} \tag{A22}$$

where ν measures elasticity of substitution. We follow standard New Keynesian literature to set $\nu = 10$, implying steady-state mark-up at around 1.1. The firm-level TFP are estimated after controlling for year fixed effect, which captures effect of aggregator Y_t on revenue of each firm. The rest of procedures strictly follow those adopted in constant return to scale model.

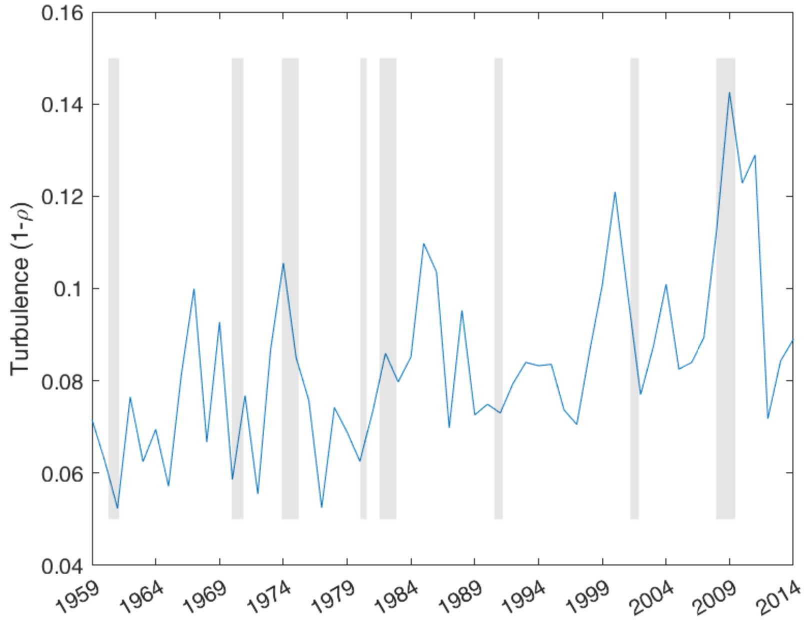

FIGURE A8. Measured micro-level turbulence (decreasing return to scale)

Note: Turbulence is measured by $1 - \rho_t$, where ρ_t is the Spearman correlation of firm TFP rankings between year t and year $t + 1$. The gray shaded bars indicate NBER recession dates.

Source: Compustat, NBER-CES, BLS, and authors' calculations.

Time-varying turbulence in the model is measured by Spearman correlation of firm-level TFP ranking in decile within industry between two consecutive years, similar to measure constructed in figure A1 of Bloom et al. (2018). Figure A8 plots the time series of firm-level turbulence from 1958 to 2015.[3] The mean, standard deviation, and autocorrelation of the estimated turbulence $(1 - \rho_t)$ are 0.084, 0.019, and 0.49, respectively.

B.3. **Reallocation and macroeconomic effects of turbulence.** The measure of turbulence constructed under the DRS production function here has similar cyclical and reallocation effects as that under the CRS production function in the benchmark model.

To examine the reallocation effects of turbulence, we re-estimate a empirical specification in Eq. (7) of the main text, with a turbulence measure constructed from the DRS production function. Table A.7 shows the estimation results. The results show that an increase in turbulence is associated with declines in the firm-level growth rates for high-productivity

[3]Our measure of turbulence is robust to alternative measures of value added, capital input, and labor input, as well as to the data samples used (not reported).

TABLE A.7. Impact of turbulence on firms with different levels of productivity

Dep. Var.	Δn_{jt}	Δk_{jt}	Δy_{jt}	Δv_{jt}
	(1)	(2)	(3)	(4)
$High\_TFP_{jt}$	0.031***	0.044***	0.109***	0.122***
	(0.010)	(0.010)	(0.010)	(0.017)
$Turb_t * High\_TFP_{jt}$	-0.922***	-0.951***	-1.053***	-1.110***
	(0.096)	(0.175)	(0.122)	(0.177)
$Constant$	0.057***	0.065***	0.042***	0.026***
	(0.003)	(0.004)	(0.003)	(0.005)
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	25,481	25,481	25,481	23,541

Note: This table shows the estimation results from the empirical specification that regresses firm-level variables (including the growth rates of employment, capital expenditure, sales, and firm value) on the measured turbulence ($Turb$) for firms with different levels of TFP under the DRS production function. The dummy $High\_TFP_{jt}$ equals one if firm j's TFP is above the median within its industry and zero otherwise. All regressions use the pseudo panel of Compustat firms that appear for at least 25 years from 1959 to 2015. The standard errors shown in the parentheses are clustered by industry. The stars denote the p-values: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

firms relative to those for low-productivity firms. The reallocation effects of turbulence are robust to alternative indicators of high firm-level TFP (lagged high-TFP indicators), alternative samples(with large industries or excluding top firms), and additional controls for the potential reallocation effects from the business cycle recessions (see Sec. B.6).

Similar to the benchmark empirical results reported in the main text, the reallocation effects of turbulence under the DRS technology also depend on financial frictions, as shown in Table A.8. An increase in turbulence is associated with significant declines in the cross-sectional dispersion of employment and capital in industries with high levels of external financing dependence.

B.4. **Macroeconomic effects of turbulence.** The macroeconomic effects of a turbulence shock under DRS technologies are also similar to those obtained under CRS technologies

Table A.8. Reallocation effect of turbulence: sensitivity to financial frictions

Dep. Var.	IQR of Employment		IQR of Capital	
	(1)	(2)	(3)	(4)
$High\_FF_{it}$	0.497***	0.633***	0.635***	0.794***
	(0.224)	(0.271)	(0277)	(0.246)
$Turb_t * High\_FF_{it}$	-5.010***	-6.629***	-6.539***	-8.545**
	(2.541)	(2.454)	(3.133)	(2.916)
constant	1.826***	1.861***	2.036***	2.081***
	(0.050)	(0.048)	(0.056)	(0.052)
Industry Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	3,647	3,522	3,647	3,522

Note: This table shows the regression of interquartile range of employment (or capital) on the measured turbulence ($Turb$) for industries with different levels of external financing dependence. In the baseline specification (Columns (1) and (3)), the dummy $High\_FF_{it}$ equals one if industry i's external financing dependence is above the median. In the alternative specification (Columns (2) and (4)), we use lagged indicator of external financing dependence (i.e., $High\_FF_{i,t-1}$ instead of $High\_FF_{it}$). All regressions use the pseudo panel of Compustat firms that appear for at least 25 years in the sample from 1958 to 2015. The standard errors shown in the parentheses are clustered by industries. The stars denote the p-values: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

reported in the main text, as shown in Figure A9.[4] As in the benchmark case, a turbulence shock leads to a recession with synchronized and persistent declines in aggregate output, consumption, investment, hours worked, and firm value. It also leads to a decline in manufacturing TFP. These macroeconomic effects of turbulence are quantitatively important. For example, a one-standard-deviation increase in turbulence (i.e., an increase of 0.1963) reduces per capita output by about 0.4 percent on impact, and by more than one percent within three years after the shock.

[4]Our measured annual series of (logged) turbulence has a first-order autocorrelation of 0.4391 and a standard deviation of 0.2185, implying a standard deviation of the innovation of 0.1963.

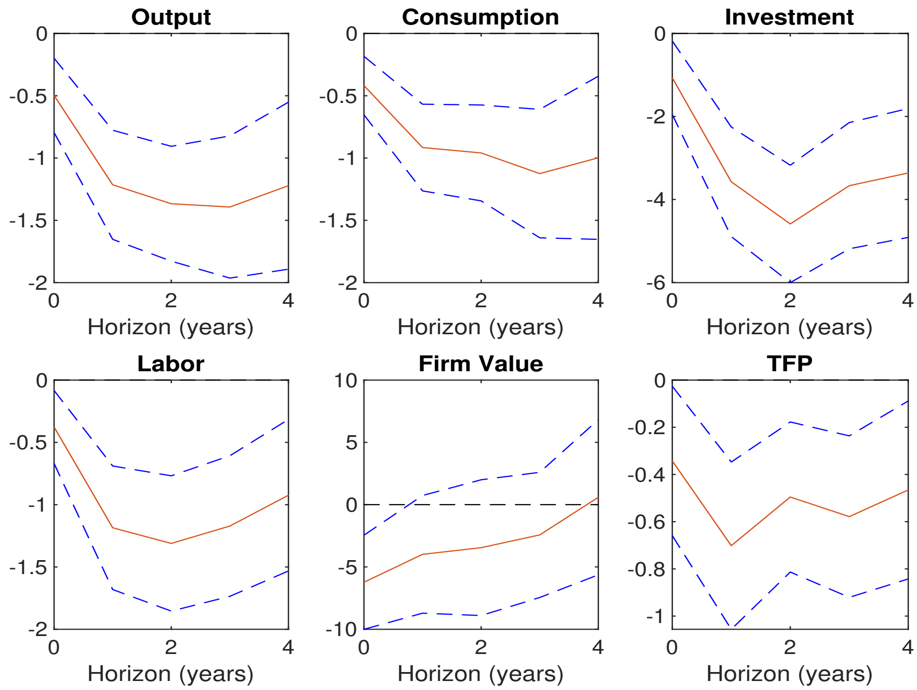

FIGURE A9. Estimated impulse response of macroeconomic variables to a turbulence shock

Note: This figure shows the impulse responses of macroeconomic variables to a one-standard-deviation (19.6%) increase in the log-level of turbulence estimated from local projections. The solid lines show the point estimates of the impulse responses. The blue dashed lines show the 68% confidence intervals.
Source: BEA, Compustat, NBER-CES, and authors' calculations.

B.5. **Quantitative impact of a turbulence shock in the RBC model.** We calibrate the parameters in the model with DRS using a similar approach as that in our benchmark model with CRS.

We set the elasticity of substitution between differentiated goods to $\nu = 10$, implying a steady-state mark-up of about 11 percent, in line with the empirical estimates of Basu and Fernald (1997). We calibrate three parameters $\bar{\rho}$, σ_z, and σ_τ in the stochastic processes of firm-level TFP and production distortions to target the three empirical moments, including (1) the average value of the Spearman rank correlations of establishment-level TFP (0.72, estimated by Bloom et al. (2018)), (2) the standard deviation of firm-level TFP shock (0.21, based on firm-level TFP constructed using the Compustat/NBER-CES data), and (3) the average IQR of equity values across firms (1.53, also from the Compustat data). The resulting calibrated values are $\bar{\rho} = 0.93$, $\sigma_z = 0.10$ and $\sigma_\tau = 0.14$. Given these parameter values, we calibrate the persistence and volatility of the turbulence shock such that the model-implied persistence and standard deviation of the Spearman rank correlation of measured firm-level TFP (which include both true TFP z_{jt} and produciton distortions τ_{jt}) match the same moments in the Spearman correlation estimated by Bloom et al. (2018). This leads to the calibrated values of $\rho_\rho = 0.605$ and $\sigma_\rho = 0.35$. We calibrated the remaining parameters to the same values as those in the benchmark model.

The qualitative impact of firm-level turbulence shock with decreasing return to scale is consistent with that in our baseline model. Figure A10 displays the impulse responses to a one-standard-deviation shock to turbulence. An increase in turbulence reduces the chance for a current high-productivity firm to remain as productive in the future, and it also increases the chance for a current low-productivity firm to get a higher productivity draw in the future. Thus, the equity values of high-productivity firms declines relative to those of low-productivity firms, leading to a decline in the dispersion of firm value and disproportionately tightening the borrowing capacity of high-productivity firms in the current period. Facing tightened credit constraints, high-productivity firms pull back hiring, reallocating labor and capital to low-productivity firms. Since high-productivity firms use more capital and labor in the steady-state than low-productivity firms, the increase in turbulence reduces the share of labor and capital in high-productivity firms, and it also reduces the dispersion of sales, in line with the empirical evidence.

Through reallocation, a turbulence shock reduces aggregate TFP and leads to a recession with synchronized declines in aggregate output, consumption, investment, and labor hours, as in the data. The recessionary effects of turbulence are sizable and persistent. For example, a one-standard-deviation turbulence shock leads to a drop in aggregate output of more than 1 percent on impact, and output stays below its steady-state level for more than ten years after the shock.

The role of financial frictions. As in the benchmark model, Figure A11 shows that the recession effects and the reallocation effects of a turbulence shock would be substantially dampened if firms' borrowing capacity could not vary with the expected equity value. This counterfactual illustrates the importance of financial frictions—and in particular, the endogenous variations of the borrowing capacity with expected firm values—for propagating turbulence shocks.

Turbulence has quantitatively important recessionary effects, both in the model and in the data. Figure A12 compares the model-implied impulse responses of aggregate variables (blue solid lines) with the empirical estimates of the impulse response (red solid lines). A one-standard-deviation turbulence shock reduces aggregate output by around 1 percent on impact, both in the data and in the model. The shock has persistent recessionary effects on aggregate output both in the model and in the data, although the theoretical impulse

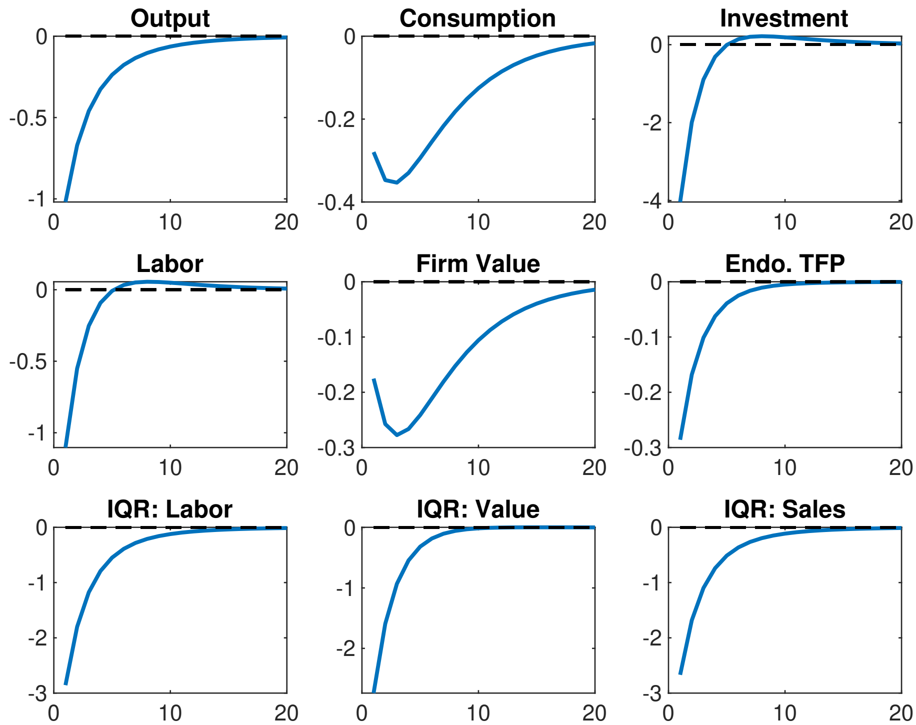

Figure A10. Impulse response to a turbulence shock in decreasing-return-to-scale model

Note: This figure shows the impulse responses to a one-standard-deviation shock to turbulence in the calibrated decreasing-return-to-scale model. The horizontal axis shows the periods (years) since the impact of the shock. The vertical axis shows the percent deviations of each variable from its stochastic steady-state level.

responses miss the hump estimated from the data. These findings suggest that turbulence plays an important role in driving business cycles. Similar to the case of output, the model-implied responses of investment and labor are both in line with those estimated from the data, although the calibrated model fails to generate the turbulence-driven large declines in consumption observed in the data.

B.6. **Robustness.** This section presents robustness of regressions under DRS specification.

Our baseline regression estimates the effects of turbulence on firms with different levels of TFP, based on current-year firm-level TFP ranking. It is possible that a firm's employment, capital or sales growth might affect its contemporaneous TFP ranking. To mitigate this concern, we construct an alternative indicator of high-productivity firms based on their TFP rankings with a one-year lag. We re-estimate the responses of firm growth to turbulence shocks for firms with different levels of productivity. Table A.9, with the lagged high-TFP

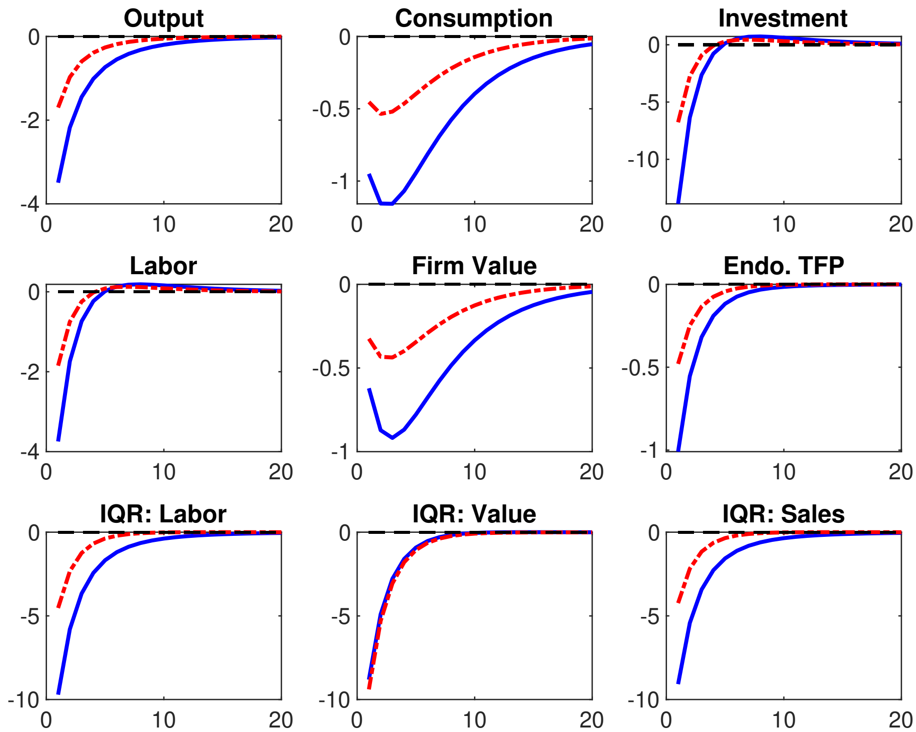

FIGURE A11. Impulse response to a turbulence shock: decreasing-return-to-scale model vs. counterfactual with quasi-fixed borrowing capacity

Note: This figure shows the impulse responses to a one-standard-deviation shock to turbulence in the decreasing-return-to-scale model (blue lines) and in the counterfactual with quasi-fixed borrowing capacity (red dash-dotted lines). The horizontal axis shows the periods (years) since the impact of the shock. The vertical axis shows the percent deviations of each variable from its stochastic steady-state level.

indicator, turbulence reduces growth for high-productivity firms relative to low-productivity firms, similar to the results obtained under the benchmark specification.

To examine the robustness of the reallocation effects of turbulence, we also consider an alternative specification in which we sort firm-level TFP into four quartiles and we replace the dummy $High\_TFP_{jt}$ in the baseline specification by the dummy indicators of the top three quartiles of the productivity distribution (denoted by $z_{2,jt}$, $z_{3,jt}$, and $z_{4,jt}$) (Table A.10). Implicitly, we treat the firms in the first quartile ($z_{1,jt}$) of the productivity distribution (i.e., firms with the lowest productivity levels) as the reference group. An increase in turbulence is associated with larger declines in employment, capital, sales and market value growth for firms with higher productivity. These reallocation effects are both statistically significant and economically important.

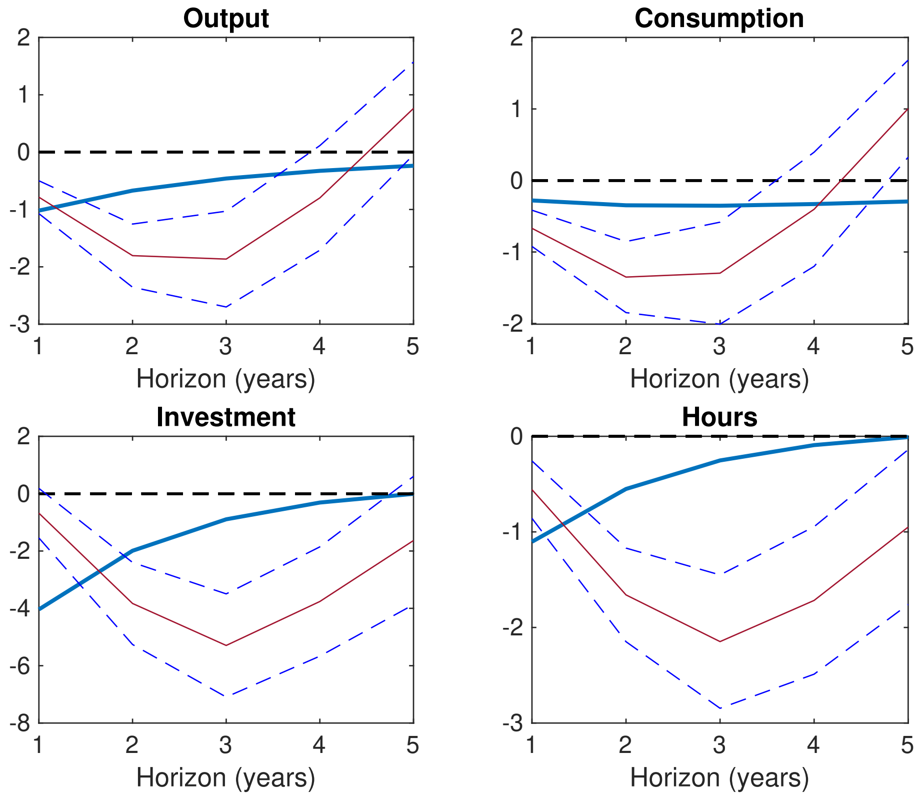

FIGURE A12. Impulse response to turbulence shock: Model vs. data (decreasing-return-to-scale)

Note: This figure shows the impulse responses of private aggregate output to a one-standard-deviation shock to turbulence in the data (red solid line) and in the calibrated annual version of the decreasing-return-to-scale model (blue solid line). The dashed lines show the 68% confidence band around the empirical estimates of the impulse responses. The horizontal axis shows the years after the impact of the shock. The vertical axis shows the percent deviations of output in the model from its steady-state level and the percentage changes in output in the data relative to its pre-shock level.

Since turbulence is countercyclical, the reallocation effects estimated from our benchmark specification might reflect the general impact of recessions instead of that of turbulence. To address this concern, we consider a regression that controls for the direct reallocation effects of recessions. In particular, we add an interaction term between NBER recession year dummy ($NBER_t$) and our high TFP indicator in the regression. As shown in Table A.11, the reallocation effect of turbulence shock remains significant after controlling for the reallocation effect of recessions.

Table A.9. Impact of turbulence on firms with different productivity: Lagged high-TFP indicators

Dep. Var.	Δn_{jt}	Δk_{jt}	Δy_{jt}	Δv_{jt}
	(1)	(2)	(3)	(4)
$High\_TFP_{jt-1}$	0.077***	0.077***	0.021	0.070***
	(0.011)	(0.011)	(0.016)	(0.021)
$Turb_t * High\_TFP_{jt-1}$	-0.911***	-0.863***	-1.144***	-1.006***
	(0.095)	(0.145)	(0.122)	(0.208)
$constant$	0.031***	0.043***	0.086***	0.050***
	(0.004)	(0.005)	(0.005)	(0.008)
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	23,802	23,802	23,802	22,377

Note: This table shows the regression of firm-level employment, capital expenditure, sales or firm value growth on the measured turbulence ($Turb$) for firms with different levels of TFP (lagged). The dummy $High\_TFP_{jt-1}$ equals one if firm j's TFP at year $t-1$ is above the median and zero otherwise. All regressions use the pseudo panel of Compustat firms that appear for at least 25 years from 1958 to 2015. The standard errors shown in the parentheses are clustered by industries. The stars denote the p-values: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

To examine the robustness of the impact of financial friction on reallocation effects of turbulence, we also consider an alternative specification in which we sort industry-level external finance dependence into four quartiles and we replace the dummy $High\_FF_{it}$ in the baseline specification by the dummy indicators of the top three quartiles of the financial friction distribution (denoted by $FF_{2,it}$, $FF_{3,it}$, and $FF_{4,it}$) (Table A.12). Implicitly, we treat the industry in the first quartile ($FF_{1,it}$) of the external finance dependence distribution (i.e., industries with the lowest external finance dependence) as the reference group. An increase in turbulence is associated with larger declines in interquartile range of employment and capital for industries with higher external finance dependence. These effects are both statistically significant and economically important.

TABLE A.10. Impact of turbulence on firms with different productivity: Finer grouping of firm TFP levels

Dep. Var.	Δn_{jt}	Δk_{jt}	Δy_{jt}	Δv_{jt}
	(1)	(2)	(3)	(4)
$z_{2,jt}$	0.089***	0.066***	0.019*	0.104***
	(0.007)	(0.015)	(0.011)	(0.019)
$z_{3,jt}$	0.079***	0.077***	-0.026	0.069**
	(0.012)	(0.015)	(0.020)	(0.030)
$z_{4,jt}$	0.086***	0.084***	-0.059*	0.017
	(0.022)	(0.017)	(0.029)	(0.039)
$Turb_t * z_{2,jt}$	-1.076***	-0.840***	-0.973***	-1.479***
	(0.107)	(0.275)	(0.152)	(0.249)
$Turb_t * z_{3,jt}$	-0.991***	-0.944***	-0.977***	-1.254***
	(0.109)	(0.185)	(0.166)	(0.301)
$Turb_t * z_{4,jt}$	-1.064***	-0.990***	-1.221***	-0.766**
	(0.141)	(0.152)	(0.126)	(0.283)
Constant	0.036***	0.049***	0.132***	0.066***
	(0.008)	(0.012)	(0.012)	(0.012)
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	25,481	25,481	25,481	23,541

Note: This table shows the regression of firm-level employment, capital expenditure, sales and value growth on the measured turbulence ($Turb$) for firms with different levels of TFP. We sort the Compustat firms into four quartiles based on their TFP levels. The dummy variables $z_{2,jt}$, $z_{3,jt}$, and $z_{4,jt}$ indicate whether a firm j's TFP is in the second, third, or fourth quartile in year t. All regressions use the pseudo panel of Compustat firms that appear for at least 25 years from 1958 to 2015. The standard errors shown in the parentheses are clustered by industries. The stars denote the p-values: $^{*} p < 0.1$; $^{**} p < 0.05$; $^{***} p < 0.01$.

Table A.11. Impact of turbulence on firms with different productivity: Control for recession effects

Dep. Var.	Δn_{jt}	Δk_{jt}	Δy_{jt}	Δv_{jt}
	(1)	(2)	(3)	(4)
$High\_TFP_{jt}$	0.031***	0.044***	0.110***	0.124***
	(0.010)	(0.010)	(0.010)	(0.017)
$Turb_t * High\_TFP_{jt}$	-0.800***	-0.940***	-0.881***	-0.891***
	(0.104)	(0.175)	(0.135)	(0.172)
$NBER_t * High\_TFP_{jt}$	-0.047***	-0.004	-0.067***	-0.095***
	(0.008)	(0.006)	(0.008)	(0.013)
$Constant$	0.057***	0.065***	0.042***	0.027***
	(0.003)	(0.004)	(0.003)	(0.005)
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	25,481	25,481	25,481	25,481

Note: This table shows the estimation results from the empirical specification that regresses firm-level variables (including the growth rates of employment, capital expenditure, sales, and firm value) on the measured turbulence ($Turb$) for firms with different levels of TFP. The dummy $High\_TFP_{jt}$ equals one if firm j's TFP is above the median within its industry and zero otherwise. The dummy $NBER_t$ equals one if year t contains a recession that lasts for at least 60 days based on the NBER recession dates. All regressions use the pseudo panel of Compustat firms that appear for at least 25 years from 1958 to 2015. The standard errors shown in the parentheses are clustered by industry. The stars denote the p-values: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A.12. Reallocation effects of turbulence: sensitivity to financial friction

Dep. Var.	IQR of Employment	IQR of Capital
	(1)	(2)
$FF_{2,it}$	0.228	0.312
	(0.302)	(0.308)
$FF_{3,it}$	0.226	0.360
	(0.306)	(0.374)
$FF_{4,it}$	0.979***	1.198***
	(0.300)	(0.352)
$Turb_t * FF_{2,it}$	-4.254	-5.558
	(3.304)	(3.590)
$Turb_t * FF_{3,it}$	-2.973	-4.496
	(3.681)	(4.430)
$Turb_t * FF_{4,it}$	-11.681***	-14.481***
	(3.151)	(3.713)
$Constant$	1.906***	2.130***
	(0.073)	(0.086)
Industry Fixed Effect	Yes	Yes
Year Fixed Effect	Yes	Yes
Observations	3,647	3,647

Note: This table shows the regression of inter-quartile range of employment (or capital) on the measured turbulence ($Turb$) for industries with different levels of external finance dependence. We sort the NAICS four-digit industries into four quartiles based on their external finance dependence. The dummy variables $FF_{2,it}$, $FF_{3,it}$, and $FF_{4,it}$ indicate whether a industry i's KZ index is in the second, third, or fourth quartile in year t. All regressions use the pseudo panel of Compustat firms that appear for at least 25 years from 1958 to 2015. The standard errors shown in the parentheses are clustered by industries. The stars denote the p-values: $^{*}\,p < 0.1$; $^{**}\,p < 0.05$; $^{***}\,p < 0.01$.

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