Allocative Efficiency and the Productivity Slowdown

Lin Shao
Bank of Canada

Rongsheng Tang
SUFE

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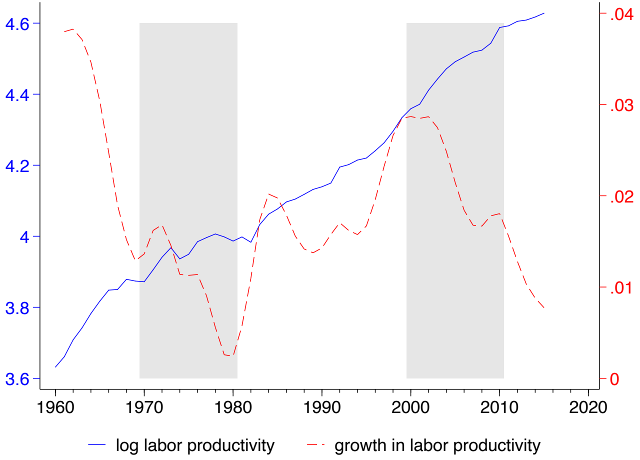
Motivation

US labor productivity slowed down significantly during the 1970s and 2000s



This paper

Evaluates the role of allocative efficiency across sectors in explaining aggregate productivity dynamics during these periods.

Model

- Measure allocative efficiency in a multi-sector economy with or w/o input-output linkages.
- Decomposing productivity growth using sector-level data (KLEMS and WIOT).

Findings

1. Allocation efficiency improved gradually during 1960-2010, contributing 20% of the observed productivity growth.
2. Deviations from this long-run trend helped give rise to slower-than-normal productivity growth during the 1970s and 2000s.
3. Crucial role of low volatility in the productivity process for allocation and growth.

Model

Production system

Value-added economy with Cobb-Douglas production functions

- One final good Y, produced by aggregating over N intermediate goods

$$Y_t = \prod_{i=1}^{N} Y_{i,t}^{\theta_{i,t}}.$$

- Intermediate good i is produced using capital and labor

$$Y_{i,t} = A_{i,t} K_{i,t}^{\alpha_{i,t}} L_{i,t}^{1-\alpha_{i,t}}.$$

Optimal allocation

- Planner's problem

$$\max_{K_{i,t},L_{i,t}} \; Y_t = \prod_{i=1}^{N} Y_{i,t}^{\theta_{i,t}}, \; s.t. \; Y_{i,t} = A_{i,t} K_{i,t}^{\alpha_{i,t}} L_{i,t}^{1-\alpha_{i,t}}, \; \sum_i K_{i,t} = K_t, \; \sum_i L_{i,t} = L_t$$

- Optimal allocation: $K^*_{i,t} = \chi^{k*}_{i,t} K_t$ and $L^*_{i,t} = \chi^{l*}_{i,t} L_t$.
  - $\chi^{k*}_{i,t} = \frac{\theta_{i,t}\alpha_{i,t}}{\sum_i \theta_{i,t}\alpha_{i,t}}$ and $\chi^{l*}_{i,t} = \frac{\theta_{i,t}(1-\alpha_{i.t})}{\sum_i \theta_{i,t}(1-\alpha_{i,t})}$.
  - $\chi^{k*}_{i,t}$ and $\chi^{l*}_{i,t}$: optimal sector-level shares of the aggregate capital and labor.

Allocative efficiency

- Define allocative efficiency: $\mathrm{E}_t = \frac{Y_t}{Y_t^*}$.
- Sufficient statistics for E_t

$$\mathrm{E}_t = \prod_{i=1}^{N} [(\frac{\chi_{i,t}^k}{\chi_{i,t}^{k*}})^{\alpha_{i,t}} (\frac{\chi_{i,t}^l}{\chi_{i,t}^{l*}})^{1-\alpha_{i,t}}]^{\theta_{i,t}},$$

where $\chi_{i,t}^k = \frac{K_{i,t}}{K_t}$ and $\chi_{i,t}^l = \frac{L_{i,t}}{L_t}$ are cross-sector allocation of K and L in the data.

- Optimal allocation $\iff \mathrm{E}_t = 1 \iff \chi_{i,t}^k = \chi_{i,t}^{k*}$ and $\chi_{i,t}^l = \chi_{i,t}^{l*}$ $\forall i$.

CES with IO linkges

Decomposition of aggregate productivity growth

- Decomposing the labor productivity growth in the data $\log \mathrm{LP}_t$ into:

$$\underbrace{\Delta \log \mathrm{LP}_t}_{\text{productivity growth in the data}} = \underbrace{\Delta \log \mathrm{E_t}}_{\text{growth in allocative efficiency}} + \underbrace{\Delta \log \mathrm{LP}_t^*}_{\text{growth in fundamental productivity}} .$$

Measuring allocative efficiency in the data

We need (i) allocation of capital and labor in the data and (ii) output elasticities ($\alpha_{i,t}$, $\theta_{i,t}$)

Data: KLEMS (2013 version) with 28 private sectors. ▸ list of sectors

- sector-level value-added output ($).
- sector-level capital and labor compensation ($).
- sector-level real capital stock, ($K_{i,t}$) and number of workers ($L_{i,t}$) (quantity)

Measuring allocative efficiency in the data

Identification issue: Separately identify technology parameter $\alpha_{i,t}$ and distortions $(\tau^k_{i,t}, \tau^l_{i,t})$.

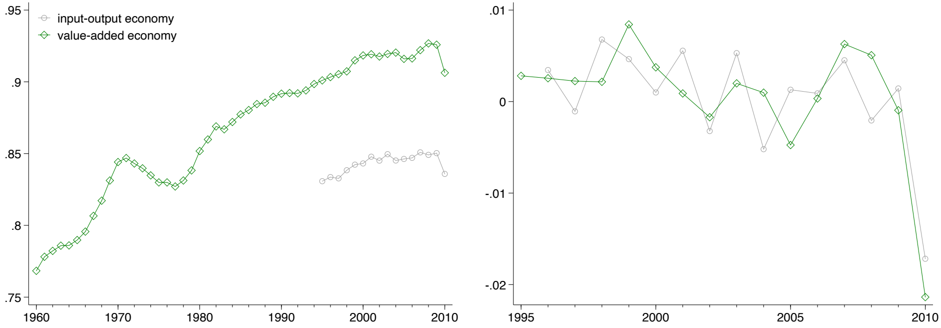
$$\frac{\overbrace{R_t K_{i,t}}^{\text{capital expenditure}}}{\underbrace{w_t L_{i,t}}_{\text{labor expenditure}}} = \frac{(1-\tau^l_{i,t})\alpha_{i,t}}{(1-\tau^k_{i,t})(1-\alpha_{i,t})},$$

Specifications: Two approaches (assumptions) used in the literature.

1. Use average labor and capital expenditure over a rolling window to identify $\alpha_{i,t}$.
   - Over time, distortions are, on average, not biased against K or L (Oberfield, 2013).
2. Use data of the later years to back out α_i.
   - Economy is unconstrained in the later years (akin to Hsieh and Klenow, 2009).
   - Measured allocative efficiency is *relative to the base year*.

Contribution of allocative efficiency to productivity slowdown

Evolution of allocative efficiency over time



(a) Allocative efficiency (b) Growth in allocative efficiency

- AE increases gradually, contributing to about 20 percent of the productivity growth.
- 1970s and 2000s are exceptions to this long-run trend.
- Measured AE is higher without input-output linkages, but growth rates are similar.

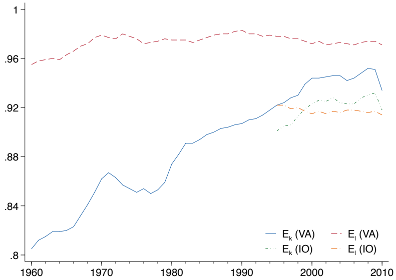
Slowdown in productivity growth and the role of allocative efficiency

	Growth rates by periods (long log-difference)			Changes in growth rates from preceding period		
	(1)	(2)	(3)	(4)	(5)	(6)
	labor productivity			labor productivity		
Periods	data	"fundamental"	E_t	data	"fundamental"	E_t
(a) VA economy (1960–2007)						
1960–69	0.24	0.16	0.08	–	–	–
1970–79	0.13	0.13	-0.01	**-0.12**	**-0.03**	**-0.08**
1980–89	0.15	0.10	0.04	0.02	-0.03	0.05
1990–99	0.19	0.16	0.03	0.05	0.06	-0.02
2000–07	0.16	0.16	0.01	**-0.03**	**-0.01**	**-0.02**

- Labor productivity growth rate in the 1970s and 2000s was 12 pps and 3 pps lower than the preceding decades, respectively.
- Approximately two-thirds of the slowdown (8/12 and 2/3) was due to slow growth in allocative efficiency.

Allocation efficiency of capital and labor

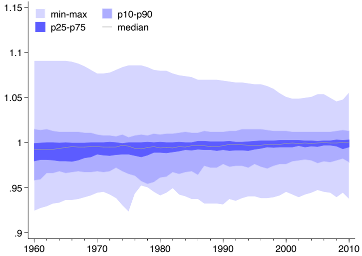
$$\mathbf{E}_t = E^{k,t} \times E^{l,t} = \underbrace{\prod_{i=1}^{N} \left(\frac{\chi^k_{i,t}}{\chi^{k*}_{i,t}} \right)^{\alpha_{i,t}\theta_{i,t}}}_{E^{k,t}} \times \underbrace{\prod_{i=1}^{N} \left(\frac{\chi^l_{i,t}}{\chi^{l*}_{i,t}} \right)^{(1-\alpha_{i,t})\theta_{i,t}}}_{E^{l,t}}$$



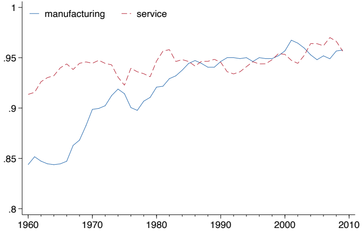
- Capital allocation is the more important driver across the sample period.

Sector-level allocative efficiency

$$\mathbf{E}_t = \prod_{i=1}^{N} E_{i,t}^{\theta_{i,t}} = \prod_{i=1}^{N} \underbrace{\left[\left(\frac{\chi_{i,t}^{k}}{\chi_{i,t}^{k*}} \right)^{\alpha_{i,t}} \left(\frac{\chi_{i,t}^{l}}{\chi_{i,t}^{l*}} \right)^{1-\alpha_{i,t}} \right]^{\theta_{i,t}}}_{E_{i,t}}$$



(a) Full distribution



(b) Manufacturing and service sector

- Distribution of E_i significantly narrows between 1960-70 and 1980-2000 but widens in the 1970s and stabilizes post-2000, mirroring the aggregate allocative efficiency trends.

Recap of the results

- From 1960 to 2007, 20 percent of productivity growth came from improvements in allocative efficiency.
- This key driver of productivity growth was missing in the 1970s and 2000s, explaining 2/3 of the productivity slowdown.

Results are robust:
CES production system; with input-output linkages; different start/end dates of the slowdown episodes; allocation within the manufacturing sector; post-2010 dynamics; heterogeneity in capital and labor inputs; allowing positive profit ...

Next:
A potential driver behind the patterns of allocative efficiency during the two slowdown episodes.

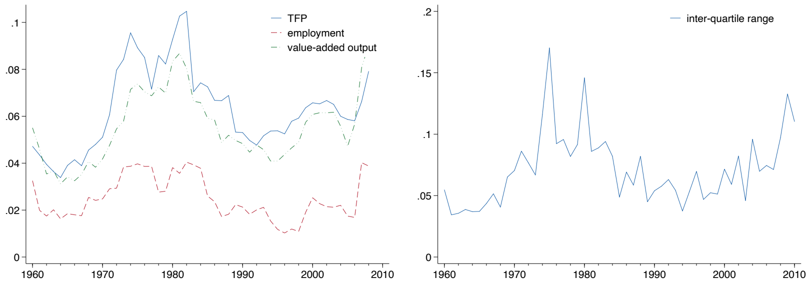
Volatility as a potential driver

Mechanisms:

- With non-convex adjustment costs, there's an inaction region.
- As volatility increases
  - $\Rightarrow$ option value of waiting increases.
  - $\Rightarrow$ inaction region expands.
  - $\Rightarrow$ sectors' capital and labor allocation are on average, further away from their optimal level.
  - $\Rightarrow$ allocative efficiency declines.
- This mechanism was discussed in papers like Asker et al. (2014) and Bloom et al. (2018).

Volatility and allocative efficiency during the slowdown episodes

Sector-level shocks were more volatile during the 1970s and 2000s



(a) S.D. in sectoral growth rates

(b) Dispersion in TFP shocks

- The 1970s and 2000s experienced an increase in sector-level volatility.

Relationship between volatility and allocative efficiency over time

	(1)	(2)	(3)
Dispersion of TFP shocks in year t	-0.072**	-0.087**	-0.080**
	(0.031)	(0.037)	(0.037)
Dispersion of TFP shocks in year $t-1$		0.003	0.009
		(0.043)	(0.046)
Dispersion of TFP shocks in year $t-2$			-0.006
			(0.027)
Allocative efficiency in year $t-1$	0.973***	0.981***	0.976***
	(0.013)	(0.012)	(0.012)
Dependent variables	$\log(\mathrm{E}_t)$	$\log(\mathrm{E}_t)$	$\log(\mathrm{E}_t)$
N	63	62	61
R^2	0.993	0.993	0.993
Observed slowdown in 1970s	-0.12	-0.12	-0.12
Predicted slowdown in 1970s	**-0.10**	**-0.10**	**-0.10**
Observed slowdown in 2000s	-0.03	-0.03	-0.03
Predicted slowdown in 2000s	**-0.02**	**-0.03**	**-0.03**

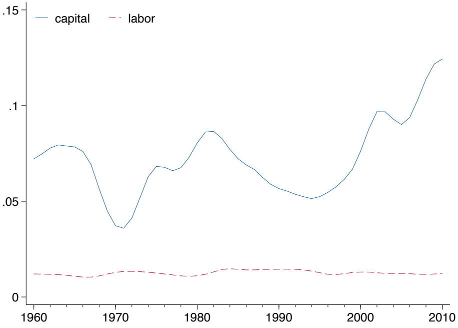
- Higher volatility is associated with lower allocative efficiency.
- Model predicts 10 pps and 2-3 pps decline in productivity growth for the 1970s and 2000s.

Sector-level relationship between volatility and allocative efficiency

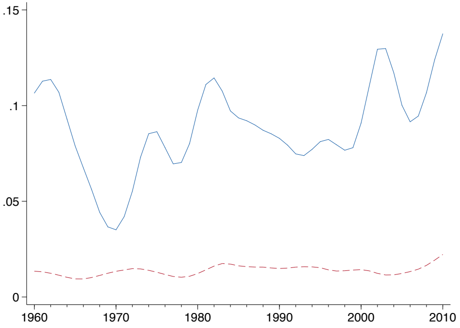
Dependent variable $\lvert \log E_{i,t} \rvert - \lvert \log E_{i,t-\Delta t} \rvert$		$\Delta t = 2$			$\Delta t = 4$	
Dispersion of TFP shock in $[t - \Delta t, t]$	0.141**	0.168*	0.154*	0.235**	0.253**	0.224*
	(0.0713)	(0.0866)	(0.0925)	(0.101)	(0.124)	(0.134)
Sector FEs	N	Y	Y	N	Y	Y
Year FEs	N	N	Y	N	N	Y
N	1593	1593	1593	1593	1593	1593
R^2	0.021	0.060	0.104	0.029	0.081	0.127

- A rise in sector-level volatility is associated with reduced *sector-level allocative efficiency* ($E_{i,t}$ deviates more from 1).

Evidence from utilization rates



(a) Standard deviation



(b) Inter-quartile range

- In models with adjustment costs, factor utilization rates correspond to positions in the inaction regions (Abel and Eberly, 1998).

$\Rightarrow$ An expansion of the inaction region leads to increased dispersion of utilization rates.

Conclusion

Conclusion

- Allocative efficiency was a key factor behind both slow productivity growth episodes.
- Slower growth in allocative efficiency accounts for 2/3 of the productivity slowdown.
- Heightened volatility may have led to slow growth in allocative efficiency.

Policy implications

- Critical role of volatility and allocative efficiency during periods of prolonged weak growth.
- This calls for policy measures to reduce volatility firms face or lower adjustment costs.

Appendix

List of sectors

AtB Agriculture hunting forestry and fishing
C Mining and quarrying
D Manufacturing
- 15t16 Food products, beverages and tobacco
- 17t19 Textiles, textile products leather and footwear
- 20 Wood and products of wood and cork
- 21t22 Pulp paper, paper products, printing and publishing
- 23 Coke refined petroleum products and nuclear fuel
- 24 Chemicals and chemical products
- 25 Rubber and plastics products
- 26 Other non-metallic mineral products
- 27t28 Basic metals and fabricated metal products
- 29 Machinery nec
- 30t33 Electrical and optical equipment
- 34t35 Transport equipment
- 36t37 Manufacturing nec; recycling

E Electricity gas and water supply
F Construction
G Wholesale and retail trade
- 50 Wholesale trade and commission trade except of motor vehicles and motorcycles
- 51 Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
- 52 Retail trade except of motor vehicles and motorcycles; repair of household goods

H Hotels and restaurants
I Transport and storage and communication
- 60t63 Transport and storage
- 64 Post and telecommunications

J Financial intermediation
K Real estate, renting and business activities
- 70 Real estate activities
- 71t74 Renting of m&eq and other business activities

M Education
N Health and social work

back

Input-output economy

Production system

- One final good Y_t

$$Y_t = \prod_{i=1}^{N} Y_{i,t}^{\theta_i}$$

- N intermediate good $\{Q_{i,t}\}_{i=1}^{N}$

$$Q_{i,t} = A_{i,t}(K_{i,t}^{\alpha_{i,t}} L_{i,t}^{1-\alpha_{i,t}})^{1-\sum_j^N \sigma_{ij,t} - \sum_j^N \lambda_{ij,t}} (\prod_{j,t}^{N} d_{ij,t}^{\sigma_{ij,t}})(\prod_{j,t}^{N} m_{ij,t}^{\lambda_{ij,t}})$$

  - Capital: $K_{i,t}$. Labor: $L_{i,t}$.
  - Domestic intermediate goods from sector j: $d_{ij,t}$.
  - Imported intermediate goods from sector j: $m_{ij,t}$.

- Resource constraint on $Q_{i,t} = Y_{i,t} + \sum_{j=1}^{N} d_{ji,t}$.

Input-output economy

Allocative efficiency

- Sufficient statistics for E_t

$$\mathrm{E}_t = \frac{Y_t - X_t}{Y_t^* - X_t^*} = E_t^{kl} \cdot E_t^d \cdot E_t^m \cdot E_t^y,$$

  - $E_t^{kl} = \prod_{i=1}^N (((\frac{\chi_{i,t}^k}{\chi_{i,t}^{k*}})^{\alpha_{i,t}} (\frac{\chi_{i,t}^l}{\chi_{i,t}^{l*}})^{1-\alpha_{i,t}})^{1-\sigma_{i,t}-\lambda_{i,t}})^{\sum_n \theta_{n,t} C_{ni,t}}.$
  - $E_t^d = \prod_{i=1}^N (\prod_{j=1}^N (\frac{\gamma_{ij,t}}{\gamma_{ij,t}^*})^{\sigma_{ij,t}})^{\sum_n \theta_{n,t} C_{ni,t}}.$
  - $E_t^m = \frac{1-\sum_{n=1}^N \frac{\theta_{n,t}\lambda_{n,t}}{\chi_{n,t}^y}}{1-\sum_{n=1}^N \frac{\theta_{n,t}\lambda_{n,t}}{\chi_{n,t}^{y*}}}.$
  - $E_t^y = \prod_{n=1}^N (\frac{\chi_{n,t}^y}{\chi_{n,t}^{y*}})^{\theta_{n,t}} \prod_{i=1}^N (\frac{\prod_s (\frac{\chi_{s,t}^y}{\chi_{i,t}^y})^{\theta_{s,t}}}{\prod_s (\frac{\chi_{s,t}^{y*}}{\chi_{i,t}^{y*}})^{\theta_{s,t}}})^{\lambda_{i,t} \sum_n (\theta_{n,t} C_{ni,t})}.$