ICT-Specific Investment Shocks and Economic Fluctuations

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Motivation

Why did U.S. output grow so slowly since the recession trough in 2009?

Fernald, Hall, Stock and Watson (2017) empirically show that two components explain nearly all this growth gap

1. Slow growth in total factor productivity (TFP)
2. Falling labor force participation

In this paper we focus on the slowdown in TFP,

$\Rightarrow$ Which variable(s) actually boost productivity? Why?

An alternative to R&D Investment

Following Romer (1990) and Coming and Gertler (2006), several papers endogenize TFP through **R&D investment**

- Financial crisis $\Rightarrow \downarrow Y^D \Rightarrow \downarrow$ R&D $\Rightarrow \downarrow$ TFP $\Rightarrow \downarrow Y^S$

Unfortunately, as showed by Oliner et al. (2007) and Jorgerson et al. (2008), TFP have started slowing down **before** the crisis.

We follow an alternative avenue and focus on the relation between **information and communication technology investment** (ICTI) and future total factor productivity

- *Expenditure in equipment and computer software meant to be used in production (as an input) for more than a year.*

Our Contribution

1. **Empirical evidence** that contemporaneous jumps in ICTI explain significant and persistent increases in future TFP
   - SVAR techniques on U.S. aggregates to identify supply shocks specific to the ICT sector

2. We analyze a **GE model** to rationalize our empirical findings and draw conclusions concerning the nature of ICT
   - We extend the two-sector model of Greenwood et al. (1997) to accommodate for the role of ICT capital in production

Information and Communication Technology

ICT Investment is defined as *total expenditure in equipment and computer software meant to be used in production (as an input) for more than a year.*

- $\uparrow$ ICT Investment $\Rightarrow$ $\uparrow$ ICT capital stock in the economy

Motivation: Empirical Challenge in Structural VAR

Empirically distinguishing between financial and uncertainty shocks is difficult

$\Rightarrow$ financial distress is empirically associated with larger volatility

Within a SVAR framework, this correlation significantly complicates identification of both shocks

1. Implausible **zero-contemporaneous restrictions**
   - $\Rightarrow$ Both F_t and U_t are fast moving
2. Unavailable instruments for **sign restrictions**
   - $\Rightarrow$ Current theoretical models predict same qualitative effects on both prices and quantities

My contribution

I want to take a step back and show evidence and theory that financial and uncertainty shocks are **qualitative different**.

In particular,

1. **Corporate cash holdings** respond differently to financial and uncertainty shocks.
   $\Rightarrow$ Identification assumption

2. I provide a **new econometric tool** to simultaneously identify two structural shocks when an internal instrument is available.
   $\Rightarrow$ Generalized Penalty Function Approach

Roadmap

1. **Cash Holdings**
2. Model
3. Empirical Strategy
4. Results
5. Conclusions

Corporate Cash Holdings

Cash and Cash Equivalents refer to assets a business holds as ready cash

- Coffer as petty cash
- Bank accounts
- Certificates of deposits

U.S. large firms have cash equal to about 15% of total assets.

It is a **stock variable**,

$$Cash_t = Cash_{t-1} + NY_t + \delta K_t - I_t + B_t - D_t.$$

Cross-Sectional Evidence

Cash and **Financial Frictions**

$\Rightarrow$ Cash is a substitute for external finance

Kaplan and Zingales (1997); Almeida, et al. (2004); Campello at al. (2010); Campello et al. (2011).

Cash and **Uncertainty**

$\Rightarrow$ Cash is positively associated with uncertainty shocks

Han and Qiu (2007); Baum et al. (2008); Bloom et al. (2018); Alfaro et al. (2018).

Aggregate Evidence

Aggregate quarterly cash (CHEQ) and assets (ATQ) using **Compustat** from 1961 to 2018.

Remove seasonality using 7-term Henderson filter on aggregate cash and aggregate assets and obtain **Cash2Assets**.

	ΔGDP	U	F
Correlations			
U	-0.48^{***}		
F	-0.36^{***}	0.22^{***}	
C2A	-0.06	0.43^{***}	-0.37^{***}

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Model - General Setup

- **Three-period partial equilibrium** model
- Firm **maximizes** sum of **dividends**
  - Discount factor β is one
- **Choice variables** are
  - **Investments** i_0 and i_1 in period 0 and 1
  - Amount to **borrow** b_0 and b_1 in period 0 and 1
  - **Cash** c in period 0 to be carried in period 1
- Feature **financial frictions** in the form of risk premium
- **Gross returns** $g(\cdot)$ happen in the last period for both investments
  - where $g'(\cdot) > 0$ and $g''(\cdot) < 0$.

Model - Analytical Setup

Period 0 $\quad d_0 = y_0 + b_0 - i_0 - c$

Period 1 $\quad d_1 = y_1 + b_1 - i_1 + c, \quad \text{where} \;\; y_1 \sim F(y_0, \sigma^2)$

Period 2 $\quad d_2 = g(i_0) - b_0(1 + r_0) + g(i_1) - b_1(1 + r_1)$

$$\max_{\{b_t, i_t, c\}_{t=0,1}} \quad \mathbb{E}\left[d_0 + d_1 + d_2 \middle| F\right]$$

$$\text{subject to} \quad r_0 = \frac{1}{2}\alpha_0 b_0 \;\; \text{and} \;\; r_1 = \frac{1}{2}\alpha_1 b_1$$

$$d_t \geq 0, \quad t = 0, 1, 2$$

Financial shock: $\uparrow \alpha_0$ vs Uncertainty shock: $\uparrow \sigma^2$

Solution

Assuming that firm needs external finance in equilibrium, model implies:

- $i_0 = y_0 + b_0 - c$,
- $i_1 = y_1 + b_1 + c$,

and first order conditions are

$$b_0 : \; g'(y_0 + b_0^* - c^*) = \underbrace{1 + \alpha_0 b_0^*}_{\text{Marginal Cost of } i_0}$$

$$b_1 : \; \mathbb{E}\left[g'(y_1 + b_1^* + c^*)\right] = \underbrace{1 + \alpha_1 b_1^*}_{\text{Marginal Cost of } i_1}$$

$$c : \; \underbrace{\mathbb{E}\left[g'(y_1 + b_1^* + c^*)\right]}_{\text{Expected Marginal Return of } i_1} = \underbrace{g'(y_0 + b_0^* - c^*)}_{\text{Marginal Return of } i_0}$$

Comparative Statics

$$b_0: \; g'(y_0 + b_0^* - c^*) = \underbrace{1 + \alpha_0 b_0^*}_{\text{Marginal Cost of } i_0}$$

$$b_1: \; \mathbb{E}\left[g'(y_1 + b_1^* + c^*)\right] = \underbrace{1 + \alpha_1 b_1^*}_{\text{Marginal Cost of } i_1}$$

$$c: \; \underbrace{\mathbb{E}\left[g'(y_1 + b_1^* + c^*)\right]}_{\text{Expected Marginal Return of } i_1} = \underbrace{g'(y_0 + b_0^* - c^*)}_{\text{Marginal Return of } i_0}$$

Uncertainty shock: $y_1 \sim Q$ which is mean-preserving spread in F

$\Rightarrow \; c^*(\alpha_0, Q) > c^*(\alpha_0, F)$ as long as $g'''(\cdot) > 0$

Financial shock: $\alpha_0^f > \alpha_0$ which is an exogenous increase in r_0

$\Rightarrow \; c^*(\alpha_0^f, F) < c^*(\alpha_0, F)$

Roadmap

1. Cash Reserves
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3. **Empirical Strategy**
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Empirical Analysis

Given the reduced-form system $X_t = B(L)X_{t-1} + \iota_t$ where

$$X_t = \begin{bmatrix} U_t \\ F_t \\ GDP_t \\ C_t \\ I_t \\ H_t \\ C2A_t \\ GDPDef_t \end{bmatrix}$$

Dataset ranges from 1978q1 to 2015q3.

Objective of the Empirical Strategy

Given the reduced-form system $X_t = B(L)X_{t-1} + \iota_t$,

$\Rightarrow$ find a rotation of $\Sigma_\iota = \iota_t'\iota_t$ such that

1. it allows F_t and U_t to respond to both shocks on **impact**
2. it respects **sign-restriction** assumptions on cash
3. it is **unique**
4. it delivers shocks **orthogonal** to each other
5. it is unaffected by the **order** of the estimation

Sequential Penalty Function Approach ($\delta \geq 0$)

1. Uncertainty Shock

$$\max_{\gamma_U} \quad \underbrace{e_U A_0 \gamma_U}_{\text{Impact on U}} \quad + \quad \delta \quad \underbrace{e_C A_0 \gamma_U}_{\text{Impact on Cash}}$$

Intuition. γ_U increases both uncertainty and cash on impact.

2. Financial Shock

$$\max_{\gamma_F} \quad \underbrace{e_F A_0 \gamma_F}_{\text{Impact on F}} \quad - \quad \delta \quad \underbrace{e_C A_0 \gamma_F}_{\text{Impact on Cash}} \quad s.t. \quad \underbrace{\gamma_U \gamma_F' = 0}_{\text{Orthogonality with U shock}}$$

Intuition. γ_F increases uncertainty and decreases cash on impact.

Sequential Penalty Function Approach ($\delta \geq 0$)

1. Financial Shock

$$\max_{\gamma_F} \quad \underbrace{e_F A_0 \gamma_F}_{\text{Impact on F}} \quad - \quad \delta \quad \underbrace{e_C A_0 \gamma_F}_{\text{Impact on Cash}}$$

Intuition. γ_F increases uncertainty and decreases cash on impact.

2. Uncertainty Shock

$$\max_{\gamma_U} \quad \underbrace{e_U A_0 \gamma_U}_{\text{Impact on U}} \quad + \quad \delta \quad \underbrace{e_C A_0 \gamma_U}_{\text{Impact on Cash}} \quad s.t. \quad \underbrace{\gamma_U \gamma_F' = 0}_{\text{Orthogonality with F shock}}$$

Intuition. γ_U increases both uncertainty and cash on impact.

Generalized Penalty Function Approach

1. **Financial Shock**

$$\max_{\gamma_F} \quad \underbrace{e_F A_0 \gamma_F}_{\text{Impact on F}} \quad - \quad \delta^* \quad \underbrace{e_C A_0 \gamma_F}_{\text{Impact on Cash}}$$

2. **Uncertainty Shock**

$$\max_{\gamma_U} \quad \underbrace{e_U A_0 \gamma_U}_{\text{Impact on U}} \quad + \quad \delta^* \quad \underbrace{e_C A_0 \gamma_U}_{\text{Impact on Cash}}$$

where δ^* is chosen such that $\gamma_U \gamma_F' = 0$.

Economic Intuition. Weight of sign restrictions should be large enough such that the two shocks are separated without any external constraint.

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Uncertainty Shock

Financial Shock

Variance Explained

Roadmap

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Conclusions

- **Cash reserves** as an internal instrument to simultaneously identify financial and uncertainty shocks.

- An **econometric tool** to overcome known SVAR shortcomings
  - $\Rightarrow$ Tests using simulated data confirm the reliability of the procedure. See **Appendix A**.

- Empirical results confirm the **relevance** and **exogeneity** of both shocks.
  - $\Rightarrow$ Correlations with external shocks is available in **Appendix B**.

- **Financial shocks** have larger effects in the **short run** while **uncertainty shocks** have a more **persistent** effect.

Next Steps

1. Empirical evidence in favor of my identification assumption
   - Using **Quarterly Financial Report** data to show that my results are mostly driven by small firms
   - Merging **Compustat** and **TRACE** to show firm-level evidence of the differential response of cash

$$\frac{Cash_{it}}{Assets_{it}} = \underbrace{\beta^U}_{(+)} U_{it} + \underbrace{\beta^F}_{(-)} F_{it} + \beta^X X_{it} + \delta_i + \lambda_t + \varepsilon_{it}$$

2. Design and analyze a **dynamic GE model**
   - to show my identification assumption survives to GE effects
   - to test whether GPFA can recover both shocks

Appendix A - Simulated Data and Generalized PFA

Consider the following structural model,

- $U_t = B_{UU}U_{t-1} + B_{UF}F_{t-1} + B_{UC}C_{t-1} + A_{UU}s_t^U + A_{UF}s_t^F$
- $F_t = B_{FU}U_{t-1} + B_{FF}F_{t-1} + B_{FC}C_{t-1} + A_{FU}s_t^U + A_{FF}s_t^F$
- $C_t = B_{CU}U_{t-1} - B_{CF}F_{t-1} + B_{CC}C_{t-1} + A_{CU}s_t^U - A_{CF}s_t^F$

where $s_t^U \sim N(0, \sigma_U^2)$, $s_t^F \sim N(0, \sigma_F^2)$ and $s_t^U \perp s_t^F$.

Objective is to estimate structural parameters

- using only $X_t = [U_t,\ F_t,\ C_t]$, and
- only knowing that $A_{ji} \geq 0$ for $j, i = \{U,\ F,\ C\}$.

$\Rightarrow$ apply GPFA to test reliability of the econometric tool

Appendix A - Small Sample Performance (T = 100)

Appendix A - Large Sample Performance (T = 100000)

Appendix B - Correlations with Other External Shocks

	Uncertainty Shocks	**Financial Shocks**
External Shocks		
BZP Military News	−0.10 (0.24)	0.08 (0.31)
Ramey Military news	0.07 (0.44)	0.02 (0.82)
LWY Exp. Tax	0.03 (0.74)	0.15 (0.11)
RRMR Unexp. Tax	−0.13 (0.16)	0.05 (0.59)
RRMR Exp. Tax	−0.08 (0.36)	0.03 (0.76)
AdjTFP AR(1)	0.08 (0.31)	−0.14 (0.11)
RR Mon. Policy	−0.13 (0.18)	−0.04 (0.70)