The Slowdown of TFP
Exogenous and Endogenous Mechanisms

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Motivation

- The neoclassical tradition (RBC literature) in macro has treated total factor productivity (TFP) as exogenous.
  (King & Rebelo 1999, Christiano, Eichenbaum & Trabandt 2014, 2018)

- The Great Recession 2008 revived interest in endogenous components in TFP for explaining long-run TFP fluctuations.

  $\rightarrow$ We explore the possibility that general-purpose technologies (GPT), in particular for the last 30 years information technologies (IT), play a role in explaining TFP fluctuations at long horizons.

Motivation II

- Our main analysis is estimating a structural VAR in which we identify a shock to the exogenous component of future TFP (a news shock) and a shock to the endogenous component of TFP (a shock to IT productivity, hereafter "IT shock").

- Along the way, we provide a solution to an econometric challenge in the literature on long-run productivity.

Our starting point: Barsky & Sims (2011)

BS identify news shocks as shocks that maximize future fluctuations in TFP. But they warn:

"*A more general objection to our empirical approach would be that a number of structural shocks, which are not really "news" in the sense defined by the literature, might affect a measure of TFP in the future without impacting it immediately. Among these shocks might be research and development shocks, investment specific shocks, and reallocative shocks. Our identification (and any other existing VAR identifications) would obviously confound any true news shock with these shocks.*"

Barsky & Sims (2011), p. 278.

$\rightarrow$ We focus on a specific subset of shocks which are "not really 'news"': shocks to the productivity of the sector that produces IT goods.

Related literatures

- One strand of literature: Exogenous TFP and news shocks
  - Beaudry & Portier (2006)
  - Barsky & Sims (2011)

  Our contribution: allow in this setting the existence of an endogenous mechanism that affects future TFP

- Another strand of literature: Endogenous TFP with R&D investment as the key variable
  - Comin & Gertler (2006)
  - Moran & Queralto (2017)
  - Guerron & Jinnai (2014)

  Our contribution: provide what we think is a more convincing test for the endogenous mechanism

A toy model

How should we think of this IT productivity shock?

Contextualize using a simple expanding variety model (Romer 1990)

Expanding variety model

Final good Y_t is the CES aggregate of a number A_t intermediate goods $Y_t^M(s)$:

$$Y_t = \left[\int_0^{A_t} Y_t^M(s)^{\frac{\theta-1}{\theta}} ds \right]^{\frac{\theta}{\theta-1}} \tag{1}$$

Expanding variety model

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Intermediate good s is Cobb-Douglas with exogenous TFP Ψ_t:

$$Y_t(s) = \Psi_t K_t(s)^{\alpha} L_t(s)^{1-\alpha} \tag{2}$$

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$\rightarrow$ letting K_t and L_t be aggregate capital and labor, final output is:

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The IT sector is a separate sector that uses IT investment $S_{i,t}$ to expand A_t. Importantly, we assume that the IT sector is also augmented by Ψ_t, as well as by the sector-specific productivity λ_t.

$$V_{i,t} = \lambda_t \Psi_t f(S_{i,t}) \tag{4}$$

▸ IT sector in detail

The shocks

$$Y_t = \underbrace{A_t^{\frac{1}{\theta-1}}}_{\text{endogenous TFP}} \underbrace{\Psi_t}_{\text{exogenous TFP}} K_t^{\alpha} L_t^{1-\alpha}$$

$\hookrightarrow$ A news shock is $\Psi_{t+k} \uparrow$ for some $k > 0$

$\hookrightarrow$ An IT productivity shock is $\lambda_t \uparrow$, which shows up in $A_{t+j} \uparrow$ with a lag $j > 0$

Crucially, both lead to an increase in future TFP, with no effect on impact.

$\rightarrow$ to a Barsky & Sims-type identification, the two shocks are observationally equivalent!
$\Rightarrow$ econometric challenge is to disentangle the two!

Identification: relative prices

The price level P is an aggregate of the prices intermediate goods. These are determined as an FOC to

$$Y_t(s) = \Psi_t K_t(s)^{\alpha} L_t(s)^{1-\alpha}$$

$\hookrightarrow$ P is a function of Ψ_t

The price of IT good, P^{IT}, is determined as an FOC to

$$V_{i,t} = \lambda_t \Psi_t f(S_{i,t}) \tag{5}$$

$\hookrightarrow$ P^{IT} is a function of Ψ_t **and** λ_t

$\Rightarrow$ The two shocks imply different responses of relative prices $\frac{P^{IT}}{P}$!

- A news shock moves both P and P^{IT}, leaving relative prices unchanged.
- An IT productivity shock moves only P^{IT}, thus changing relative prices.

Empirical analysis

We run a SVAR using aggregate, quarterly US data. The data vector is:

$$\mathbf{X_t} = \begin{bmatrix} TFP_t \\ SP_t \\ IT_t \\ GDP_t \\ C_t \\ RP_t \end{bmatrix} \tag{6}$$

- $RP = \pi^{IT} / \pi^{CPI}$.
- All variables are real (except price indexes) and in log levels (except for RP, which is in growth rates).
- The dataset ranges from 1989:q1 - 2017:q2.

From reduced form to structural form

Structural Form

$$(\mathbf{AD})^{-1}\mathbf{X_t} = \mathbf{C(L)X_{t-1}} + \mathbf{s_t} \tag{7}$$

Reduced Form

$$\mathbf{X_t} = \underbrace{\mathbf{ADC(L)}}_{\mathbf{B(L)}}\mathbf{X_{t-1}} + \underbrace{\mathbf{ADs_t}}_{\mathbf{i_t}} \tag{8}$$

- AD is the impact matrix
- A is s.t. $As_t s_t' A' = i_t i_t' = \Sigma$ and $s_t s_t' = I$
- D is a rotation matrix s.t. $DD' = I \Rightarrow AD(AD)' = \Sigma$

We impose our identifying assumptions on the matrix D. ▸ Technicalities

Identification strategy overall

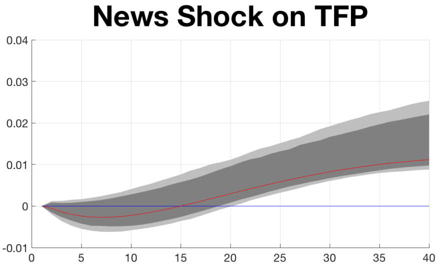
$$\epsilon_t^{TFP} = \underbrace{V_{t-k}}_{\text{news shock}} + \underbrace{IT_{t-k}}_{\text{IT productivity shock}} + \underbrace{\varepsilon_t}_{\text{surprise tech shock}} \quad (9)$$

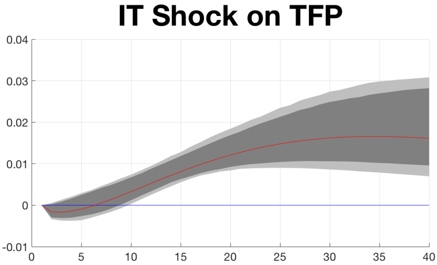
1. The news shock V_{t-k} maximizes the FEV of future TFP subject to the restriction that it has no effect on the relative price RP at a small number of quarters (enough for prices to adjust, so 6-12);
2. The IT shock maximizes the remaining FEV of future TFP;
3. The tech shock ε_t is considered as a residual shock and is left unrestricted (unidentified).

Our favorite specification

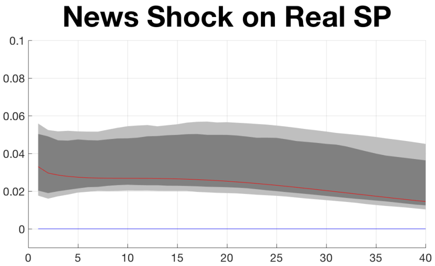
- Recall: dataset is quarterly and covers 1989:q1-2017-q2.
- One lag (as suggested by BIC and HQ).
- Horizon of FEV-maximization: 60 quarters.
- Restriction on relative prices after a news shock is imposed at 8 quarters.

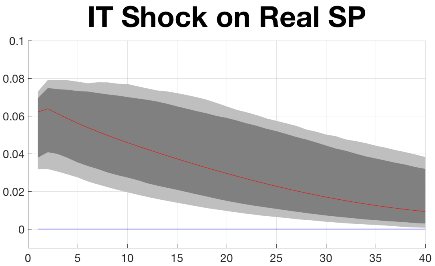
TFP response to both shocks



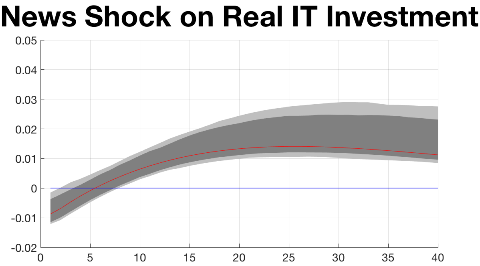


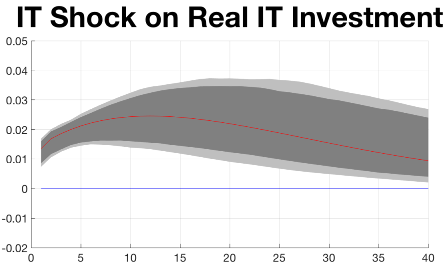
Real SP500 response to both shocks



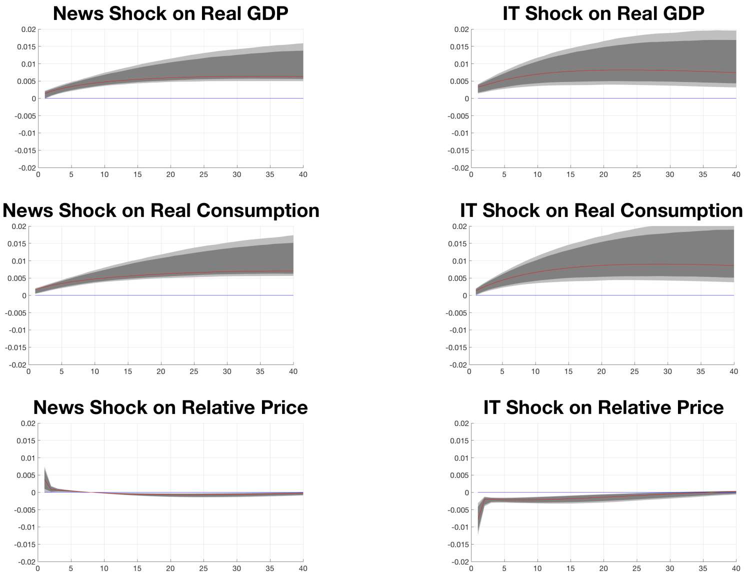


IT investment response to both shocks





Other responses to both shocks



FEV explained by the two shocks at 60 periods

	News	IT	Total
TFP	0.20384	0.52596	0.72981

For BS, FEV of news was 45%.

Interpretation

1. Shape and timing of the responses reflect ...
   - both the Barsky & Sims result;
   - as well as the the conjecture that the IT shock looks similar to news along certain dimensions;
   - but relative prices do indeed introduce a margin of difference between the two shocks.

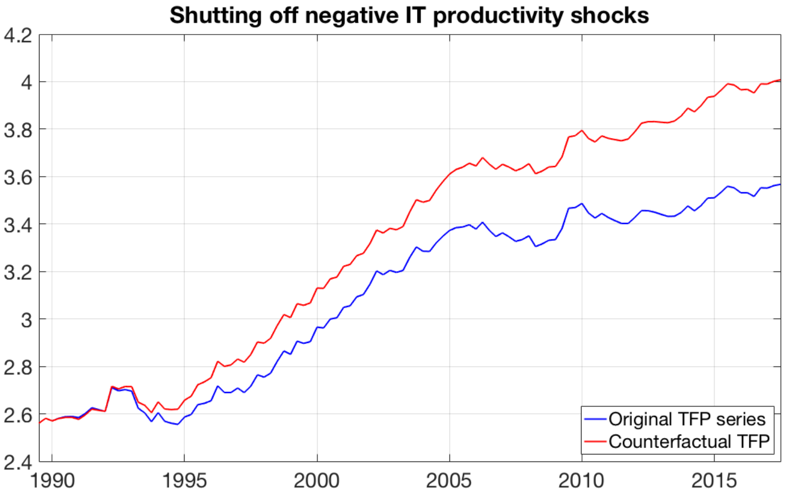
2. Shares of FEV of TFP explained ...
   - are also in line with the Barsky & Sims result;
     (for BS, news explains around 45%, compared to 20% here)
   - yet suggest that the IT shock plays an important role as well (around 52%).
   - And indeed the IT shock *complements* the news shock, instead of substituting for it.
     For BS, the single identified shock explains around 45%, while our two identified shocks explain around 73%.

Robustness checks

- Different variables
  - Add the Michigan index of consumer confidence (expected business conditions 5 years ahead)
  - Replace IT prices with capital prices (following Comin & Gertler)
- Different horizons at which we impose the restriction on relative prices for the news shock

  $\rightarrow$ ran 6, 8, 10, 12 and 16 quarters.
- Increase the number of lags (2)
- Check whether VAR is information-sufficient to identify the news shock (Forni-Gambetti test) (p-val of 12%)

A counterfactual



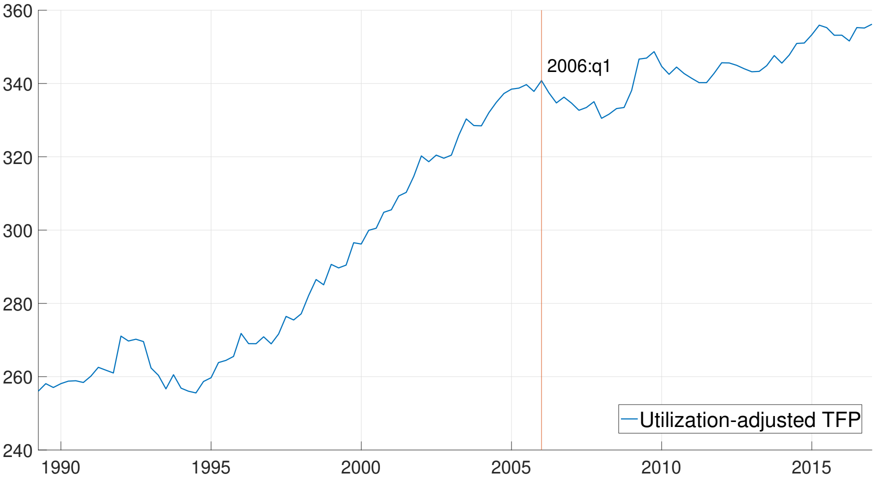
Conclusion

- Provided a test for the role of IT as an example of GPTs in explaining fluctuations in long-run TFP, and in doing so, overcame an econometric challenge prevalent in the literature on long-run productivity.
- The results show that by controlling for the presence of news shocks, IT productivity shocks are important drivers of TFP fluctuations at long horizons.
- This result does not contrast however with the findings of the news shock literature since we still find that news also play a significant role in explaining TFP.
- Moreover, IT productivity shocks can be thought of as giving more microfoundations to what classical news shocks carry information on.

Work ahead

- Technically, should do a VECM due to cointegration and wanting to have variables in the VAR as growth rates rather than levels...
- Dig deeper: IT is just an example of GPTs for the last 30 years
  $\hookrightarrow$ could redo analysis for different time periods with different GPTs (electricity in 1920s, airplane industry in 1960s ...)
- Use a fully structural model to see if we can find interesting interactions between the two shocks?
  $\hookrightarrow$ In particular, we're thinking of noise shocks on IT productivity
- But there are also other shocks that are similar to news shocks and yet not news shocks in the Barsky & Sims sense: reallocative shocks, shocks to inventories, etc...

The current TFP slowdown



Barsky & Sims FEV of TFP explained

Table 1
Forecast error variance decomposition.

	$h=1$	$h=4$	$h=8$	$h=16$	$h=24$	$h=40$
TFP	0.000	0.062	0.126	0.269	0.366	$\boxed{0.454}$
	(0.00)	(0.06)	(0.11)	(0.14)	(0.15)	(0.16)
Consumption	0.050	0.234	0.377	0.493	0.524	0.507
	(0.09)	(0.18)	(0.24)	(0.27)	(0.27)	(0.26)
Output	0.111	0.091	0.242	0.382	0.429	0.431
	(0.07)	(0.10)	(0.18)	(0.23)	(0.24)	(0.24)
Hours	0.622	0.200	0.105	0.092	0.094	0.089
	(0.23)	(0.16)	(0.13)	(0.15)	(0.16)	(0.15)
Stock price	0.140	0.200	0.185	0.189	0.193	0.181
	(0.17)	(0.20)	(0.20)	(0.21)	(0.22)	(0.21)
Confidence	0.245	0.343	0.353	0.333	0.310	0.286
	(0.21)	(0.22)	(0.22)	(0.22)	(0.20)	(0.18)
Inflation	0.138	0.220	0.226	0.205	0.191	0.180
	(0.18)	(0.18)	(0.15)	(0.15)	(0.14)	(0.14)
Total TFP	1.000	0.948	0.943	0.951	0.948	$\boxed{0.910}$
Total output	0.731	0.282	0.364	0.451	0.491	0.520

The letter *h* refers to the forecast horizon. The numbers denote the fraction of the forecast error variance of each variable at various forecast horizons to our identified news shock. Standard errors, from a bootstrap simulation, are in parentheses. "Total TFP" shows the total variance of TFP explained by our news shock and the TFP innovation combined. "Total output" shows the total variance of output explained by the news shock and the TFP innovation combined.

Return

Production of IT goods

Production function for IT goods:

$$V_{i,t} = \lambda_t \Psi_t f(S_{i,t}) \tag{10}$$

where $S_{i,t}$ is investment by producer i in IT goods and λ is the productivity of the IT sector.

The IT producer's problem is to max discounted profits $J_{i,t+1}$

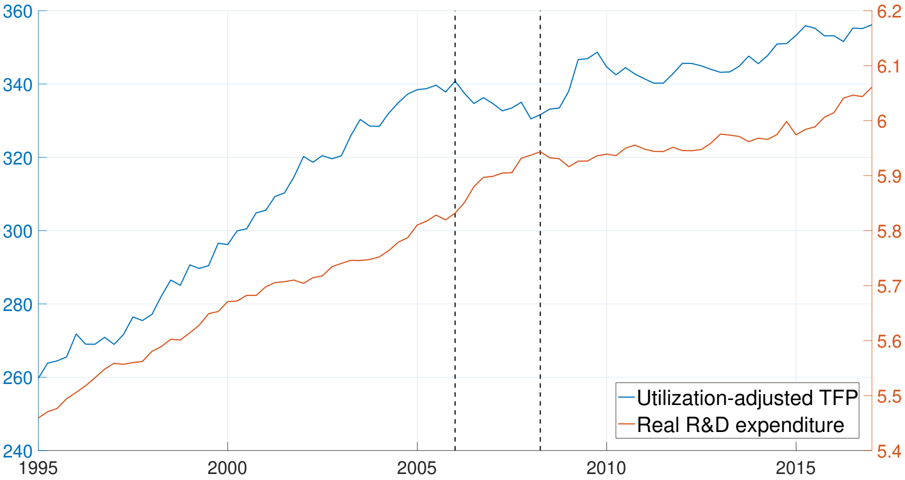
$$\max_{S_{i,t}} \mathbb{E}(\Lambda_{t,t+1}, J_{i,t+1})\lambda_t \Psi_t f(S_{i,t}) - P_t^{IT} S_{i,t} \tag{11}$$

FOC:

$$P_t^{IT} = \mathbb{E}(\Lambda_{t,t+1}, J_{i,t+1})\lambda \Psi_t f_1 \tag{12}$$

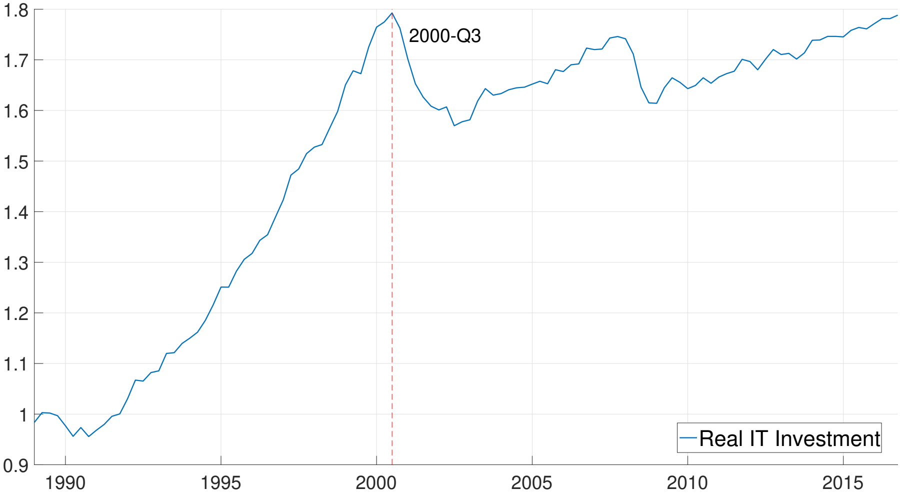
Return

Timing: RD drop vs TFP drop



Return

IT investment: a drop at the right time



Return

Identification Strategy

$$D = \begin{bmatrix} d_{11} & \gamma_{12} & \gamma_{13} & d_{14} & \cdots \\ d_{21} & \gamma_{22} & \gamma_{23} & d_{24} & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \end{bmatrix} \tag{13}$$

- Indifferent over d_{ij} as long as D is orthogonal
- $A\gamma_2$ is the impact response to a news shock
- $A\gamma_3$ is the impact response to a IT productivity shock
- First element of both $A\gamma_2$ and $A\gamma_3$ is zero due to the no-contemporaneous effect of both shocks on TFP
- $A\gamma_2$ is such that the FEV of TFP is maximized subject to zero long-run effect on RP
- $A\gamma_3$ is maximizing the remaining FEV of TFP

Return