Endogenous Technology Adoption and R&D as Sources of Business Cycle Persistence

Anzoategui, Comin, Gertler, and Martinez

Discussion by

Christopher Tonetti

Stanford GSB

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The Question

1. Why did output growth slow down persistently during Great Recession?
   - Reduced physical capital accumulation?
   - Reduced labor supply?
   - Reduced productivity growth?
2. TFP growth dropped strongly before and during recession
3. What contributed to the drop in TFP growth
   - Reduced expenditure on innovation (R&D)?
   - Reduced efficiency of innovation activity?
   - Reduced adoption of already invented ideas?
   - Exogenous movements beyond measured/filtered innovation and adoption behavior?
4. Key result: “Liquidity” shock reduced adoption activity

How to Judge the Paper?

- Plausible and intriguing idea about very important question
- Relatively easy to interpret the results
- Harder to understand what generates the results
- Free parameters or disciplined by data and cross-equation restrictions?
- Potential problem:
  - Fact: We measure productivity drops
  - Model: Add an unobserved factor with arbitrary time path that directly affects productivity
  - Result: Productivity drop in model is explained by drop in the unobserved factor
- The strength of the paper is determined by whether the unobserved factor of **adopted ideas** moves arbitrarily or not and if its movement is consistent with the movement of other observables

Main Suggestions to Authors

- More focus on showing the adoption process is tightly disciplined
  - More discussion on the calibration
  - More discussion on what is generating patterns in the filtered latent states
  - More analysis of behavior of non-targeted variables
  - More discussion of why so many bells and whistles are necessary and how they interact with novel features
- I need more help understanding what is generating quantitative results and convincing that this is the mechanism
- Great idea, very plausible, and consistent with interesting firm-level data (Andrews et. al. 2015)
- This will ultimately be a fantastic paper with big impact

What are the Results?

- The key outputs of the analysis are filtered latent states
  - Output growth is measured
  - TFP growth is calculated (basically) directly from measured variables
  - Shocks are filtered
  - Endogenous component of TFP, stock of potential ideas, and stock of adopted ideas are filtered
- Main result: Filtered time series for adoption rate falls sharply in recession driven by “liquidity” demand shock, driving the drop in GDP growth
- Filtered time series are the result of data + model + parameter values
- Next slides: What in the data/model/parameters is generating this result?

Data

- Estimation to match model output to data on Y, C, I, L, W, π, r, $R\&D$
- R&D is pro-cyclical, but not huge movement during recent recession
- Likely not decreased R&D that's causing the high frequency, large, prolonged drop in TFP growth
- Endogenous TFP is function of innovation (measured R&D) and adoption (no macro data)
- If not, R&D, maybe adoption decreased. Can't measure it, can try to infer if that is the case with **filtering**
- First, some case-study evidence that adoption is pro-cyclical
  - This adoption data not used in structural analysis, just motivation

Model

- Ideas disappear at rate ϕ; skilled labor wage w_{st}
- Profit from producing intermediate good (monopolistic competition): Π_{mt}
- Value of adopted idea: $V_t = \Pi_{mt} + \phi E_t[\Lambda_{t,t+1} V_{t+1}]$
- Adopters buy idea from innovator at cost J_t and adopt at rate λ_t (a function of L_{sat})
- Value of unadopted idea: $J_t = \max_{L_{sat}} E_t[\phi \Lambda_{t,t+1}[\lambda_t V_{t+1} + (1 - \lambda_t) J_{t+1}] - w_{st} L_{sat}]$
- Innovators create an idea with probability φ_t (a function of L_{sat})
- R&D FOC: $E_t[\Lambda_{t,t+1} \varphi_t J_{t+1}] = w_{st}$
- Adoption FOC: $Z_t \lambda' E_t[\phi \Lambda_{t,t+1}[V_{t+1} - J_{t+1}]] = w_{st}$

The Mechanism: Procyclical Adoption

$$V_t = \Pi_{mt} + \phi E_t[\Lambda_{t,t+1} V_{t+1}]$$

$$J_t = \max_{L_{sat}} E_t[\phi \Lambda_{t,t+1}[\lambda_t V_{t+1} + (1-\lambda_t) J_{t+1}] - w_{st} L_{sat}]$$

$$Z_t \lambda' E_t[\phi \Lambda_{t,t+1}[V_{t+1} - J_{t+1}]] = w_{st}$$

Adoption is procyclical

- w_{st} sticky
- In a boom, V_{t+1} increases more than $J_{t+1} \rightarrow \uparrow \lambda_t$
- V_{t+1} increases because profits Π_{mt} increases
- J_{t+1} increases because it is discounted V_{t+1} and persistence in boom
- J_{t+1} increases less because discounting, probability of adoption $\neq 1$, and mean reversion

Why does R&D Move less than Adoption in Great Recession?

Innovation and Adoption FOCs

$$E_t[\Lambda_{t,t+1} J_{t+1}] = \frac{w_{st}}{\chi_t Z_t L_{srt}^{\rho_z - 1}}$$

$$E_t[\phi \Lambda_{t,t+1}[V_{t+1} - J_{t+1}]] = \frac{w_{st}}{Z_t \lambda'} = \frac{w_{st}}{\psi_t Z_t L_{sat}^{\rho_\lambda - 1}}$$

- Recall, R&D didn't change much (data), adoption tanks (filtered)
- Recall main finding is negative liquidity shock drives fall in adoption
- How will negative shock to $\Lambda_{t,t+1}$ not affect R&D much but have big effect on adoption?
  - ϕ changes effective discount rate for adopters vs. innovators
  - Different elasticities of success w.r.t. labor expenditure (ρ_λ vs. ρ_z) means same change in SDF differentially affects adoption vs. innovation activity

The SDF Links Financial Prices and Adoption Behavior

$$E_t[\Lambda_{t,t+1}J_{t+1}] = \frac{w_{st}}{\chi_t Z_t L_{srt}^{\rho_z - 1}}$$

$$E_t[\phi\Lambda_{t,t+1}[V_{t+1} - J_{t+1}]] = \frac{w_{st}}{\psi_t Z_t L_{sat}^{\rho_\lambda - 1}}$$

$$1 = E_t[\Lambda_{t,t+1}R_{k,t+1}]$$

$$1 = E_t[\Lambda_{t,t+1}R_{t+1}] + \zeta_t$$

- SDF prices all assets: ideas, bonds, physical capital, etc.
- Does the SDF shock that matches R&D and TFP data hit short-term interest rate **levels** well?
- Is this long vs. short risk exposure? Does SDF shock hit long-short spreads well?
- Evidence on profit flows (V) vs. risk premia (Λ) over Great Recession?
- Can you provide more specifics on link between R_k and λ_t
- Great opportunity to use more finance analysis to prove not just free parameters to hit desired targets

The Parameters 1/2

Free parameters to hit desired targets or external discipline?

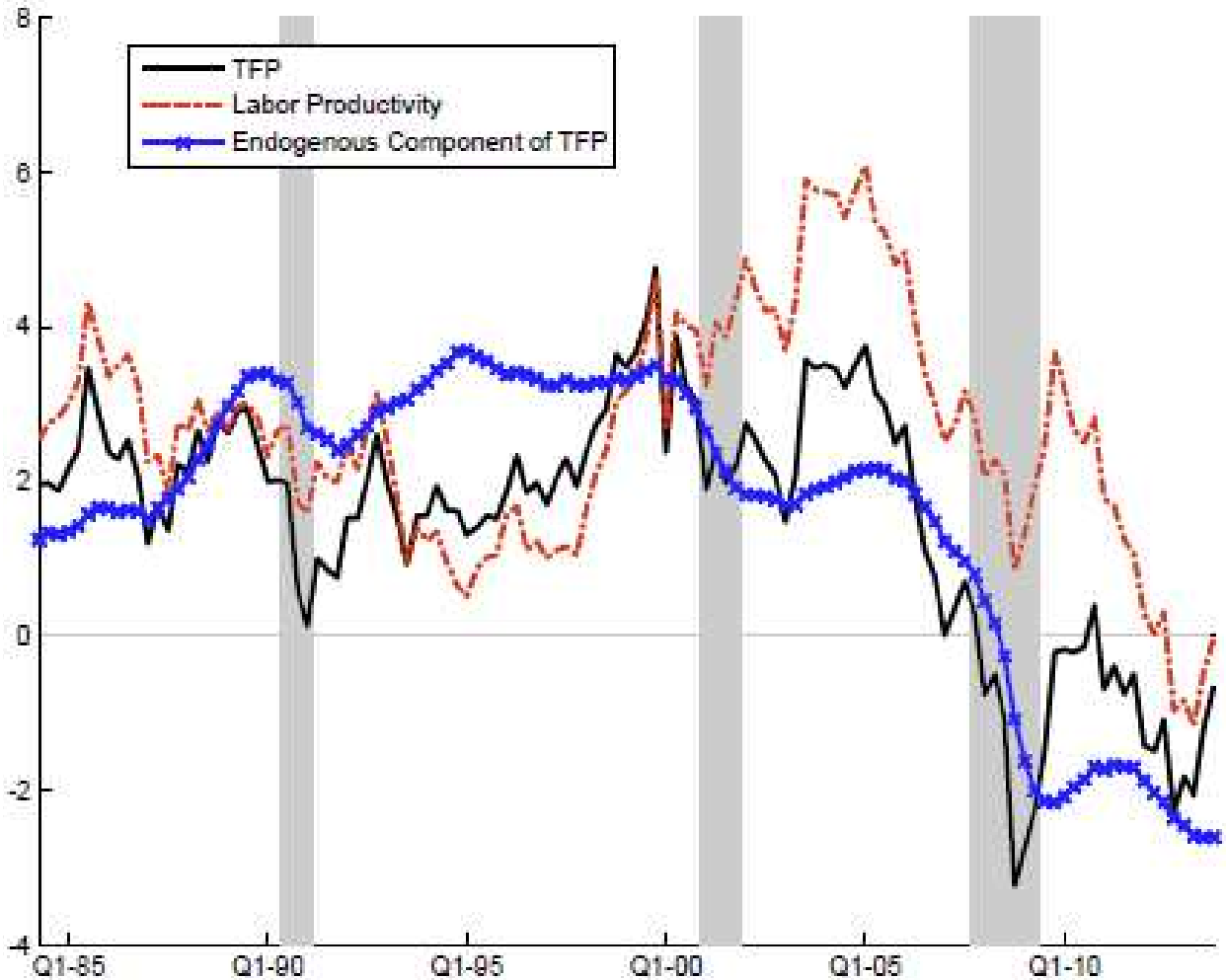
1. Elasticity of adoption rate w.r.t. adoption expenditures to hit R&D to GDP ratio of 2.2%
   - $\rho_\lambda = 0.95$
   - Comin and Gertler (2006): "admittedly, this estimate is crude. . . [but] provides a plausible benchmark"
   - Elasticity is key parameter in business cycle analysis
   - Analysis of FOCs suggests robustness to this parameter is essential!
     - Especially if don't have strong evidence for baseline value
2. Average time from invention to adoption
   - $\bar{\lambda}$ s.t. 7 years on average
   - Great use of adoption data from Comin and Hobijn (2010)

The Parameters 2/2

3. Rate at which ideas disappear
   - ϕ set to eight percent idea depreciation (annual?)
   - Comin and Gertler (2006) use three percent annual
   - "Falls in the middle of a broad range of estimates. . . in the literature"
4. Elasticity of innovation rate. w.r.t. innovation expenditures part of joint estimation
   - $\rho_z = 0.34$
   - Low relative to literature: Girliches 0.6-1.0
   - Comin and Gertler (2006) use 0.8
     - Maybe not comparable due to quarter vs. year, but then also for adoption elasticity
   - Suggest calibrating this variable just like above three to 0.6 or 0.8 and check robustness

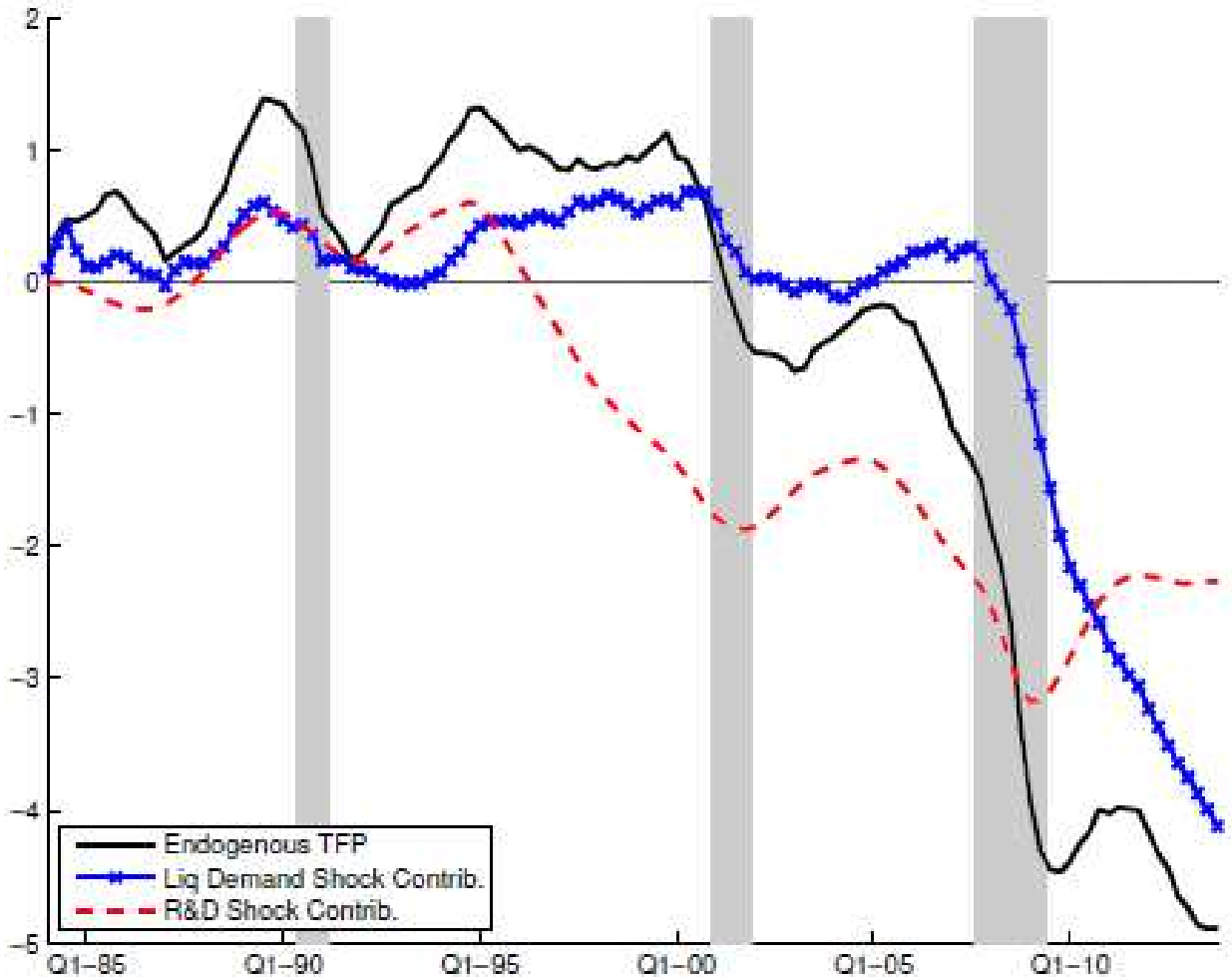
- Ultimately: R&D won't move but adoption will move strongly because elasticities are low for R&D and high for adoption based on above calibration/estimation

The Results: TFP Drop is Endogenous



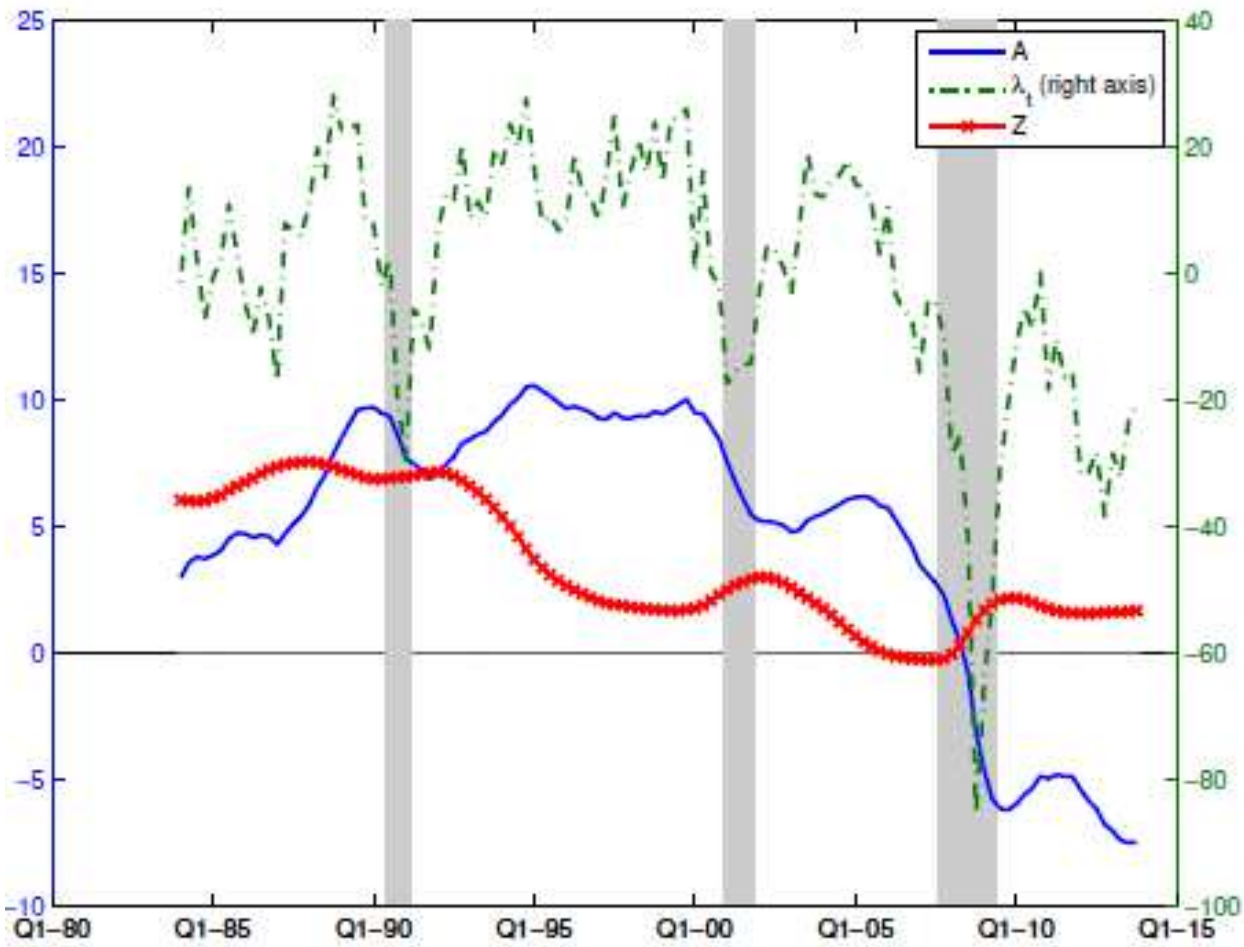
- Filtered endogenous TFP shock drives measured TFP

The Results: SDF Shock Works through Endogenous TFP



- Filtered “liquidity” demand shock drives endogenous TFP

The Results: Adoption Drops Precipitously



- Filtered adoption rates drives drop in filtered endogenous TFP

Where do the Results Come From?

- Need to get drop in calculated TFP since it is in the data
- R&D doesn't drop much
- So either adoption drops hard or decrease in TFP is exogenous
- With very high elasticity of adoption, adoption drops hard
- Results crucially rest on elasticity of adoption, which is number picked by authors who previously said its measure is "admittedly crude."
  - Probably can't get better direct measures and need to make progress and not just give up
  - Authors are best game in town and on the right approach, but need to do more checks on implications of ρ_λ on observables to add convincing evidence this number is roughly right
  - Also do robustness to this number to check sensitivity of results
- Chance to make predictions:
  - $Z_t - A_t$ is really big now
  - Predict fast recovery now that liquidity shock is gone (financial spreads are more normal)?