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

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Conference on Macroeconomics and Monetary Policy
Federal Reserve Bank of San Francisco
4 March 2016
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 $Y$, $C$, $I$, $L$, $W$, $\pi$, $r$, $R&D$
- 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 $\phi$; skilled labor wage $w_{st}$

- Profit from producing intermediate good (monopolistic competition): $\Pi_{mt}$

- 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 $\lambda_t$ (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 $\varphi_t$ (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 \( J_{t+1} \) → ↑ \( \lambda_t \)
- \( V_{t+1} \) increases because profits \( \Pi_{mt} \) 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

\[
E_t[\Lambda_{t,t+1} J_{t+1}] = \frac{W_{st}}{\chi_t Z_t L^{\rho z srt - 1}}
\]

\[
E_t[\phi \Lambda_{t,t+1} [V_{t+1} - J_{t+1}]] = \frac{W_{st}}{Z_t \lambda'} = \frac{W_{st}}{\psi_t Z_t L^{\rho \lambda_{sat} - 1}}
\]

- 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?
  - \( \phi \) changes effective discount rate for adopters vs. innovators
  - Different elasticities of success w.r.t. labor expenditure (\( \rho_\lambda \) vs. \( \rho_z \)) means same change in SDF differentially affects adoption vs. innovation activity
The SDF Links Financial Prices and Adoption Behavior

\[ E_t[\Lambda_{t,t+1}J_{t+1}] = \frac{W_{st}}{\chi_tZ_tL_{srt}^{\rho z-1}} \]

\[ E_t[\phi\Lambda_{t,t+1}[V_{t+1} - J_{t+1}]] = \frac{W_{st}}{\psi_tZ_tL_{sat}^{\rho \lambda-1}} \]

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 (\Lambda) over Great Recession?
- Can you provide more specifics on link between \( R_k \) and \( \lambda_t \)
- 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)
3. Rate at which ideas disappear
   - $\phi$ 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
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 $\rho_\lambda$ 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)?