Accounting for Growth in the Age of the Internet
The Importance of Output-Saving Technical Change

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* The views expressed are our own and not necessarily those of the Federal Reserve Bank of Philadelphia or the Federal Reserve System.
ISSUES ADDRESSED

• The growth in real GDP has slowed despite a period of vibrant innovation. This is the Solow Paradox Redux.

• Much research, many explanations:
  – It’s real; it’s the legacy of the Great Recession; it’s measurement error

• We suggest that a shift in the growth accounting paradigm is needed
FACTOIDS

• Many of the Internet Age benefits go directly to consumers, bypassing market GDP
  – “the internet has made information free, copious, and ubiquitous”, Schmidt and Rosenberg (2014)

• Rapid uptake of the tech revolution
LANCASTER 1966 CONSUMPTION TECHNOLOGY MODEL

• Utility is based on the blending of the characteristics of the goods produced, not the goods themselves, via a consumption technology.

• Distinction between resource cost of goods produced and the utility benefits of consumption of their characteristics.

• The consumption technology can shift over time, allowing consumers to use each dollar of income more efficiently.
GROWTH ACCOUNTS WITH AND WITHOUT THE CONSUMPTION TECHNOLOGY

- Production function: \( Q_t = e^{\lambda t} (L_t)^\alpha (K_t)^{1-\alpha} \)
  - Growth equation: \( q_t = \lambda + \alpha \eta_t + (1-\alpha) \kappa_t \)

- Standard utility function: \( U(C_t) = m(C_t)^\mu \)
  - Consumption Function: \( C_t = (1-\sigma)Q_t \)
  - Growth equation: \( u_t = \mu c_t = \mu q_t \)

- New utility function: \( U(C_t) = e^{\omega t}(e^{\beta t}(1-\sigma)Q_t)^\mu \)
  - Growth equation: \( u_t = \omega + \mu \beta + \mu q_t \)
COMBINED UTILITY AND PRODUCTION FUNCTIONS ($\mu=1$)

- Combined: $U(C_t) = (1-\sigma) e^{\omega t} e^{\beta t} e^{\lambda t} (L_t)^\alpha (K_t)^{1-\alpha}$

- Growth Equation: $u_t = \omega + \beta + \lambda + \alpha \eta_t + (1-\alpha) \kappa_t$

  - Output-Saving Innovation: $\omega + \beta$

  - Resource-Saving Innovation: $\lambda$

  - Resource-Using Growth: $\alpha \eta_t + (1-\alpha) \kappa_t$
MEASURING OUTPUT-SAVING INNOVATION

- Can express the utility formulation in its price-dual form
- Compensating and equivalent variations
- Helps locate consumer surplus in expanded accounts
Implications

• Conventional GDP not a sufficient statistic for the “Internet Age”
• Resource-based GDP can go down while welfare increases
• Resource-based GDP should not be adjusted for costless part of quality change
• Resource-based GDP is still an indispensable tool for policy.
CONVENTIONAL GROWTH ACCOUNTING WITH PRODUCT QUALITY CHANGE (HYBRID GDP)

• Production w/o: \( Q_t = e^{\lambda t} (L_t)^\alpha (K_t)^{1-\alpha} \)

  – Growth equation: \( q_t = \lambda + \alpha \eta_t + (1-\alpha) \kappa_t \)

• Production with: \( Q^e_t = e^{\beta t} Q_t = e^{\beta t} e^{\lambda t} (L_t)^\alpha (K_t)^{1-\alpha} \)

  – Growth equation: \( q^e_t = [\beta + \lambda] + \alpha \eta_t + (1-\alpha) \kappa_t \)
CONVENTIONAL GROWTH ACCOUNTING WITH COSTLY INNOVATION IN INTANGIBLES

• Production func w/o:  \( Q_t = e^{\lambda t} (L_t)^\alpha (K_t)^{1-\alpha} \)
  
  – Growth equation: \( q_t = \lambda + \alpha \eta_t + (1-\alpha)\kappa_t \)

• Production func:  \( Q^e_t = e^{\lambda t} (L_t)^\alpha (K_t)^\theta (R_t)^{1-\alpha-\theta} \)
  
  – Growth equation: \( q^e_t = \lambda + \alpha \eta_t + \theta \kappa_t + (1-\alpha-\theta)r_t \)
Costly vs Costless Innovation

Contribution to Labor Productivity Growth from TFP and Intangible Capital Stocks, 1955-2007

-6 yr. avg. TFP
- 4 yr. avg. Intangibles
THE SERVICE SECTORS

• Hard to measure, rapid growth.
• The utility of many services is contingent on an initial state (health, knowledge, education, finance).
  – Outcomes are different from purchased services
• Lancaster characteristics model natural way to think about this
  – Implied utility function is \( U(C_t, \Theta_{t-1}) \)
LAST THOUGHTS

THIS ANALYSIS POINTS TO THE DESIRABILITY OF AN EXPERIMENTAL INNOVATION ACCOUNT IN WHICH REAL “GDP” IS MEASURED AT RESOURCE COST AND CONSUMER WELFARE TREATED SEPARATELY.

• THE CURRENT “HYBRID” GDP APPROACH WILL MISS MANY OF THE BENEFITS OF MEDICAL INNOVATION AND THE DIGITAL REVOLUTION. A SMALL GDP SHARE DOES NOT NECESSARILY IMPLY LOW BENEFITS.