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Capital Input and the Sources of U.S. Economic Growth across Industries: A Comparison of Alternative Approaches

Jon D. Samuels
U.S. Bureau of Economic Analysis, jon.samuels@bea.gov

Jay Stewart
Bureau of Labor Statistics, stewart.jay@bls.gov

Erich H. Strassner
U.S. Bureau of Economic Analysis, erich.strassner@bea.gov

David B. Wasshausen
U.S. Bureau of Economic Analysis, david.wasshausen@bea.gov

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Capital Services Measurement and the Sources of U.S. Economic Growth

Jon Samuels (BEA)
Jay Stewart (BLS)
Erich Strassner (BEA)
Dave Wasshausen (BEA)

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The views expressed in this paper are solely those of the authors and not necessarily those of the U.S. Bureau of Economic Analysis, or the U.S. Bureau of Labor Statistics.
Introduction

• Economic modeling is in large part the art of astute simplification.

• With the goal of drawing general conclusions.

• Similar for economic statistics.

• Potential problem: Conclusions may be an artifact of the simplifications.
Introduction

• This paper: modeling (measuring) capital services and the sources of U.S. economic growth.

• Long-standing call for statistics on the sources of growth
  o Solow (1957), Denison (1967), Griliches and Jorgenson (1967)
  o Postwar Recovery, Big Slump, IT Boom, the Great Recession
  o “... differences between the BEA and BLS estimates have led many researchers to construct their own measures ...”
Introduction

- Output measurement: SNA, widely applied.

- Input measurement: SNA, OECD manuals, less widely applied. This has important consequences for analysis.

- Input measurement: conceptual and implementation issues.

- This paper: capital services.
Introduction

• Compare two approaches: 1) BLS 2) Jorgenson et al.
  o Major conceptual difference: vintage accounting.
  o Implementation differences: rates of return, negative services prices, capital gains, taxes.

• Findings: sources of growth similar, some differences across industries.
  o Related to implementation, not simplification.
Capital Services Measurement – Three Steps

1) Calculate the productive capital stock
   - Perpetual Inventory Method (PIM)
   - Assume constant quality units
   - Assume a functional form for deterioration (age-efficiency function)
   - By asset and industry
Capital Services Measurement – General Methodology

2) Calculate the capital service price (rental rate of capital) – Opportunity cost concept that accounts for depreciation, forgone returns, taxation, and capital gains
   - Age-price function
   - Wealth stock
   - Internal rate of return
   - By asset and industry

3) Aggregation the productive stock into estimates of capital service flows using capital service prices as weights.
The Productive Capital Stock – Perpetual Inventory Method

The productive capital stock:

\[ K_{k,i,t}^S = \sum_{a=0}^{\infty} s(a)I_{k,i,t-a} \]

s(a) is the age-efficiency function (a = age)

\( I_{k,i,t-a} \) is investment (asset k, industry i, time t-a)

JHS (BEA) geometric: \( s(a) = (1 - \delta_k)^a \)
BLS’s Age-Efficiency Function I

BLS hyperbolic: \[ s(a, \Omega) = \frac{(\Omega-a)}{(\Omega-\beta a)} \] if \( a < \Omega \)

\( \Omega \) is the maximum service life of the asset

\( \beta \) is a shape parameter:

If \( \beta > 0 \) \( \Rightarrow \) \( s(a, \Omega) \) is concave

If \( \beta < 0 \) \( \Rightarrow \) \( s(a, \Omega) \) is convex

BLS assumes \( \beta = 0.5 \) for equipment and \( \beta = 0.75 \) for structures
Hyperbolic Age-Efficiency Profiles for Different $\Omega$
BLS’s Age-Efficiency Function II

Note that $\Omega$ is the maximum service life of an asset, but we have data on the average service life of assets in a category.

BLS accounts for heterogeneity of service lives within an asset category through the cohort age-efficiency function:

$$\bar{s}(a, \bar{\Omega}) = \int_{\Omega_{\text{min}}}^{\Omega_{\text{max}}} f_{\bar{\Omega}}(a, x) \cdot s(a, x) dx$$

$f_{\bar{\Omega}}(a, x)$ is the distribution of service life within an asset category.

BLS assumes that $f_{\bar{\Omega}}(a, x)$ is a modified truncated normal distribution.
Final Capital Stock Equations

JHS (BEA): \[ K_{k,i,t}^S = K_{k,i,t-1}^S (1 - \delta_a) + I_{k,i,t} \]

Geometric – Deteriorate rate does not vary with age, so no need to keep track of vintage

BLS: \[ K_{k,i,t}^S = \sum_{a=0}^{\Omega_{\text{max}}} \bar{s}(a, \bar{\Omega}) I_{k,i,t-a} \]

Hyperbolic – Deterioration rate varies with age of asset, so it is necessary to keep track of the vintage of investment
The Age-Price Function and the Wealth Stock

The wealth stock is given by:

\[ K_t^W = \sum_{\tau=t}^{\infty} p(\tau - t) \cdot I_{2t-\tau} \]

\[ p(a, \bar{\Omega}) = \frac{\sum_{\alpha=a}^\infty s(\alpha) \cdot (1 - r)^{\alpha-a}}{\sum_{\alpha=0}^\infty s(\alpha) \cdot (1 - r)^\alpha} \]

where:

\[ s(a) = (1 - \delta_k)^a \quad \text{JHS (BEA)} \]

\[ s(a) = \bar{s}(a, \bar{\Omega}) = \int_{\Omega_{\text{min}}}^{\Omega_{\text{max}}} f_{\bar{\Omega}}(a, x) \cdot s(a, x) dx \quad \text{BLS} \]
Example – Photocopy and Related Equipment

BEA:

- Depreciation rate = 18 percent per year
- Average service life = 9 years

BLS:

- Average service life = 11 years

How much difference does it make?
Age-Efficiency and Age-Price Profiles

Age-Efficiency/Price Functions

- Age-Efficiency L-bar = 11
- Age-Price L-bar = 11
- Geometric Age-Efficiency/Price
Simulated Capital Stock

Alternative Capital Stock Measures

- BLS K Stock L-bar=9 (BEA SL)
- BLS K Stock L-bar=11 (BLS SL)
- K Stock geometric - BEA
Growth Rates

Log Change in Alternative Capital Stock Measures

- Growth in ln(kstock9)
- Growth in ln(kstock11)
- Growth in ln(dkstock_geo)
Rental Prices I

The rental price formula is essentially the same the BLS and JHS methodologies.

The rental price formula accounts for:

- The (internal) rate of return
- Changes in the price of new assets
- Economic depreciation
- Taxes
Rental Prices II

Most of the differences are due to differences in implementation

- Treatment of negative rental prices
- Calculation of capital income (mainly calculation of non-corporate capital income)
- Treatment of land input

We are still investigating differences in implementation
Empirical Exercise

- Impact of BLS assumptions versus Jorgenson et al. (JHS) assumptions on estimates of U.S. sources of growth.

- Industry-level production account.
  - Forthcoming “Growth and Stagnation in the World Economy” ed. by Jorgenson, Fukao, Timmer
    - [www.bea.gov/industry/index.htm#integrated](http://www.bea.gov/industry/index.htm#integrated)

- Growth accounting: bottom up from industry to aggregate.
  - Direct aggregation across industries.
Empirical Exercise

- Growth accounting details:
  - Industry MFP growth:
    \[
    \Delta \ln MFP_j = \Delta \ln Q_j - w_{Kj} \Delta \ln Q_{Kj} - w_{Lj} \Delta \ln Q_{Lj} - w_{Xj} \Delta \ln Q_{Xj}
    \]
  - Useful definition:
    \[
    \Delta \ln Q_{QKj} = \Delta \ln Q_{Kj} - \Delta \ln Q_{Zj}
    \]

\[
\Delta \ln MFP_j = \Delta \ln Q_j - w_{Kj} (\Delta \ln Q_{QKj} + \Delta \ln Q_{Zj}) - w_{Lj} \Delta \ln Q_{Lj} - w_{Xj} \Delta \ln Q_{Xj}
\]

- Aggregation:

\[
\Delta \ln V = \sum_j w_j \frac{\bar{w}_{K,j}}{\bar{w}_{V,j}} (\Delta \ln Q_{QKj} + \Delta \ln Q_{Zj}) + w_j \frac{\bar{w}_{L,j}}{\bar{w}_{V,j}} \Delta \ln Q_{Lj} + w_j \frac{1}{\bar{w}_{V,j}} \Delta \ln MFP_j
\]
Productive Stock Growth 1998-2012: JHS versus BLS

- Data processing, internet publishing, and other information services
- Forestry, fishing, and related activities
- Amusements, gambling, and recreation industries
- Support activities for mining

Graph showing trends and data points for different industries.
Capital Input Growth 1998-2012: JHS versus BLS

- Securities, commodity contracts, and investments
- Educational services
- Computer systems design and related services
- Management of companies and enterprises
- Other services, except government
- Air transportation
Capital Quality Growth 1998-2012: JHS versus BLS

- Securities, commodity contracts, and investments
- Management of companies and enterprises
- Educational services
- Other services, except government
Capital Contributions to Industry Output Growth 1998-2012
Industry MFP Contributions to Agg. VA Growth 1998-2012

Real Estate
Sources of Aggregate Growth

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<td>Value-Added</td>
<td>1.94</td>
<td>2.71</td>
<td>0.56</td>
<td>-1.69</td>
<td>2.06</td>
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<tr>
<td>Capital Input</td>
<td>1.13</td>
<td>1.51</td>
<td>0.44</td>
<td>0.60</td>
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<tr>
<td>Non-college Labor</td>
<td>-0.17</td>
<td>-0.02</td>
<td>-0.44</td>
<td>-1.27</td>
<td>0.11</td>
<td>0.13</td>
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<td>MFP</td>
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<td>0.56</td>
<td>0.21</td>
<td>-0.91</td>
<td>0.96</td>
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<td>Capital Input</td>
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Notes: Average annual percentages. Aggregate value added growth is the aggregate of share weighed industry value added growth. The contribution of capital, labor, and TFP is the domar-weighted industry contributions.
## Quality Growth Differences and Industry Characteristics

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<tr>
<th>VARIABLES</th>
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<tr>
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<td>absdiffkqual</td>
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<tr>
<td>Stock Growth</td>
<td>0.0890***</td>
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<td></td>
<td>(0.0286)</td>
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<tr>
<td>Land Income Share</td>
<td>-0.357*</td>
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<td>(0.186)</td>
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<tr>
<td>Operating Surplus/VA</td>
<td>-1.590***</td>
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<td></td>
<td>(0.544)</td>
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<tr>
<td>Share in Agg. VA</td>
<td>-4.039</td>
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<tr>
<td></td>
<td>(5.544)</td>
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<tr>
<td>Constant</td>
<td>1.133***</td>
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<td></td>
<td>(0.263)</td>
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<td>Observations</td>
<td>60</td>
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<td>R-squared</td>
<td>0.240</td>
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</table>

Absdiffkqual is the absolute value of the difference in capital quality growth between the two methods, by industry. Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1
Conclusions

- Aggregate estimates of the sources of growth largely unaffected between these two measures.
  - Some differences across industries.
  - Probably related to implementation.
- Puzzles remain, e.g.:
  - Investment over the business cycle.
  - Rates of return across industries.
  - Utilization.
  - Land quality.
- Shouldn’t trivialize capital measurement.