Measures of Productivity Change: Which Outcome Do You Want?

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Background

Measuring productivity change, generally defined as output quantity change relative to input quantity change, raises some methodological issues:

Using a KLEMS-Y model, an array of input and output concepts exist; each with different interpretations and potentially different outcomes.

Empirical evidence showing that non-neoclassical assumptions have become a reality in today’s world, should therefore also be embodied in multi-factor (MFP) measures.

As a result, the role of profits becomes much more prominent leading to different defined concepts.
Approach

Three dimensions:

First, 5 input-output models for measurement of productivity change (KLEMS-Y, KL-VA, KL, NVA, K-CF, K-NCF) can be derived under zero and nonzero profit assumptions.

Second, different profit concepts by considering the role of unutilized capital, unexpected asset revaluations, taxes and time-series depreciation; a total of 5 different profit concepts exist.

Nonzero profit assumptions are captured due to variations in the construction of capital input costs with exogenous interest rates.

Numerical evidence using national accounting data from the Netherlands’ system of productivity measurement (firm level data could also be applied).
What is productivity (change)?

Usual financial performance measures are:
– profit = revenue minus cost (positive, negative, or zero);
– profitability = revenue divided by cost (greater than 1, less than 1, or equal to 1).

Profit and profitability change is caused by price and quantity change and we want to disentangle these two components.

Natural decomposition for profit is additive (indicators) and for profitability multiplicative (indices).

The quantity component of profit (-ability) change, also called real profit (-ability) change, is called total factor productivity change.
Formal definitions

TFP index: $\text{IPROD} \equiv \frac{Q(\text{output})}{Q(\text{input})}$
Good choice: Fisher

TFP indicator: $\text{DPROD} \equiv Q(\text{output}) - Q(\text{input})$
Good choice: Bennet

Interpretation of difference-type measures requires that all prices be deflated by some general inflation index (for example: headline CPI).
This sounds simple, but …

… what precisely is to be considered as input and output?

Let us take a closer look at the cost components.
KLEMS-Y model

Input:
Cost + Profit = (Gross) Output: Revenue

Capital K
Labour L
Energy E
Materials M
Services S

Unit

Output Y (Goods & Services)
Capital input cost $C_K$ (ex post)

consists of four components:

- $C_{Kw}$ = “waiting cost” (interest rate $r$ times value of productive capital stock used)
- $C_{Ke}$ = anticipated time-series depreciation (effect of time and ageing)
- $C_{Ku}$ = unanticipated revaluation
- $C_{Ktax}$ = tax

$\theta =$ share of utilized capital
Formal accounting identity

\[ C_{Kw}(r) + C_{Ke} + C_{Ku} + C_{Ktax} + C_{L} + C_{EMS} + \Pi = R \]

Add unutilized capital to profits
Add unanticipated revaluation to profit
Add unutilized capital \((1-\theta) C_K\) and unanticipated revaluation
Add anticipated time-series depreciation, unanticipated revaluation and tax

Set profit equal to 0 and solve for \(r\rightarrow\)
\[ C_{Kw}(r_{endo}) + C_{Ke} + C_{Ku} + C_{Ktax} + C_{L} + C_{EMS} = R \]
KL-VA model

Input:
Primary inputs cost + Profit = Value added

Capital K → Unit → Revenue minus E,M,S cost
Labour L →
K-CF model

Capital input cost + Profit = Cash flow
KL-NVA model

Input:
Partial primary inputs cost + Profit = Net value added (ex post)

Output:
Value added - ex post
t-s depreciation and tax

Capital (waiting cost) Labor

K L
K-NCF model

Capital (waiting cost)

K

Input:
Waiting cost of (owned) capital

+ Profit =

Unit

Net value added (ex post)
- L cost

Output:
Net cash flow (ex post)
Conclusion

There is no single answer to the question: what is the percentage of productivity change?

The answer depends on
– the input-output model (KLEMS-Y, etcetera);
– the rate of return on owned capital (endogenous or exogenous);
– the profit concept (e.g., in-/excluding unexpected revaluations, unutilized capital, etc.);
– the (in-) completeness of inputs and outputs.
Empirical illustration (see Table)

– Netherlands 1996-2008
– Nine industries and commercial sector
– Variation between sectors and subperiods
– Sensitive to models
– Sensitive to exo/endogenous rate of return
– Sensitive to profit concept definitions (e.g., in/exclusion of unanticipated revaluations)
<table>
<thead>
<tr>
<th>Model</th>
<th>( \Gamma ) = 0</th>
<th>( \Pi^* ) = 0</th>
<th>( \Pi^{**} ) = 0</th>
<th>( \Pi^{***} ) = 0</th>
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</thead>
<tbody>
<tr>
<td>KLEMS-Y</td>
<td>0.74</td>
<td>0.76</td>
<td>0.77</td>
<td>0.79</td>
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<tr>
<td>KL-VA</td>
<td>2.43</td>
<td>2.27</td>
<td>2.57</td>
<td>2.44</td>
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<tr>
<td>KL-NVA</td>
<td>2.82</td>
<td>2.56</td>
<td>2.89</td>
<td>2.44</td>
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<td>K-CF</td>
<td>5.87</td>
<td>6.12</td>
<td>6.10</td>
<td>6.34</td>
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<tr>
<td>K-NCF</td>
<td>9.12</td>
<td>8.89</td>
<td>9.36</td>
<td>8.84</td>
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</table>
## Absolute average annual differences between model Pi-1 exogenous and rest

<table>
<thead>
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<th>Model</th>
<th>$\Gamma\neq 0$</th>
<th>$\Pi' = 0$</th>
<th>$\Pi'' \neq 0$</th>
<th>$\Pi''' = 0$</th>
<th>$\Pi^{**} \neq 0$</th>
<th>$\Pi^{***} = 0$</th>
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</thead>
<tbody>
<tr>
<td>KLEMS-Y</td>
<td>0.07</td>
<td>0.08</td>
<td>0.07</td>
<td>0.03</td>
<td>0.07</td>
<td>0.08</td>
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<tr>
<td>KL-VA</td>
<td>0.17</td>
<td>0.24</td>
<td>0.32</td>
<td>0.13</td>
<td>0.13</td>
<td>0.31</td>
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<tr>
<td>KL-NVA</td>
<td>0.26</td>
<td>0.14</td>
<td>0.24</td>
<td>0.09</td>
<td>0.17</td>
<td>0.18</td>
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<tr>
<td>K-CF</td>
<td>0.39</td>
<td>0.97</td>
<td>1.07</td>
<td>0.33</td>
<td>0.56</td>
<td>1.00</td>
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<tr>
<td>K-NCF</td>
<td>0.33</td>
<td>1.00</td>
<td>1.02</td>
<td>0.46</td>
<td>0.52</td>
<td>1.56</td>
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Note: The table compares the average annual differences between model Pi-1 with exogenous and other models.