

Methodological Alternatives for Productivity Measurement

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Outline

Theory of Productivity Measurement

- Primal (Quantity Decomposition)
- Dual (Price Decomposition)
- Price Cap Theory

Conceptual Ideal

- Actual Practice
- Proposed Plan

Primal Method

- Production Function: $Y = AF(K, L, M)$

$$- \dot{Y}/Y = (\dot{A}/A) + \left(\frac{F_K K}{Y}\right) (\dot{K}/K) + \left(\frac{F_L L}{Y}\right) (\dot{L}/L) + \left(\frac{F_M M}{Y}\right) (\dot{M}/M)$$

$$- TFPG = \dot{Y}/Y - \left(\frac{F_K K}{Y}\right) (\dot{K}/K) - \left(\frac{F_L L}{Y}\right) (\dot{L}/L) - \left(\frac{F_M M}{Y}\right) (\dot{M}/M)$$

What we need to measure

- Output: \dot{Y}/Y

- Factor Inputs: $\dot{K}/K, \dot{L}/L, \dot{M}/M$

- Elasticities: $\frac{F_K K}{Y}, \frac{F_L L}{Y}, \frac{F_M M}{Y}$

Measuring Output: Aggregation

- $Y = U(y_1, y_2, \dots, y_N)$

- $\dot{Y}/Y = \sum_i \left(\frac{y_i P_i}{E_Y} \right) \cdot (\dot{y}_i / y_i)$

Expenditure Shares: $\frac{y_i P_i}{E_Y}$

Real Output: \dot{y}_i / y_i

Measuring Real Output

Current Practice: Disaggregated Revenues

Regulated: Renta Basica mensual, Servicio Local Medico, Instalacion, Larga Distancia Nacional, Large Distance International

Non-Regulated: Local Otro, Telefonos Publicos, Servicios moviles, Television por cable, Comunicaciones de Empresas, Guias Telefonicas, Otros.

Output Prices (Derive Output from Revenue)

Price of What?

Quality Adjustment?

Price of New Products? (Internet services)

Price of Products that Disappear? (Cellular phones)

Output subject to price cap?

- Difficult (almost impossible) to calculate TFPG for only a subset of firm's products.
- Solution: Calculate Hypothetical Price Cap

Hypothetical Price Cap

- Assume all products subject to price cap:

$$\dot{P}^{hypothetical} / P^{hypothetical} = \frac{y_{pc} P_{pc}}{E_Y} \cdot \left(\dot{p}_{pc} / p_{pc} \right) + \frac{y_n P_n}{E_Y} \cdot \left(\dot{p}_n / p_n \right)$$

- Then back out the price cap of regulated products:

$$\dot{p}_{pc} / p_{pc} = \frac{\dot{P} / P - \frac{y_n P_n}{E_Y} \cdot \left(\dot{p}_n / p_n \right)}{\left(\frac{y_{pc} P_{pc}}{E_Y} \right)}$$

Measuring Aggregate Labor

- $L = L(l_1, l_2, \dots, l_N)$

- $\dot{L}/L = \sum_i \left(\frac{w_i l_i}{E_L} \right) \cdot (\dot{l}_i / l_i)$

- Current Practice: $\dot{L}/L = \sum_i \left(\frac{l_i}{L} \right) \cdot (\dot{l}_i / l_i)$

- Bias: $\sum_i \left(\frac{l_i}{L} \right) \cdot \left(\frac{w_i}{\bar{w}} - 1 \right) \cdot (\dot{l}_i / l_i)$

Measuring Labor: Proposed Plan

- Telefonica Payroll Records
- Disaggregate Between Ejecutivos, Empleados, Obreros
- Compare average wage of Ejecutivos, Empleados, and Obreros in Telefonica with wages in household survey (ENAH)

Measuring Capital

- Aggregation Across *Vintages*

Old vs. New Capital

- Aggregation Across *Varieties*

Telephone Switching Equipment vs. Telephone Poles.

Aggregation Across Vintages

- $K_t = \sum_i (1 - \delta)^{t-i} \cdot I_{t-i}$

- Don't observe history of I

- Current Practice:

Book value of capital: $K_{book_t} = \sum_i P_{I_{t-i}} \cdot I_{t-i}$

Use wholesale price index

Assume that I has grown at a constant rate

Aggregating Across Vintages: Proposed Plan

- Use Annual Expenditure Data (instead of Book Value)

$$P_{I_{t-i}} \cdot I_{t-i} \text{ instead of } K_{book_t} = \sum_i P_{I_{t-i}} \cdot I_{t-i}$$

Don't need to assume constant growth

- Use better measures of price of investment

Disaggregated investment deflators (National Accounts)

United Nations Data on Price of Peru's Imports of
Telecommunications Equipment

Aggregation Across Varieties

$$- \dot{K}/K = \sum_i \left(\frac{r_i k_i}{E_K} \right) \cdot (\dot{k}_i / k_i)$$

- Don't observe r_i

- *Impute* r_i from theory

$$\text{Hall-Jorgenson rental price formula: } r_i = \frac{P_{I_i}}{P} \left(wacc - \delta_i - \frac{\dot{P}_{I_i}}{P_{I_i}} \right)$$

Current Practice:

wacc: cost of debt and equity (weights not very sensitive to wacc)

Wholesale Prices for P_{I_i}

Measuring Marginal Products

Robert Solow (1957)

Assumptions:

- Firms take prices as given
- Firms minimize costs
- Constant returns to scale

$$\Rightarrow PF_K = R$$

$$\Rightarrow F_K K / Y = RK / PY$$

Market Power?

Robert Hall (1988, 1990)

Assumptions:

- Firms minimize costs
- Constant returns to scale

$$\Rightarrow \frac{P}{(1 + \textit{markup})} \cdot F_K = R$$

$$\Rightarrow F_K K / Y = \frac{RK}{(PY / (1 + \textit{markup}))} = RK / \textit{Cost}$$

Increasing Returns to Scale?

- Hall/Solow TFPG does not measure \dot{A}/A
- For purposes of price cap regulation, we want Hall/Solow TFPG, *not* \dot{A}/A .

What if Firms do not Minimize Costs?

Estimate Marginal Products

$$\dot{Y}/Y = (\dot{A}/A) + \left(\frac{F_K K}{Y}\right) (\dot{K}/K) + \left(\frac{F_L L}{Y}\right) (\dot{L}/L) + \left(\frac{F_M M}{Y}\right) (\dot{M}/M)$$

Valid Under One of Two Conditions:

- Include \dot{A}/A in the regression (but that is what we want to estimate!)
- Inputs are not correlated with \dot{A}/A (but we know that just can't be true).

Summary: Primal Approach

Output: Calculate Hypothetical Price Cap to adjust for non-regulated services.

Labor: Measure Labor Quality Better (disaggregated Telefonica data plus national household survey)

Capital: Aggregate across vintages better (using annual investment data and better price deflators). Aggregation across varieties is best practice (show that aggregation is not sensitive to different assumptions about WACC)

Output Elasticities: Use of Cost Shares is best (practical) practice

Dual Approach

$$\text{Revenue} = \text{Cost} + \text{Profits: } PY = RK + WL + P_M M + \pi$$

$$\dot{Y}/Y - \frac{RK}{C} \cdot (\dot{K}/K) - \frac{WL}{C} \cdot (\dot{L}/L) - \frac{P_M M}{C} \cdot (\dot{M}/M)$$

$$= \frac{RK}{C} \cdot (\dot{R}/R) + \frac{WL}{C} \cdot (\dot{W}/W) + \frac{P_M M}{C} \cdot (\dot{P}_M / P_M) + \frac{\pi}{C} \cdot \frac{(\dot{\pi}/PY)}{(\pi/PY)} - (\dot{P}/P)$$

LHS: Hall/Solow Primal TFPG

RHS: Dual TFPG

Theory of Price Cap Regulation

$$TFPG_{dual} = \underbrace{\frac{RK}{C} \cdot (\dot{R}/R) + \frac{WL}{C} \cdot (\dot{W}/W) + \frac{P_M M}{C} \cdot (\dot{M}/M)}_{\dot{P}_I / P_I} + \frac{\pi}{C} \cdot \frac{(\dot{\pi}/PY)}{(\pi/PY)} - (\dot{P}/P)$$

$$\text{Price Cap: } \dot{P}^{cap} / P^{cap} = CPI - X$$

$$X = (TFPG^O - TFPG^E) + \left[\left(\dot{P}_I^E / P_I^E \right) - \left(\dot{P}_I^O / P_I^O \right) \right]$$

What is the Price Cap Formula?

$$\dot{P}^{cap} / P^{cap} = CPI - X$$

$$\dot{P}^{cap} / P^{cap} = CPI - \left\{ (TFPG^O - TFPG^E) + \left[\left(\dot{P}_I^O / P_I^O \right) - \left(\dot{P}_I^E / P_I^E \right) \right] \right\}$$

$$\dot{P}^{cap} / P^{cap} = \underbrace{\left(TFPG^E - \left(\dot{P}_I^E / P_I^E \right) + CPI \right)}_{=0} + \left(\dot{P}_I^O / P_I^O - TFPG^O \right)$$

$$\Rightarrow \dot{P}^{cap} / P^{cap} = \dot{P} / P - \frac{\pi}{C} \cdot \frac{(\pi / PY)}{(\pi / PY)}$$

$$\text{Constant Market Power} \Rightarrow \dot{P}^{cap} / P^{cap} = \dot{P} / P$$

What Does Theory of Dual TFPG Deliver?

- Hall/Solow TFPG (Primal or Dual) is exactly what we want (even if it does not only measure technology)
- Equality of Dual and Primal TFPG is based only on an accounting identity.
- Key Difference: Dual TFPG based on *Prices* (not Quantity).

What we need to measure:

- Output Prices: $\dot{P}/P = \sum_i \left(\frac{y_i P_i}{E_Y} \right) \cdot (\dot{p}_i / p_i)$

- Rental Price of Capital: $\dot{R}/R = \sum_i \left(\frac{r_i k_i}{E_K} \right) \cdot (\dot{r}_i / r_i)$

- Wages: $\dot{W}/W = \sum_i \left(\frac{w_i l_i}{E_L} \right) \cdot (\dot{w}_i / w_i)$

Measuring Aggregate TFP

- Output: GDP
- Labor Force: Use National Household Survey.
 - Disaggregate by rural-urban, male-female, schooling, age.
 - Impute Wages for Self-Employed Urban Workers
 - Impute Wages for Rural Workers based on Consumption
- Capital Stock: Use Disaggregated Investment
 - Machinery and Equipment, Vehicles, Construction

Alternative Methodologies

Stochastic Frontier

- Decomposes TFPG into changes in “world frontier” and distance from “world frontier”
- Relies on regression of output on inputs

Data Envelopment Analysis

- Uses Linear Programming to “fit” production function
- Useful when there is no price data