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# MEASURING AND EXPLAINING TOTAL FACTOR PRODUCTIVITY (TFP) GROWTH AND PATTERNS IN PHILIPPINE AGRICULTURE: *A REGIONAL PANEL DATA FRAMEWORK*

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# Objectives:

The general objective of this study is to analyze the trends and causes of productivity growth in Philippine agricultural sector. The specific objectives are as follows:

1. Estimate TFP using the index number approach;

2. Identify factors that might have caused movements in TFP over a period of time; and

3. Identify policy alternatives for increasing productivity growth.

# Methodology

Part I: TFP estimation-- applying the index number approach proposed by Dumagan and Ball (2009) on Philippine data at the regional level (1974-2004).

Part II: Econometric analysis -- relating the measured TFP to explanatory factors such as technological change, infrastructure, and so on.

# Part I: TFP Estimation

## Time Period and Data Definitions

Time Periods: $s, t \quad ; \quad t = s + 1$

Outputs: $i = 1, 2, \cdots, M$ ; Prices: $p_{i,s}, p_{i,t}$ ; Quantities: $q_{i,s}, q_{i,t}$

Inputs: $j = 1, 2, \cdots, N$ ; Prices: $w_{j,s}, w_{j,t}$ ; Quantities: $x_{j,s}, x_{j,t}$

Revenue Index $R_{st} \equiv \dfrac{\sum_i^M p_{i,t} q_{i,t}}{\sum_i^M p_{i,s} q_{i,s}}$

# Törnqvist Price and Quantity Indexes for Outputs

Output price $(P_{st}^T)$ and output quantity $(Q_{st}^T)$ indexes:

$$P_{st}^T \equiv \prod_i^M \left(\frac{p_{i,t}}{p_{i,s}}\right)^{1/2(r_{i,s}+r_{i,t})} \quad ; \quad Q_{st}^T \equiv \prod_i^M \left(\frac{q_{i,t}}{q_{i,s}}\right)^{1/2(r_{i,s}+r_{i,t})}$$

Revenue shares $r_{i,s} \equiv \frac{p_{i,s}q_{i,s}}{\sum_i^M p_{i,s}q_{i,s}}$ ; $r_{i,t} \equiv \frac{p_{i,t}q_{i,t}}{\sum_i^M p_{i,t}q_{i,t}}$

$$\sum_i^M r_{i,s} = \sum_i^M r_{i,t} = 1$$

# Törnqvist Price and Quantity Indexes for Inputs

Input price $(W_{st}^T)$ and input quantity $(X_{st}^T)$ indexes:

$$W_{st}^T = \prod_j^N \left(\frac{w_{j,t}}{w_{j,s}}\right)^{1/2(c_{j,s}+c_{j,t})} \quad ; \quad X_{st}^T = \prod_j^N \left(\frac{x_{j,t}}{x_{j,s}}\right)^{1/2(c_{j,s}+c_{j,t})}$$

Cost shares: $c_{j,s} = \frac{w_{j,s}x_{j,s}}{\sum_j^N w_{j,s}x_{j,s}} \quad ; \quad c_{j,t} = \frac{w_{j,t}x_{j,t}}{\sum_j^N w_{j,t}x_{j,t}}$

$$\sum_j^N c_{j,s} = \sum_j^N c_{j,t} = 1$$

# Revenue-Side Törnqvist TFP Indexes

***Direct*** **TFP:** $E_{st}^{TR*} \equiv \dfrac{Q_{st}^{T}}{X_{st}^{T}} \equiv \dfrac{\text{Output Quantity Index}}{\text{Input Quantity Index}}$

***Exact*** **TFP:** $E_{st}^{TR} \equiv \dfrac{R_{st}/P_{st}^{T}}{X_{st}^{T}}$

$$\equiv \frac{\text{Revenue Index}/\text{Output Price Index}}{\text{Input Quantity Index}}$$

$$\equiv \frac{\textit{Implicit}\ \text{Output Quantity Index}}{\text{Input Quantity Index}}$$

$E_{st}^{TR*} \approx E_{st}^{TR}$ because $R_{st} \approx P_{st}^{T}\, X_{st}^{T}\, E_{st}^{TR*}$ while $R_{st} = P_{st}^{T}\, X_{st}^{T}\, E_{st}^{TR}$

$$R_{st} = P_{st}^{T} X_{st}^{T} E_{st}^{TR}$$

# Revenue Growth Decomposition by Törnqvist Indexes

$$R_{st} = P_{st}^{T}\, X_{st}^{T}\, E_{st}^{TR} \quad ; \quad ln(R_{st}) = ln(P_{st}^{T}) + ln(X_{st}^{T}) + ln(E_{st}^{TR})$$

$$ln(R_{st}) = \sum_{i}^{M} \frac{1}{2}(r_{i,s} + r_{i,t}) ln\left(\frac{p_{i,t}}{p_{i,s}}\right) + \sum_{j}^{N} \frac{1}{2}(c_{j,s} + c_{j,t}) ln\left(\frac{x_{j,t}}{x_{j,s}}\right) + ln(E_{st}^{TR})$$

Everything is known from data except TFP defined by $E_{st}^{TR}$. Hence, TFP growth defined by $ln(E_{st}^{TR})$ is computed as a *residual*.

Revenues rise as output prices, input quantities, and TFP rise.

# Philippine Agricultural Data:

Time-series and Cross-sectional data set

Years 1974-2004 and 12 regions
Agricultural products:
Crops
•rice, corn, sugarcane, coconut, tobacco
•root crops (camote, cassava, gabi, pao galiang, tugui, and ubi or yam)
•fruits (banana, mango and pineapple)
•vegetables (cabbage, eggplant, garlic, radish, and tomato)

Livestock and poultry products
•meat of cattle, carabao (water buffalo), hogs, goat, chicken, and ducks
•chicken and duck eggs

Agricultural Inputs
Labor
Agricultural Machinery, Tractors, Animal Labor
Fertilizer and Seeds

Farmgate prices

Source: Bureau of Agricultural Economics

# Part II:TFP Determinants

This study will try to estimate several types of panel data analytic models:

1.Constant coefficients model
2.Fixed effects model
3.Random effects model.

Basic Model

$$Y_{it} = \alpha_i + \sum_j^K \beta_{ij} X_{ijt} + \mu_i$$

The constant coefficients model

•if the regional as well as the temporal effects are insignificant, one can pool the panel data and run an ordinary least squares regression using above equation.

# Part II:TFP Determinants

The fixed effects model

•If there are no significant temporal effects, but with significant differences across the different regions.
•Under this model, one can assume that the error term has the following components:

1. Non-varying unobserved region-specific component
2. An idiosyncratic component that is unique to each region-year observation.

$$Y_{it} = \alpha_i + \sum_j^K \beta_j X_{ijt} + \varepsilon_{it}$$

$$\varepsilon_{it} = u_i + e_{it}$$

# Part II: TFP Determinants

$$Y_{it} = \alpha_i + \sum_j^K \beta_j X_{ijt} + u_i + e_{it}$$

- The OLS estimate of the $\beta_j$ coefficients will be unbiased as long as the unobservable region-specific component ($u_i$) is uncorrelated with $X_{ijt}$.

- If correlated, the problem can be addressed as follows:

1. by appending to regression equation dummy variables to designate a particular region.
2. by time-demeaning transformation of the variables $Y_{it}$ and $X_{ijt}$ .

# Part II: TFP Determinants

$$\bar{Y}_i = \alpha_i + \sum_j^K \beta_j \bar{X}_{ij} + u_i + \bar{e}_i$$

$$Y_{it} - \bar{Y}_i = \alpha_i + \sum_j^K \beta_j (X_{ijt} - \bar{X}_{ij}) + (e_{it} - \bar{e}_i)$$

The random effects model

- The random effects model assumes that there is zero correlation between $u_i$ and $X_{ijt}$ or cov ($X_{ijt}$ , $u_i$ ) = 0. Otherwise, the random effects estimates are biased.

- Under the random effects specification, the model is given by

$$Y_{it} = \alpha_i + \sum_j^K \beta_j X_{ijt} + \varepsilon_{it}$$

# Part II: TFP Determinants

The composite error term is given by

$$\varepsilon_{it} = u_i + e_{it}$$

Note that the composite error for each time period $t$ is a function of $u_i$ and thus the error term ($\varepsilon_{it}$) is serially correlated across time.

To account for the correlation, the random effects model can be estimated by using the generalized least squares (GLS) with autoregressive serial correlation. Under the GLS transformation,

$$Y_{it} - \theta\bar{Y}_i = \alpha_i + \sum_j^K \beta_j(X_{ijt} - \theta\bar{X}_{ij}) + (e_{it} - \theta\bar{e}_i)$$

# Part II: TFP Determinants

Determinants of TFP

| | |
|---|---|
| *Road density* ***(ROAD)*** | Ratio of the road length (Km) and farm area in thousand hectare.<br><br>Teruel and Kuroda, 2005 |
| *Degree of rural electrification* ***(ELECT)*** | Proportion of rural villages with electricity to total number of villages potential for energization.<br><br>Teruel and Kuroda, 2005 |
| *Irrigation (**IRRIG**)* | Proportion of farm area with irrigation facilities to total cultivated area.<br><br>Teruel and Kuroda, 2005 |
| *Research and Development* ***(HYV)*** | Proportion of Farm areas planted with HYVs to total cultivated area<br><br>Evenson,1986; Evenson and Quizon,1991; Evenson, Pray, and Rosegrant, 1999 and Ali and Byerlee ,2002. |
| *Agricultural Extension* ***(EXT)*** | Proportion of graduates finishing agriculture-related course to total graduates<br><br>Hayami and Ruttan (1985) |

# Part II: TFP Determinants

Determinants of TFP

| | |
|---|---|
| *Human capital* ***(LIT)*** | Basic or simple Literacy rate<br><br>Craig, Pardey and Roseboom (1997) |
| *Policy Variable* ***(NRA)*** | Nominal Rate of Assistance (NRA) - percentage change in gross returns per unit of output relative to the situation of no assistance<br><br>Estimates taken from David, et al. (2007) |
| *Historical precipitation* ***(RAIN)*** | Mean rainfall<br><br>Craig, Pardey and Roseboom, 1997 |

# Empirical Results

## Contributions to Growth of Revenues, Philippines, 1974-2004*

| | |
|---|---|
| **Growth of Output Prices** | **7.55** |
| Rice | 1.70 |
| Corn | 0.68 |
| Sugarcane | 0.48 |
| Coconut | 0.73 |
| Tobacco | 0.09 |
| Rootcrops | 0.34 |
| Fruits | 0.59 |
| Vegetables | 0.11 |
| Meat | 2.54 |
| Eggs | 0.31 |
| **Growth of Input Quantities** | **0.97** |
| Seeds | 0.01 |
| Fertilizers | 0.16 |
| Animal labor | 0.08 |
| Machine | 0.02 |
| Land | 0.27 |
| Labor | 0.43 |
| **Growth of TFP** | **2.19** |
| | |
| **Growth of Revenues** | **10.71** |

*Figures are percentage-point contributions to revenue growth.

## Contributions to Growth of Revenues by Region, 1974-2004*

| Region | Growth of Output prices | Growth in Input Quantities | Growth of TFP | Growth of Revenues |
|---|---|---|---|---|
| Ilocos | 7.54 | 0.85 | 3.12 | 11.51 |
| Cagayan Valley | 8.12 | 1.51 | 2.28 | 11.91 |
| Central Luzon | 7.73 | 0.67 | 3.77 | 12.17 |
| Southern Tagalog | 7.30 | 0.14 | 2.79 | 10.23 |
| Bicol | 8.01 | 0.84 | 1.04 | 9.90 |
| Western Visayas | 7.95 | 0.52 | 1.33 | 9.80 |
| Central Visayas | 8.10 | -0.21 | 2.67 | 10.56 |
| Eastern Visayas | 7.41 | 0.65 | 1.88 | 9.94 |
| Western Mindanao | 7.20 | 2.31 | 1.18 | 10.69 |
| Northern Mindanao | 6.51 | 1.53 | 2.40 | 10.44 |
| Southern Mindanao | 7.19 | 1.01 | 2.16 | 10.36 |
| Central Mindanao | 7.53 | 1.80 | 1.68 | 11.01 |
| Philippines | 7.55 (71%) | 0.97 (9%) | 2.19 (20%) | 10.71 (100) |

*Figures are percentage-point contribution to revenue growth.

## Contributions to Growth of Revenues by Subperiod, 1975-2004*

| Year | Growth in Output Prices | Growth in Input Quantities | Growth of TFP | Growth of Revenues |
|---|---|---|---|---|
| 1975-79 | 3.82 | 0.66 | 6.22 | 10.01 |
| 1980-84 | 17.54 | 0.34 | 1.27 | 19.15 |
| 1985-89 | 8.39 | 3.20 | -0.70 | 10.87 |
| 1990-94 | 6.28 | 0.98 | 1.70 | 8.96 |
| 1995-99 | 5.84 | 0.81 | 2.20 | 8.86 |
| 2000-04 | 3.47 | 0.01 | 3.58 | 7.04 |

*Figures are percentage-point contribution to revenue growth.

## Estimation Results for TFP Determinants

| | Plain OLS | OLS_PCSE | OLS_PCSE_AR1 |
|---|---|---|---|
| ROAD | 0.0814*** | 0.0814** | 0.0812* |
| LIT | 0.0084 | 0.0084 | 0.0029 |
| NRA | 0.0041** | 0.0041*** | 0.0043*** |
| HYV | 0.0898** | 0.0898** | 0.0811* |
| IRRIG | 0.0880 | 0.0880 | 0.0835 |
| RAIN | 0.0067 | 0.0067 | 0.0058 |
| EXT | 0.0020 | 0.0020 | 0.0049 |
| ELECT | 0.0497* | 0.04970* | 0.0478 |
| D7579 | -1.7640 | -1.7640 | -1.7443 |
| D8090 | -3.1033* | -3.1033 | -3.1303 |
| D9100 | -1.5350* | -1.5350 | -1.588 |
| F(26, 333) | 2.06 | | |
| P-value | 0.0021 | | |
| Wald $Chi^2$ (26) | | 50.28 | 48.67 |
| P-value | | 0.0029 | 0.0045 |

Note: * , ** and *** denote significant at 10, 5 and 1% level, respectively.

## Estimation Results for TFP Determinants

| Determinants | FE | RE |
|---|---|---|
| ROAD | 0.0821*** | 0.0814*** |
| LIT | 0.0926 | 0.0084 |
| NRA | 0.004** | 0.0041*** |
| HYV | 0.0891 | 0.0898 |
| IRRIG | 0.0943 | 0.088 |
| RAIN | 0.0065 | 0.0067 |
| EXT | 0.003 | 0.002 |
| ELECT | 0.0585** | 0.0497* |
| D7479 | -2.0218 | -1.764 |
| D8090 | -3.2736* | -3.1033* |
| D9100 | -1.6279 | -1.535 |
| F(26, 322) | 2.01 | |
| P-value | 0.0029 | |
| Wald chi2(26) | | 53.67 |
| P-value | | 0.0011 |

Note: * , ** and *** denote significant at 10, 5 and 1% level, respectively.

# Summary and Conclusion:

1. Output prices contributed on the average 7.55 percentage points (71%) to revenue growth of 10.71 percent for the entire period.

2. The contribution of output prices is significantly higher than the average contribution of input quantities and TFP of 0.97 (9%) and 2.19 (20%), respectively.

3. All inputs of production contributed just about 1 percentage point to revenue growth.

4. Significant productivity gaps are observed among the different regions.

# Summary and Conclusion:

5. TFP growth was at its peak in the late 70s, followed by the deceleration in the 1980s and resurgence in the 1990s until the early part of the recent decade.

6. The analysis on the determinants of TFP growth substantiated the importance farm-to-market roads and rural electrification to enhance agricultural productivity. It also gave credence to the need to invest in research and development.

7.Overall, this study recommends further examination of the role of agricultural output prices in determining farm incomes and that initiatives be undertaken to boost agricultural productivity through investments in infrastructure and research and development.

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# Thank you