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Measuring and Explaining Total Factor Productivity (TFP) Growth and Patterns in Philippine Agriculture: *A Regional Panel Data Framework*

Romeo G. Teruel, Ph.D.*[1]
University Research Center,
University of St. La Salle, Bacolod City, Philippines

Jesus C. Dumagan, Ph.D.
Philippine Institute for Development Studies
NEDA sa Makati Building, Makati City, Philippines

Abstract

The first part of the study attempts to estimate the Total Factor Productivity (TFP) growth in Philippine agriculture using the productivity measurement procedure proposed by Dumagan and Ball (2008). Employing the superlative Törnqvist index, their technique works directly with the observed nominal values of revenues, decomposing growth in revenues into output price and output quantity growth, and then decomposing the latter into input quantity growth and a residual term representing TFP growth. The second part investigates the determinants of agricultural productivity using the panel data analytic models such as the constant coefficients, the fixed effects, and the random effects model.

Applying the technique to Philippine agriculture, the growth in output prices contributed on the average 7.55 percentage points (pct.pts.) to revenue growth of 10.71 percent for the entire period. This is significantly higher than the average contribution of the growth in output quantities of 3.16 pct. pts. For the output quantity decomposition, input quantities and TFP contributed 0.97 and 2.19 pct. pts., respectively. This reveals that output growth in Philippine agriculture has been mainly driven by productivity.

The panel data analysis substantiates the importance of roads, rural electrification, and research and development to enhance agricultural productivity. Overall, this study recommends to examine further the role of output prices in determining farm incomes and undertake initiatives to boost agricultural productivity through investments in infrastructure and research and development.

Keywords: agricultural productivity, Törnqvist index framework, fixed and random effects models, Philippines

[1] **Corresponding Author:** University of St. La Salle, Bacolod City, Tel Numbers: (6334)432-1184, (63)9285-2131-48, Fax Number: (6334)435-2595, Email address: rgteruel@yahoo.com

I. Introduction

A straightforward approach towards estimating total factor productivity (TFP) in Philippine agriculture would be at the aggregate sector level. This provides a comprehensive examination of TFP growth, complementing studies of TFP growth at the level of major agricultural commodities. The most recent attempt in doing so would be Teruel and Kuroda (2005), which implemented a reduced-form econometric approach to measuring and explaining TFP growth in Philippine agriculture at the regional level. While this approach is the most standard type of application of TFP analysis, there is a need to explore alternative approaches that avoid its stringent data requirements and assumptions.

Index number procedures are promising and practicable alternatives, but have seldom been applied in the Philippine context. In particular, the problem of obtaining a theoretically sound yet tractable measure of real output and input growth at the aggregate level─a prerequisite for measuring TFP growth─has been addressed in the "superlative" Fisher and Törnqvist index growth decomposition procedures applied by Dumagan and Ball (2009) to US agriculture. Their procedures work directly with observed nominal values (rather than constructed real values) of revenues or costs, decomposing growth in revenues into output price and output quantity growth, and then decomposing the latter into input quantity growth and a residual term representing TFP growth. Alternatively, growth in costs is decomposed into input price and input quantity growth, and then the latter into output quantity growth and the residual TFP growth.

There were two stages in this study of agricultural TFP growth. The first stage was the measurement of TFP growth, by applying the above-mentioned superlative index procedure to Philippine data at the regional level (1974-2004). The results were then compared with those from other methodologies. The second stage involved relating the measured TFP to explanatory factors among which are human capital, infrastructure, technology, and policy. This would directly inform the evaluation of policy levers in terms of their impacts on TFP growth.

II. Objectives

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

1. Estimate TFP using the Törnqvist 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.

III. Measuring TFP

III.1 Superlative index number procedure

This study follows the usual index framework of measuring TFP growth as a *residual*. In this study, however, the residual TFP growth is derived from a proposed *nominal* revenue (or cost) growth decomposition framework that yields *all* the results from the common procedure focusing on *real* growth decomposition. Thus, the proposed decomposition framework is analytically more general. Moreover, consider that this framework decomposes the growth in revenues or costs into the growth contributions of prices, quantities, and TFP. Since revenues or costs measure payments (i.e., incomes) to factors of production, the growth decomposition is also more informative for policy purposes. The results have important implications for income-enhancing policies because policies affecting prices or quantities could differ from those designed to boost productivity growth.

In the application to the Philippine agricultural sector, the growth in revenues (i.e., nominal value of gross output) was decomposed into the contributions of growth in output prices, input quantities, and TFP. It is assumed that the data were generated by a constant returns to scale (CRS) technology so that factor payments just exhaust the value of output. This result allows a second decomposition of the growth in total costs of the sector into the contributions of output quantities, input prices, and TFP.

Among TFP indexes, the superlative Fisher and Törnqvist indexes are very popular in empirical applications. A well-known result is that under CRS, the TFP index in the revenue side and the TFP index in the cost side are *exactly* equal using the Fisher index procedure or *approximately* equal using the Törnqvist index procedure (Diewert, 1976, and 1992). Moreover, the Fisher and Törnqvist TFP indexes–either from the revenue or cost side–are very close approximations to each other. The above results were also shown analytically and empirically by Dumagan and Ball (2009) for the US agricultural sector (1948-2001). In light of these results and given that the Törnqvist index is mathematically easier to implement in growth decompositions than the Fisher index, this paper applies the former index to decompose revenue growth in Philippine agriculture (1974-2004) into the contributions of growth in output prices, input quantities, and TFP.

III.2. TFP level and growth

At this juncture, it would be enlightening to characterize what the TFP measure from the proposed Törnqvist index framework represents.

TFP measurement involves determining its *level* and *growth*. In the case of production of multiple outputs with multiple inputs, TFP level may be defined as combined output per unit of combined inputs, given by the ratio,

$$\text{TFP} = \frac{\text{output quantity index}}{\text{input quantity index}} = \frac{\text{relative change in aggregate output}}{\text{relative change in aggregate input}}.$$

In the above ratio, TFP growth–i.e., change in TFP level–involves changes either in the output quantity index or in the input quantity index or in both. These changes come from four sources:

(1) *Technical change* or shift of the production possibility frontier (PPF);

(2) *Technical efficiency change* or movement to or from existing PPF;

(3) *Scale efficiency change* (firm level) implying that firm size is "small" if returns to scale are increasing or "large" if returns to scale are decreasing;

(4) *Output mix effect* (firm Level) if firm size permits changing output mix given the available inputs.

This study is at the *sector* level encompassing the whole Philippine agriculture sector. In this case, sector *size* may not be a decision variable. Therefore, of the above four sources of TFP growth, scale efficiency change and output mix effect are not relevant. That is, technical change and technical efficiency change remain relevant at the sector level. However, consider that CRS may be an appropriate assumption at this level. If optimizing behavior–i.e., producing at optimal point on PPF–is also assumed, there is no movement to or from the PPF (i.e., no technical efficiency change). Hence, only technical change is relevant to this study of TFP growth in Philippine agriculture. In this case, superlative index numbers, e.g., the Fisher or Törnqvist TFP index, provide a theoretically well-grounded measurement procedure. However, as previously discussed, this paper implements the Törnqvist index framework.

III.3. Törnqvist index framework

The basic growth decomposition framework starts from an index number representation of the revenue function (and cost function) so that the growth decomposition is consistent with standard economic theory. The framework is practical because it utilizes the Törnqvist index that is easily constructed from available data.

Let there be two adjoining periods. In each period, outputs are produced and inputs are employed with given prices and corresponding quantities defined by,

$$\text{Time Periods:} \quad s, t \quad ; \quad t = s + 1 \tag{1}$$

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

$$\text{Inputs:} \quad j = 1, 2, \cdots, N \quad ; \quad \text{Prices:} \quad w_{j,s}, w_{j,t} \quad ; \quad \text{Quantities:} \quad x_{j,s}, x_{j,t} \,. \tag{3}$$

The ratio of the total nominal value of outputs (or inputs) in the current period to that in the preceding period yields the revenue (or cost) index,

$$\text{Revenue Index:} \quad R_{st} \equiv \frac{\sum_i^M p_{i,t} q_{i,t}}{\sum_i^M p_{i,s} q_{i,s}} \quad ; \quad \text{Cost Index:} \quad C_{st} \equiv \frac{\sum_j^N w_{j,t} x_{j,t}}{\sum_j^N w_{j,s} x_{j,s}} \,. \tag{4}$$

It appears that the revenue index (R_{st}) is the relative change in total nominal value of outputs while the cost index (C_{st}) is the relative change in total nominal cost of inputs. In turn, R_{st} and C_{st} can be expressed in terms of Törnqvist price and quantity indexes for outputs and inputs to yield the Törnqvist TFP index.

The Törnqvist output price (P_{st}^T) and output quantity (Q_{st}^T) indexes are, by definition,

$$P_{st}^T \equiv \prod_i^M \left(\frac{p_{i,t}}{p_{i,s}}\right)^{1/2(r_{i,s}+r_{i,t})} \quad ; \quad Q_{st}^T \equiv \prod_i^M \left(\frac{q_{i,t}}{q_{i,s}}\right)^{1/2(r_{i,s}+r_{i,t})} \tag{5}$$

where the revenue shares are,

$$r_{i,s} \equiv \frac{p_{i,s} q_{i,s}}{\sum_i^M p_{i,s} q_{i,s}} \quad ; \quad r_{i,t} \equiv \frac{p_{i,t} q_{i,t}}{\sum_i^M p_{i,t} q_{i,t}} \quad ; \quad \sum\nolimits_i^M r_{i,s} = \sum\nolimits_i^M r_{i,t} = 1 \,. \tag{6}$$

Similarly, the Törnqvist input price (W_{st}^T) and input quantity (X_{st}^T) indexes are defined by,

$$W_{st}^T \equiv \prod_j^N \left(\frac{w_{j,t}}{w_{j,s}}\right)^{1/2(c_{j,s}+c_{j,t})} \quad ; \quad X_{st}^T \equiv \prod_j^N \left(\frac{x_{j,t}}{x_{j,s}}\right)^{1/2(c_{j,s}+c_{j,t})} \tag{7}$$

where the cost shares are,

$$c_{j,s} \equiv \frac{w_{j,s} x_{j,s}}{\sum_j^N w_{j,s} x_{j,s}} \quad ; \quad c_{j,t} \equiv \frac{w_{j,t} x_{j,t}}{\sum_j^N w_{j,t} x_{j,t}} \quad ; \quad \sum\nolimits_j^N c_{j,s} = \sum\nolimits_j^N c_{j,t} = 1 \,. \tag{8}$$

By definition, on the revenue side,

$$\mathit{Direct}\ \text{TFP:} \quad E_{st}^{TR*} \equiv \frac{Q_{st}^T}{X_{st}^T} \equiv \frac{\text{Output Quantity Index}}{\text{Input Quantity Index}} \quad ; \tag{9}$$

$$\mathit{Exact}\ \text{TFP:} \quad E_{st}^{TR} \equiv \frac{R_{st}/P_{st}^T}{X_{st}^T} \equiv \frac{\text{Revenue Index/Output Price Index}}{\text{Input Quantity Index}} \quad ; \tag{10}$$

$$\equiv \frac{Implicit \text{ Output Quantity Index}}{\text{Input Quantity Index}} \,. \tag{11}$$

Consider that,

$$E_{st}^{TR*} \approx E_{st}^{TR} \tag{12}$$

because

$$R_{st} \approx P_{st}^{T}\, Q_{st}^{T} \approx P_{st}^{T}\, X_{st}^{T}\, E_{st}^{TR*} \quad \text{while} \quad R_{st} = P_{st}^{T}\, X_{st}^{T}\, E_{st}^{TR} \,. \tag{13}$$

Similarly, on the cost side,

$$Direct \text{ TFP:} \quad E_{st}^{TC*} \equiv \frac{W_{st}^{T}}{P_{st}^{T}} \equiv \frac{\text{Input Price Index}}{\text{Output Price Index}} \;; \tag{14}$$

$$Exact\ TFP\text{:} \quad E_{st}^{TC} \equiv \frac{W_{st}^{T}}{C_{st}/Q_{st}^{T}} \quad ; \quad C_{st} = R_{st} \,; \tag{15}$$

$$\equiv \frac{W_{st}^{T}}{R_{st}/Q_{st}^{T}} \equiv \frac{\text{Input Price Index}}{Implicit \text{ Output Price Index}} \,. \tag{16}$$

Consider also that,

$$E_{st}^{TC*} \approx E_{st}^{TC} \tag{17}$$

because (13) to (15) imply,

$$C_{st} = R_{st} \approx P_{st}^{T}\, Q_{st}^{T} \approx \frac{W_{st}^{T}\, Q_{st}^{T}}{E_{st}^{TC*}} \quad \text{while} \quad C_{st} = \frac{W_{st}^{T}\, Q_{st}^{T}}{E_{st}^{TC}} \,. \tag{18}$$

The objective is to decompose the growth of revenues–mathematically, the natural logarithm of R_{st}–into the growth contributions of output prices, input quantities, and TFP. Alternatively, the growth of costs–the natural logarithm of C_{st}–is decomposable into the growth contributions of input prices, output quantities, and TFP. However, under CRS and competitive optimizing behavior, the revenue growth and cost growth decompositions–using the Törnqvist index framework–will yield TFP growth contributions that are empirically indistinguishable (Dumagan and Ball, 2009). Therefore, for the purposes of determining the TFP growth contribution, revenue growth decomposition will suffice.

It follows from (13) that,

$$R_{st} = P_{st}^{T}\, X_{st}^{T}\, E_{st}^{TR} \quad ; \quad ln(R_{st}) = ln(P_{st}^{T}) + ln(X_{st}^{T}) + ln(E_{st}^{TR}) \,. \tag{19}$$

Hence, revenues rise (fall) with a rise (fall) in output prices, input quantities, or TFP. Moreover, combining (5) to (8) with (19) yields the decomposition of revenue growth, $ln(R_{st})$, into the growth contributions of output prices, input quantities, and of TFP,

$$ln(R_{st}) = \sum_{i}^{M} \frac{1}{2}(r_{i,s} + r_{i,t}) ln\left(\frac{p_{i,t}}{p_{i,s}}\right) + \sum_{j}^{N} \frac{1}{2}(c_{j,s} + c_{j,t}) ln\left(\frac{x_{j,t}}{x_{j,s}}\right) + ln(E_{st}^{TR}) . \qquad (20)$$

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

Conceptually,

Output Growth = Revenue Growth − Growth of Output Prices ; (21)

= Growth of Input Quantities + TFP Growth . (22)

Thus, it follows from (20) to (22) that,

$$\text{Output Growth} = ln(R_{st}) - \sum_{i}^{M} \frac{1}{2}(r_{i,s} + r_{i,t}) ln\left(\frac{p_{i,t}}{p_{i,s}}\right); \qquad (23)$$

$$= \sum_{j}^{N} \frac{1}{2}(c_{j,s} + c_{j,t}) ln\left(\frac{x_{j,t}}{x_{j,s}}\right) + ln(E_{st}^{TR}) . \qquad (24)$$

III.4. Data for growth decompositions

This study used the original cross-sectional and time-series data set of Teruel and Kuroda (2005) on Philippine agriculture that was updated and extended to 2004. This is a regional data set on agricultural products and inputs assembled for the years 1974-2004. This accounts for 88 percent of the total volume of crop production and almost 100 percent of the total poultry and livestock production. The data were reported on a calendar year basis using the 12-region classification for the Philippines.

The revenue growth and output growth decompositions in (20) and (24) were applied to agricultural data in each of 12 regions[2], covering annually in each region 25 crops and livestock products for the outputs and 8 inputs over 31 years during 1974-2004. In the data set, quantities were reported in thousands of metric tons, prices in pesos per kilogram, and areas in hectares.

The crop categories composed of rice, corn, sugarcane, coconut, tobacco, root crops (camote, cassava, gabi, pao galiang, tugui, and ubi or yam), fruits (banana, mango and pineapple) and vegetables (cabbage, eggplant, garlic, radish, and tomato). Livestock and

[2] Ilocos (1), Cagayan Valley (2), Central Luzon (3), Southern Tagalog (4), Bicol (5), Western Visayas (6), Central Visayas (7), Eastern Visayas (8), Western Mindanao (9), Northern Mindanao (10), Southern Mindanao (11), and Central Mindanao(12).

poultry products, on the other hand, included meat of cattle, carabao (water buffalo), hogs, goat, chicken, and ducks, as well as chicken and duck eggs. The prices reported in the data set were farmgate prices. Gaps in the price data was filled by estimation.

The data on land variable were computed as the sum of the areas for all the crops. Land price was calculated as the residual of total revenue net of measured costs for agricultural labor, fertilizer, seeds, and machinery and animal services.

Labor data were from the quarterly labor force surveys of the National Statistics Office (NSO), formerly the National Census and Statistics Office (NCSO). Labor was reported in terms of equivalent man-days (MD) spent in agricultural production. Equivalent animal work days were computed based on the number of work carabaos and work cattle by assuming that these animals work an average of 220 and 150 days a year, respectively.[3] The cost of services of work animals per workday was assumed to be one-half of the daily wage of agricultural labor.[4]

Fertilizer quantities were reported in metric tons of nutrients, i.e., nitrogen, phosphorus and potassium. The data on seeds, which include rice and corn seeds, were taken from the supply-use data of BAS. Price of seeds was based on the farmgate prices of corn and rice.

The sources of the data for the construction of the data series on agricultural machinery are: (i) the 1978 BAEcon Capital Formation Study and (ii) annual national estimates of gross domestic capital formation from the Economic and Social Statistics Office (ESSO) of the National Statistical Coordination Board (NSCB). To estimate national stock values of agricultural machinery for 1974–2005, the following equation was used,

$$K_i = (1-d)K_{t-1} + I_t. \tag{25}$$

K refers to the stock value of agricultural machinery, I to investment in agricultural machinery, d to the depreciation rate, and t to the time subscript. The benchmark figure used for K is the 1973 value of agricultural machinery, which was 185.6 million pesos in current prices, reported in the 1978 BAEcon Capital Formation Study, and the depreciation rate is assumed to be 10 percent. The investment data is the data on gross domestic capital formation in agricultural machinery and tractors (in current prices) taken from ESSO of NSCB. The estimated annual national stock values of agricultural machinery in current prices were deflated using implicit price indices computed from ESSO data. The deflated figures (now expressed in constant 1974 prices) were then distributed to the regions using the

[3] The assumptions on the number of workdays are adopted from Quizon (1980).
[4] This was the assumption used in the Evenson data set.

regional distribution of tractors, as computed using data from the Census of Agriculture. The regional shares in the total number of tractors were interpolated for the missing years.

The amount of capital services of agricultural machinery in each region depend on the (deflated) value of the capital stock, the interest rate and the depreciation rate. The relationship can be expressed as,

$$K_{st} = (d + r)K_t. \quad (26)$$

K_{st} is the value of capital services in year t; K_t is the deflated value of capital stock in year t; d is the annual depreciation rate which was assumed to be 10 percent; and r is the annual interest rate, also assumed to be 10 percent. Implicit price indices were computed from ESSO data as the ratio of current price to constant price estimates of gross domestic capital formation in agricultural machinery and tractors. The indices have 1985 as base year but these indices will be rebased to 1974.

III.5. Growth decomposition results

This is the first study that implemented the Dumagan and Ball (2009) growth decomposition procedure–based on the Tornqvist index framework outlined in section 3.3–to the agricultural sector of Philippine regions and to the entire Philippine agricultural sector. It is also the first study that estimated Philippine agriculture TFP for years 2001-2004. This section specifically highlights the new estimates of productivity growth both at the regional and national levels since 1975.

The above growth decomposition procedure was applied individually to 25 crops and livestock products for the outputs and 8 inputs in the original data set. Due to space constraints, however, the results to be presented were aggregated, which is permissible because the decomposition procedure yields additive components as can be seen from equations (20) to (24). Thus, the results for crops were aggregated into 8 major categories: rice, corn, sugarcane, coconut, tobacco, rootcrops, fruits, and vegetables. On the other hand, the results for livestock and poultry products were aggregated into meat and egg categories. The results for inputs are for seeds, fertilizers, animal labor, machine, land, and human labor.

III.5.1. Growth contributions in the entire agricultural sector and whole period

In (20), growth of revenues can be broken down into the contribution of output prices, input quantities, and TFP. Table 1 shows the magnitude of contribution of these different components to revenue for years 1974-2004. The output prices contributed on the average 7.55 percentage points to revenue growth of 10.71 for the entire 1974-2004 period.

Table 1 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.

This indicates that output prices accounted around 70 percent of the growth of revenue. This is significantly higher than the individual contribution of input quantities and TFP of 0.97 (9.03%) and 2.19 (20.47%), respectively or higher than the contribution of output growth as a whole of around 30 percent to revenue growth. The significant contribution of output prices to revenue growth can be attributed to the discernable growth rates in the prices of rice and meat of 1.70 percent and 2.54 percent, respectively. From Table 1, it can be observed that inputs of production contributed just about 1 percentage point to output growth. The output growth in Philippine agriculture, therefore, has been driven by productivity but not by the use of inputs of production. This empirical result confirms evidences from previous studies on the relative importance of productivity to output growth (see, for example Teruel and Kuroda, 2005). The growth of TFP of 2.19 percent confirms previous findings of country-specific studies that there has been a positive growth in Philippine agriculture (Teruel and Kuroda (2004, 2005). The positive TFP growth for Philippine agriculture also draws support from previous cross-country studies (Trueblood and Coggins (1997), Suhariyanto and Thirtle (2001), Martin and Mitra (1999), Coelli and Rao (2003) and Mundlak (2002, 2004).

Table 2 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
	(65.48)**	(7.40)	(27.12)	(100.00)
Cagayan Valley	8.12	1.51	2.28	11.91
	(68.20)	(12.66)	(19.14)	(100.00)
Central Luzon	7.73	0.67	3.77	12.17
	(63.55)	(5.49)	(30.96)	(100.00)
Southern Tagalog	7.30	0.14	2.79	10.23
	(71.34)	(1.41)	(27.25)	(100.00)
Bicol	8.01	0.84	1.04	9.90
	(80.96)	(8.52)	(10.52)	(100.00)
Western Visayas	7.95	0.52	1.33	9.80
	(81.18)	(5.26)	(13.56)	(100.00)
Central Visayas	8.10	-0.21	2.67	10.56
	(76.70)	(-2.03)	(25.33)	(100.00)
Eastern Visayas	7.41	0.65	1.88	9.94
	(74.54)	(6.54)	(18.92)	(100.00)
Western Mindanao	7.20	2.31	1.18	10.69
	(67.36)	(21.57)	(11.07)	(100.00)
Northern Mindanao	6.51	1.53	2.40	10.44
	(62.35)	(14.64)	(23.01)	(100.00)
Southern Mindanao	7.19	1.01	2.16	10.36
	(69.44)	(9.70)	(20.86)	(100.00)
Central Mindanao	7.53	1.80	1.68	11.01
	(68.39)	(16.32)	(15.29)	(100.00)
Philippines	7.55	0.97	2.19	10.71
	(70.50)	(9.03)	(20.47)	(100.00)

*Figures are percentage-point contribution to revenue growth.
**Figures in parentheses are relative contributions.

III.5.2. Growth contributions in different regions for the whole period

The productivity performance of different regions in the Philippines is reflected in Table 2. As can be seen in Table 2, the TFP estimates are indicative of discernable divergence in terms of productivity performance across different regions over the period 1974-2004. This divergence can be partly attributed to the interplay of factors like agro-climatic differences, policy reforms as well as to other support systems accorded by the government to different regions. This viewpoint was well reiterated in Fan, Hazell, and Haque (2000) arguing that policy makers tend to invest more in technology, human capital development and infrastructure in regions that are better endowed by good agro-climatic conditions or in regions that are more densely populated. Thus, they added that the regional disparity in productivity caused by this investment may actually be the result of deliberate decisions by the government, leaving poorer regions trapped at low levels of productivity.

All 12 administrative regions had positive productivity growth rates for the entire 1974-2004 period. Among these 12 regional production areas, Central Luzon had the highest annual productivity growth of 3.77 percent. This region is noted for its rice sector, being the rice granary of the Philippines and having the highest average yield per hectare (3.44 MT/ha) for the last decade. The livestock and poultry subsector in this region also contributed 17 percent to total output during the same decade, second only to Southern Tagalog. Additionally, it is worth noting that based on the estimates presented in Table 2, growth in rice as well as in meat prices in this production area contributed much to the growth in revenue.

For the same time period, the region of Central Luzon was followed by Ilocos and Southern Tagalog with TFP growth of 3.12 percent and 2.79 percent, respectively. Other better performing regions with TFP growth rates above 2 percent per year were Central Visayas (2.67%), Northern Mindanao (2.40%), Cagayan Valley (2.28%) and Southern Mindanao (2.16%). On the other hand, the remaining regions with positive productivity growth rates but far below the national average of 2.19 percent were Eastern Visayas (1.88%), Central Mindanao (1.68%), Western Visayas (1.33%), and Western Mindanao (1.18%). Bicol Region is noted to be the least with productivity growth of 1.08 percent for the entire 1974-2004. Surprisingly, with closer scrutiny conducted by Teruel and Kuroda (2008), Bicol is not the least endowed among regions in term of roads, irrigation, rural electrification, area planted with HYV and share to government expenditure as of year 2000. The relative poor performance of Bicol region may probably indicate that other factors like the localized agro-climatic condition might have affected its productivity performance, the region being a typhoon-prone agricultural production area.

It can be gleaned from Table 2 that across regions the contribution of output prices to revenue growth is higher than the contribution of input and productivity. The results also illustrate that in all the production areas output growth has been driven by productivity but not by the increase in the use of inputs in agricultural production.

The above results seem to corroborate the spatial pattern of TFP growth in Philippine agriculture shown in Teruel and Kuroda (2008).

III.5.3. Growth contributions by subperiod

There are discernible temporal patterns of TFP growth in Philippine agriculture based on 5-year subperiod TFP estimates. These estimates are presented in Table 3. As indicated in this table, there has been a positive growth in TFP for the different subperiods except for 1985-1989. The agricultural sector performed relatively better during the latter part of the 1970s with TFP growing at an annual rate of 6.22 percent. The TFP, however, declined in the subsequent subperiods as indicated by the growth rates of 1.27 percent for years 1980-1984 and -0.70 for 1985-1989 period. Thereafter, a steady recovery in TFP can be observed in the decade of the 1990s (1.70% growth rate for 1990-1994 and 2.20% for 1995-2000 subperiod) and this has followed through until year 2004 (3.58 percent for 2001-2004 subperiod).

The above temporal pattern of TFP growth in the Philippines–that is, deceleration in the 1980s and resurgence in the 1990s–has been shown in studies by Teruel and Kuroda (2005). Mundlak, et al (2004), on the other hand, have also shown declining TFP from the 1980s but it persisted until year 2000. Both these studies have emphasized that productivity level during the Green Revolution era has not been sustained or paralleled, despite substantial policy changes put in place since 1986 to invigorate agriculture in the Philippines.

Looking at Table 3, there was a significant growth in revenue from the first subperiod; from 9.37 to 19.15 percent. The growth in output prices contributed much to revenue growth. Prices of meat products, rice and coconut during this period were major contributors to growth in output prices. After this subperiod, there was a decline in the growth of revenue in all the subsequent subperiods. This trend can actually be explained by the continued deceleration across years in the growth contribution of prices of most of the crops, livestock, and poultry products which emphasizes the importance of using price policy to enhance income in Philippine agriculture. The same growth patterns can also be discerned in terms of growth contribution of input quantities to revenue. The TFP estimates show signs of recovery in recent subperiods but the extent is not strong enough to reverse the temporal decline of revenue growth in Philippine agriculture.

IV. Explaining TFP

The revenue growth decomposition framework in section 3 yielded the growth contributions of TFP in each region each year, a total of 12 x 30 = 360 estimates of TFP level and growth.[5] These estimates remain, however, to be explained because only conventional inputs (e.g., the usual physical land, labor, and capital categories) were considered in the growth decomposition. Thus, as presented in detail below, the next stage of this study attempted to explain the contributions to productivity of non-conventional inputs such as human capital, technology, infrastructure, and policy.

IV.1. Empirical model for explaining TFP

To explain the regional and temporal patterns in TFP, the annual regional TFP estimates for years 1975-2004 using the above-mentioned Dumagan and Ball (2009) framework comprise the dependent variable in a regression with a number of explanatory variables that represent *measures* of human capital, infrastructure, technology, and policy. To answer questions on how one or combination of these factors may drive productivity growth in Philippine agriculture, this study followed the framework of Evenson and McKinsey (1991) and Rosegrant and Evenson (1992)

The basic empirical model is given by,

$$Y_{it} = \alpha_i + \sum_{j}^{K} \beta_{ij} X_{ijt} + \mu_i \,. \tag{27}$$

In (28), Y_{it} refers to TFP of region i at time t; X_{ijt} represents the jth explanatory variable or determinant of TFP (among a total of K determinants); α_i and β_{ij} are the parameters to be estimated; and μ_i is the error term. In a panel framework, the parameters α_i and β_{ij} may be allowed to vary across regions by employing interaction terms with regional dummies.

The explanatory variables assumed to affect TFP are road density (**ROADS**), degree of rural electrification (**ELECT**), irrigation (**IRRIG**), proportion of farm areas planted with HYVs as proxy for research and development (**HYV**), number of graduates finishing agriculture-related courses as proxy for agricultural extension (**EXT**), literacy rate for human capital (**LIT**), nominal rates of assistance as proxy for government policy (**NRA**) and historical precipitation (**RAIN**).

In this study, a panel data set was used for estimation with spatial dimension pertaining to the 12 regions of the country and temporal dimension covering 31 years from 1974-2004. The first advantage of the panel data is that the sample is relatively larger compared to the case where there is only one observation per region. This large sample permits greater

[5] Note that the data cover 31 years, 1974-2004. However, TFP growth is annual so that the growth in 1975, for example, uses 1974-75 data. Thus, there are only 30 TFP level and growth estimates each year for each of the 12 regions.

estimation power; thus, the coefficients can be estimated more precisely. Since the standard errors in this case are lower, it is more likely to find statistically significant coefficients. However, the use of panel data has its own problem because of possible heterogeneity bias. If this heterogeneity across region and time is ignored, then this leads to inconsistent or meaningless estimates of the parameters of interest.

To address this problem, this study tried to estimate several types of panel data analytic models: the constant coefficients model, the fixed effects model, and the random effects model. These will be discussed in turn.

The constant coefficients model (or the pooled regression model) assumes that the coefficients for both intercepts and slopes are constant. In the event that the regional as well as the temporal effects are insignificant, one can pool the panel data and run an ordinary least squares regression using (27) above.

On the other hand, the fixed effects model (or the Least Squares Dummy Variable (LSDV) model) assumes constant slopes but different intercepts across the different sectional units. This indicates that there are no significant temporal effects, although there are significant differences across the different regions. Thus, under this model, one can assume that the error term (ε_{it}) has an unobserved region-specific component (μ_i) that does not vary over time and an idiosyncratic component (e_{it}) that is unique to each region-year observation. Algebraically, the fixed effects model can be written as,

$$Y_{it} = \alpha_i + \sum_{j}^{K} \beta_j X_{ijt} + \varepsilon_{it}. \quad (28)$$

Notice that the intercept (α_i) is indexed with respect to region i to indicate that it differs across regions. In contrast, the slope parameter (β_j) is constant or the same across regions (i.e., not indexed to i) for the same explanatory variable j. The error term is,

$$\varepsilon_{it} = u_i + e_{it}. \quad (29)$$

By substitution of (29), (28) becomes,

$$Y_{it} = \alpha_i + \sum_{j}^{K} \beta_j X_{ijt} + u_i + e_{it}. \quad (30)$$

Given the above model, the OLS estimate of the β_j coefficients will be unbiased as long as the unobservable region-specific component (u_i) is uncorrelated with X_{ijt}. This assumption, however, does not hold true in practice and this has to be tested empirically. If u_i is correlated with X_{ijt}, then this implies that ε_{it} is also correlated with X_{ijt}. This problem can be accounted for in the estimation by appending to (27) 11 (or $12 - 1$) dummy variables to designate a particular region (among 12 regions). Alternatively, instead of adding dummy variables to (30), one can also address the problem on correlation by time-demeaning transformation of the variables Y_{it} and X_{ijt} .

An alternative to the constant coefficients and fixed effects models is the random effects model. Under this model, the u_i is assumed to be randomly distributed with a mean zero and a constant variance ($u_i \sim \text{IID}(0, \sigma_u^2)$) rather than stable or fixed as in the case of fixed effects model. Like the simple OLS, the random effects model assumes that there is zero correlation between u_i and X_{ijt} or $\text{Cov}(X_{ijt}, \mu_i) = 0$. Otherwise, the random effects estimates are biased.

For the random effects model, a composite error term is formed as,

$$\varepsilon_{it} = u_i + e_{it.} \tag{31}$$

Thus, the model to be estimated under the random effects specification is given by

$$Y_{it} = \alpha_i + \sum_{j}^{K} \beta_j X_{ijt} + \varepsilon_{it}. \tag{32}$$

As shown in (32), the composite error for each time period t is a function of u_i and thus the error term (ε_{it}) is serially correlated across time. This serial correlation in the error terms can be substantial and this will result in biased OLS estimates of the β_j coefficients because the usual pooled OLS standard errors ignore this correlation.

To account for the correlation, the random effects model (32) was estimated in this study using the generalized least squares (GLS) with autoregressive serial correlation. This estimation procedure, however, requires GLS transformation that eliminates serial correlation in the error term (Wooldridge, 2006).[6]

In this study, the Hausman specification test was used to determine the correlation between μ_i and X_{ijt}. If μ_i and X_{ijt} are correlated, the random effects estimates are biased (inconsistent) while the fixed effects coefficients are unbiased (consistent). In this case, there will be a large difference between the random effects and fixed effects coefficient estimates. On the contrary, if μ_i and X_{ijt} are uncorrelated, the random effects and fixed effects coefficients are both unbiased (consistent); but the fixed effects coefficients are inefficient while the random effects coefficients are efficient. In this case, the difference between the

[6] This GLS transformation will not be discussed in here because it requires sophisticated matrix algebra (see Wooldridge, 2002, Chapter 10).

Table 3 Contributions to growth of revenues by subperiod, 1975-2004

Year	Growth of Output Prices											Growth of Input Quantities					Growth of TFP	Growth of Revenues
	Rice	Corn	Sugar	Coconut	Tobacco	Rootcrops	Fruits	Veg	Meat	Eggs	Seeds	Fertilizers	Animal labor	Machine	Land	Labor		
1975-79	0.36	0.10	0.51	0.27	0.15	0.27	-0.05	0.06	1.83	0.32	0.01	0.17	0.01	0.07	-1.82	0.90	6.22	9.37
1980-84	3.75	1.51	1.34	3.24	0.17	0.77	1.10	0.34	4.54	0.78	-0.01	-0.29	0.36	-0.04	-0.32	0.64	1.27	19.15
1985-89	2.14	1.09	0.79	-0.26	0.04	0.19	0.94	0.09	3.14	0.23	0.01	0.68	-0.21	-0.01	2.19	0.54	-0.70	10.87
1990-94	1.71	0.44	0.26	0.02	0.07	0.26	0.59	0.08	2.65	0.20	0.00	0.12	-0.12	0.02	0.34	0.62	1.70	8.96
1995-99	1.42	0.28	0.01	1.25	0.05	0.38	0.97	0.08	1.27	0.13	0.04	0.22	0.28	0.04	0.10	0.13	2.20	8.86
2000-04	0.83	0.63	-0.01	-0.14	0.06	0.16	-0.03	-0.01	1.80	0.18	0.01	0.07	0.15	0.04	0.03	-0.29	3.58	7.04

random effects and fixed effects coefficient estimates may not be large. For the Hausman specification test, the null hypothesis (H_0) was set as μ_i is uncorrelated with the X_{ijt}.

The Hausman specification test indicates whether the two sets of coefficient estimates are significantly different. If the chi-square statistic is positive and statistically significant, the null hypothesis is rejected in which case the fixed effects model is preferable because the coefficients are consistent. If the chi-square statistic is not positive and statistically significant, the null hypothesis cannot be rejected in which case the random effects model is preferable because the coefficients are consistent and efficient.

IV.2. Data for the determinants of TFP

For the analysis on the determinants of TFP, the following data were gathered:

Road density was measured by dividing the road length in kilometers by the corresponding farm area in thousand hectares. The data on road length were taken from the Department of Public Works and Highways (DPWH).

Degree of rural electrification was measured as the proportion of barangays (villages) with electricity to total number of barangay potential for energization.

Irrigation was defined as the proportion of farm area with irrigation facilities to total cultivated area. The regional data on irrigation were obtained from BAS.

The research and development variable was proxied in this study by the proportion of the farm area planted with high yielding rice varieties (HYVs) to total cultivated rice area. This proxy variable has been interpreted as a technology variable in empirical studies conducted by Evenson (1986), Evenson and Quizon (1991), Evenson, Pray, and Rosegrant (1999) and Ali and Byerlee (2002). The data on HYVs were obtained from the unpublished tables of BAS.

In this study, agricultural extension was defined as the proportion of graduates finishing agriculture-related courses to total number of graduates. It is assumed that these graduates serve as agents of change, i.e., they help disseminate recommended technology to farmers for adoption. This variable is close in spirit to Hayami and Ruttan's (1985), though they used it as proxy for education or human capital, due to the unavailability of data on the educational level of the agricultural labor.

It has been shown empirically that investment in forms of human capital has contributed to the improvement of productivity (Evenson and McKinsey, 1991; Pray and Evenson, 1991; Pardey, Roseboom, and Craig, 1992; Rosegrant and Evenson, 1992). The human capital in this study was proxied instead by the basic or simple literacy rate was defined as the percentage of the population who can read and write and understand simple messages in any language or dialect. These data were taken from NSCB.

The nominal rates of assistance (NRA) were used to proxy government policy and policy reforms. NRA on output is defined as the percentage change in gross returns per unit of output relative to the situation of no assistance. The NRA measures the extent to which consumers pay higher prices and taxpayers pay subsidies to support local output. It is a useful indicator of the effects of assistance on incentives to produce or consume certain commodities. In this study, the annual national NRA estimates by David, et al. (2007) for the different main agricultural products were used to calculate the annual NRA for different regions. These products included the following: Banana, coconut, corn, sugar, rice, beef, chicken, and pig meat. The NRA for a particular year and region was computed using the regional value of production of the aforementioned products as weights.

Mean rainfall was also included in the estimation to account for its effects to productivity. In the study by Craig, Pardey and Roseboom (1997), rainfall was found to be significantly associated with output per worker. The rainfall data were obtained from the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) and from the published tables of NSCB.

IV.3. Effects of TFP determinants

This section discusses and uses the results from pooled OLS, fixed effect and random effect models to examine the degree to which the changes in TFP are driven by variables representing infrastructure, research, extension, human capital, and policy[7].

In the estimation, the dependent variable is the annual growth rates of TFP (GTFP) and it is assumed to be a function of independent variables also expressed in growth rates. To account for the differences in TFP growth and trends across different subperiods, the following subperiod dummy variables were appended in the estimation: D7580, D8190, D9100, and D0104.

The first estimation was done by applying the plain ordinary least squares (OLS) method (named 'OLS' hereafter) to equation (27). Another OLS regression was also done (named 'OLS_PCSE' hereafter) and this involved data transformation which is based on PCSE. Another one (named 'OLS_PCSE-AR1' hereafter) was also carried out allowing for

[7] Prior to estimation, series of regression diagnostic tests were conducted. All assumptions related to linear regression model are satisfied; it is homoscedastic, the model does not need more variables, the residuals are normally distributed and the regressors are not multicollinear.[7] In this study, the problem of autocorrelation was also accounted for by using the GLS estimation technique. Results of regression diagnostic tests are available from the authors upon request.

the first-order autocorrelation (AR1) within panels and the coefficient of the AR(1) process is common to all the panels. The last two OLS-based estimations were employed to correct problems related to heteroscedasticity and autocorrelation. However, one can argue that the estimates for regression coefficients from OLS, OLS_PCSE and OLS_PCSE-AR1 are likely to be biased because region-specific unobserved heterogeneity in the error term is not properly accounted for in the estimation or if it is also possibly correlated with any of the independent variables in the model. To account for this unobserved heterogeneity, which is assumed to be constant across time, the fourth estimation which is the fixed effects estimation (named "FE" hereafter) was carried out following (28). Finally, using (32), the random effects estimation (named "RE" hereafter) was also implemented allowing for region-specific unobserved variables entering through the error term (Wooldridge, 2002). In this study, the Generalised Least Squares (GLS) was used to estimate the random and fixed effect models. This was done also for the purposes of checking the problem of heteroskedasticity using White's error correction procedure. The Hausman test was conducted to examine the suitability of the FE and RE models.

Table 4 shows the details of all the estimation results for TFP determinants. Columns 1, 3, and 5 present the results of OLS-based estimations. The t- and z-values are shown in columns 2, 4, and 6. Column 1 contains the coefficients estimated using the OLS technique but without taking into consideration the problem of heteroscedasticity as well as autocorrelation[8].

The results suggest ROAD, NRA, HYV, and ELECT are significant explanatory variables contributing positively to changes in TFP. Among these variables, the estimate for ROAD is strongly significant at 1 percent level as indicated by the computed t-value of 3.24. On the other hand, ELECT is only significant at 10 percent level (t = 1.84). All coefficients for period dummy variables have negative signs. The estimated coefficients for D7479 and D9100 are not significant implying that productivity growth in the late 70s and the decade of the 90s is not statistically different from the TFP growth in recent years (2001-2004). However, based on the regression estimates, growth in TFP during the years 1980-1990 is lower than in 2001-2004 and it is significant at 10 percent. This substantiates Teruel and Kuroda's (2005) evidence on the productivity deceleration during 1980s, the period characterized as the lost decade of the Philippines.

[8] In all the estimation, multiplicative interaction terms were appended. The results though will not be discussed in detail here but they are readily available upon request.

Interestingly, the estimation results based on OLS_PCSE and OLS_PCSE_AR1 are broadly consistent with the plain OLS except for the period dummy variables. Estimated coefficients are more or less of the same magnitude and have plausible signs. Coefficients of variables ROAD, NRA, HYV, and ELECT are still positive and significant, though one can discern that for NRA it becomes strongly significant as indicated by its t-value. The coefficients for the different period dummy variables including the D8090 are negative but not significant implying that there are no significant differences in TFP growth across subperiods. This is inconsistent with the results based on plain OLS.

The overall significance test was carried out for OLS, OLS_PCSE and OLS_PCSE_AR1 using the F- and Wald Chi^2 tests. For these tests, the null hypothesis is that the group of independent variables does not reliably predict the dependent variable. For the plain OLS, the F(26,333) = 2.06 and the associated p-value is 0.0021. This entails rejection of the null hypothesis at 1 percent level of significance. For the OLS_PCSE, the Wald Chi^2 (26) = 50.28 with p-value of 0.0029. Similarly, this also implies rejection of the null at 1 percent level. The same conclusion can also be inferred for the OLS_PCSE_AR1 as evident by the Wald Chi^2 (26) = 48.67 with associated p-value of 0.0045. It is worth noting however that the r^2 is only around 15 percent for OLS, OLS_PCSE and OLS_PCSE_AR1.

For the FE specification, the results are presented in column 7 and the associated t-values in column 8 of Table 4. When the time invariant unobserved regional characteristics are accounted for, the significance of ROAD, NRA, HYV, and ELECT persisted. Though, one can notice the marked difference with previous OLS-based estimations, that is, the variable NRA now becoming significant only at 5 percent instead of 1 percent level in the two-sided t-test. However, one can further observe that ELECT is now significant at 5 percent level. It is worth mentioning that the magnitude of estimated coefficients do not show considerable changes when compared with previous estimations. Of particular interest is the estimate for D8090 which confirms the results based on plain OLS that the TFP growth in the decade of the 80s is significantly lower than in years 2001-2004.

In relation to FE specification, the overall significance test was also employed in order to check if the estimated coefficients of all the independent variables are jointly zero. For this test, the calculated F(26, 322) is 2.01and the p-value is 0.0029. This establishes that the independent variables when taken as a group can reliably predict the dependent variable. Another F-test was also done to determine if all u_i = 0. As previously mentioned, the u_i is the component of the error term that accounts for the region-specific heterogeneity. The F-test gave a computed F (11, 322) of 0.44 with associated p-value of 0.9372 and this leads to the non-rejection of null that all $u_i = 0$. This test result can be corroborated by the variance due to u_i which is only 1.5 percent of the total variance and by the correlation coefficient between the u_i and the independent variables (X_i) which is equal to -0.014. The latter coefficient illustrates that the fixed effects are not correlated with the independent variables (X_i). Overall, this seems to imply that the OLS-based estimations are preferred than FE and this suggests that the estimated coefficient obtained using OLS method may not be misleading because unobserved heterogeneity is not properly accounted for.

As an alternate to OLS- and FE-based estimations, the estimates for RE model and the corresponding z-values are reported in columns 9 and 10 of Table 4. In this estimation, the u_i and the independent variables (X_i) are assumed to be uncorrelated and this is the key difference between the FE and RE specifications. The estimation results show that the magnitude of estimated coefficients, the sign and the level of significance are more or less the same when compared with the previous OLS- and FE-based estimations. The estimation reconfirms the importance of ROAD, NRA, HYV, and ELECT as determinants of TFP growth. Variables ROAD and NRA are significant at 1 percent level in the two-sided t-test exemplifying again their importance as determinants of TFP growth. The results also validate the previous findings that the productivity growth in the 1980s is relatively lower than the growth in years 2001-2004. The RE-based estimates also produce evidence that TFP growth in the late 1970s and in the 1990s is not statistically different from the growth in 2000-2004 subperiod. This is very surprising because of the many attempts of the government in the past to invigorate the Philippine agriculture through policy reforms and investment.

For the Hausman test, the computed $Chi^2(24)$ is 3.23 with p-value = 1, thus the null cannot be rejected. This implies that RE is preferred than FE specification. Since the null hypothesis that u_i and X_{it} are uncorrelated, there is a need to further determine whether the u_i are distributed randomly across regions. It is worth emphasizing that RE model is the same with OLS model where the constant term varies randomly across regions. To check the null hypothesis that there is no significant variation in u_i across region, the Breusch-Pagan Lagrange test for random effects was conducted on the error term in the estimation. Based on this test, the computed $Chi^2(24)$ is 2.14 and the p-value is 0.1439 leading to the non-rejection of the null. Based on this test, one cannot make a conclusion that RE is preferable to OLS specification.

V. Conclusion and Recommendation

This study estimated TFP level and growth in Philippine agriculture using the productivity measurement procedure proposed by Dumagan and Ball (2009). The procedure decomposes growth in revenues into output price and output quantity growth, and then the latter into input quantity growth and a residual term representing TFP growth (or decomposes growth in costs into input price and input quantity growth, and then the latter into output quantity growth and the residual TFP growth).

Applying the above procedure to the Philippine agricultural sector using the most recent agricultural data set covering 12 administrative regions and years 1974-2004, output prices contributed on the average 7.55 percentage points to revenue growth of 10.71 percent for the entire period. This indicates that output prices accounted about 70 percent of the growth of revenues. This is significantly higher than the average contribution of input quantities and TFP of 0.97 (9.03%) and 2.19 (20.47%), respectively. The significant contribution of output prices to revenue growth can be attributed to the discernable growth rates in the prices of rice (1.70%) and meat (2.54%). From the estimation, all inputs of production contributed just about 1 percentage point to revenue growth. This implies that output growth in Philippine agriculture has been mainly driven by productivity and minimally by the inputs of production. This phenomenon can be discerned not only at the national level but also across the different regions.

Productivity gaps are observed among the different regions. Central Luzon is noted to be the most productive region and Bicol being the least. Generally, regional production areas in Luzon are noted to be more productive than in Visayas and Mindanao. In terms of temporal pattern, 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. The extent of the recent improvement in TFP growth was not enough to achieve the level of the late 1970s. It can be pointed out that the highest TFP growth rate recorded so far has not been paralleled despite government efforts and initiatives to revive the less dynamic agricultural sector of the Philippines. A case in point is the Agriculture and Fishery Modernization Act (AFMA) implemented in 1997. Across time, revenue growth was also seen to be declining. This can be attributed to the decrease in the growth contribution of output prices–that overall remained relatively large–and to the decrease in the growth contribution of input quantities that was relatively small in the first place.

Table 4. Estimation results for TFP determinants

	Plain OLS	t-value	OLS_PCSE	t-value	OLS_PCSE_AR1	t-value	FE	t-value	RE	z-value
ROAD	0.0814	(3.24)***	0.0814	(2.53)**	0.0812	(2.58)***	0.0821	(3.08)***	0.0814	(3.10)***
LIT	0.0084	(0.03)	0.0084	(0.02)	0.0029	(0.01)	0.0926	(0.28)	0.0084	(0.03)
NRA	0.0041	(2.23)**	0.0041	(2.88)***	0.0043	(3.03)***	0.0040	(2.41)**	0.0041	(2.56)***
HYV	0.0898	(2.16)**	0.0898	(2.16)**	0.0811	(1.93)*	0.0891	(2.11)**	0.0898	(2.15)**
IRRIG	0.0880	(1.23)	0.0880	(1.52)	0.0835	(1.44)	0.0943	(1.59)	0.0880	(1.51)
RAIN	0.0067	(0.64)	0.0067	(0.51)	0.0058	(0.43)	0.0065	(0.63)	0.0067	(0.66)
EXT	0.0020	(0.25)	0.0020	(0.19)	0.0049	(0.48)	0.0030	(0.31)	0.0020	(0.21)
ELECT	0.0497	(1.84)*	0.0497	(1.78)*	0.0478	(1.77)*	0.0585	(2.03)**	0.0497	(1.79)*
D7479	-1.7640	(-0.91)	-1.7640	(-0.71)	-1.7443	(-0.75)	-2.0218	(-0.99)	-1.7640	(-0.88)
D8090	-3.1033	(-1.93)*	-3.1033	(-1.38)	-3.1303	(-1.5)	-3.2736	(-1.82)*	-3.1033	(-1.76)*
D9100	-1.5350	(-1.02)	-1.5350	(-0.75)	-1.5880	(-0.83)	-1.6279	(-0.98)	-1.5350	(-0.94)
ROAD x HYV	-0.0024	(-1.84)*	-0.0024	(-1.62)	-0.0021	(-1.47)	-0.0023	(-1.51)	-0.0024	(-1.58)
ROAD x IRRIG	0.0016	(0.87)	0.0016	(0.89)	0.0016	(0.89)	0.0012	(0.62)	0.0016	(0.85)
ROAD x EXT	0.0007	(0.56)	0.0007	(0.56)	0.0007	(0.62)	0.0007	(0.50)	0.0007	(0.53)
ROAD x ELECT	-0.0041	(-2.99)***	-0.0041	(-2.94)***	-0.0038	(-2.8)***	-0.0044	(-3.11)***	-0.0041	(-2.96)***
HYV x IRRIG	-0.0012	(-0.58)	-0.0012	(-0.62)	-0.0012	(-0.65)	-0.0009	(-0.42)	-0.0012	(-0.58)
HYV x EXT	0.0010	(1.76)*	0.0010	-1.54	0.0008	(1.34)	0.0010	(1.34)	0.0010	(1.40)
HYV x ELECT	-0.0003	(-0.21)	-0.0003	(-0.22)	-0.0002	(-0.16)	-0.0003	(-0.22)	-0.0003	(-0.20)
IRRIG x EXT	-0.0003	(-0.29)	-0.0003	(-0.29)	0.0000	(-0.03)	-0.0005	(-0.47)	-0.0003	(-0.28)
IRRIG x ELECT	-0.0009	(-0.82)	-0.0009	(-0.79)	-0.0008	(-0.73)	-0.0009	(-0.70)	-0.0009	(-0.71)
EXT x ELECT	-0.0007	(-0.81)	-0.0007	(-0.71)	-0.0006	(-0.59)	-0.0008	(-0.82)	-0.0007	(-0.77)
LIT x ROAD	0.0159	(0.55)	0.0159	(0.62)	0.0160	(0.64)	0.0220	(0.87)	0.0159	(0.64)
LIT x HYV	0.0083	(0.41)	0.0083	(0.49)	0.0117	(0.68)	0.0060	(0.35)	0.0083	(0.50)
LIT x IRRIG	-0.0552	(-1.64)	-0.0552	(-1.81)*	-0.0555	(-1.82)*	-0.0559	(-1.73)*	-0.0552	(-1.73)*
LIT x EXT	-0.0077	(-2.17)**	-0.0077	(-1.63)	-0.0062	(-1.35)	-0.0069	(-1.46)	-0.0077	(-1.64)*
LIT x ELECT	-0.0099	(-0.24)	-0.0099	(-0.27)	-0.0099	(-0.28)	-0.0207	(-0.54)	-0.0099	(-0.27)
CONSTANT	3.5417	(2.7)***	3.5417	(1.92)*	3.5941	(2.1)**	3.5654	(2.41)**	3.5417	(2.44)**

Note: Figures in parentheses are t-statistics. * , ** and *** denote significant at 10, 5 and 1% level, respectively..

The first part of this study on revenue growth decomposition found that output prices contributed substantially to agricultural revenues that by some measure encompass payments (i.e., farm incomes) to factors of production in farming. Also, compared to growth in input quantities, TFP growth accounted mostly for growth in quantities of agricultural outputs.

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

Thus, 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.

VI. References

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