Impacts of Total Factor Productivity on Agricultural Growth in Pacific Island Countries

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ABSTRACT

The agriculture sector plays an important role in small Pacific Island economies and has significant impacts on the livelihood of households. However, total agricultural production and productivity in these economies are generally low. This, together with limited sources of factor inputs, calls for improving technical efficiency and technology to enhance agriculture production. Based on the Malmquist index approach, this study computes growth of total factor productivity and its components, namely, pure technical efficiency growth, scale efficiency growth and technological growth for the agriculture sector of 15 Pacific Island countries over 1980-2012. Impacts of these productivity growth measures are further quantified by estimating panel data regression models using the generalized method of moments estimators. There is sufficient statistical evidence that agriculture's total factor productivity growth and its components, which though are slow in Pacific Island countries, contribute significantly to these small economies' agricultural growth.

Keywords: *Agriculture, productivity, growth*

INTRODUCTION

The role of the agriculture sector in Pacific Island countries (PICs) cannot be over emphasized. In the case of Papua New Guinea and the Solomon Islands, agriculture contributes around 35-40 per cent to GDP, whereas in Samoa, Tonga, Fiji and Vanuatu, agriculture's contribution to GDP lies between 12-20 per cent. Agriculture also provides income and a means of livelihood to around 50-70 per cent of the total population and remains an important foreign exchange earner for countries in the region.

However, factors such as limited productive agricultural land, rapid population growth in most of PICs and the current wave of trade liberalization (i.e., removal or elimination of subsidies, tariffs and non-tariff barriers to trade) require these countries to improve efficiency and competitiveness of the agriculture sector. An increased productivity and production of the agriculture sector will improve food security, employment creation and enhance living standards of the people in the region. In addition, efficient agricultural production is important for growth and development of other sectors such as the tourism industry. Enhanced productivity will also improve trade performance of PICs. PICs are also experiencing increasing levels of urbanisation and improving agriculture productivity is vital for feeding the growing urban population.

In this context, for better agricultural policy, it is imperative; (i) to measure and decompose total factor productivity (TFP) and (ii) to examine the impacts of TFP and its components, namely, technical efficiency and technology, on the growth of agriculture production. Decomposition of TFP into technical efficiency and technological progress can provide insight to policy makers with respect to technological progress in the agriculture sector and how efficiently this sector is using its endowment.

Therefore, the main purpose of this study is to identify the contribution of TFP to production growth in the agriculture sector of small Pacific Island countries. The sample in this study covers 15 PICs, namely, Cook Islands, Fiji, French Polynesia, Kiribati, Marshall Islands, Micronesia (Federated States of), Nauru, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu over the period 1980-2012. The non-parametric data envelopment analysis (DEA) approach is used to compute the Malmquist indices which form the measures of TFP and its components. Contribution of agricultural production efficiency and technical progress in the agriculture sector is estimated by a panel regression model using the generalized method of moments estimators. From a policy-making point of view, this study is novel in that it is the first study that examines TFP and its components' impacts on the growth of agriculture production in PICs.

The rest of the paper is organized as follows: Section 2 gives a brief overview of the agriculture sector in Pacific Island countries; Section 3 presents a brief literature review; Section 4 describes methodology and data which are used to compute productivity measures, followed by the presentation of computed productivity measures; Section 5 quantifies impacts of agricultural productivity growth on agricultural production growth in PICs; and Section 6 provides conclusion and policy recommendations.

OVERVIEW OF THE AGRICULTURE SECTOR IN PACIFIC ISLAND COUNTRIES

There is reasonable diversity in the agriculture sector among the South Pacific Island countries. The large Melanesian countries (Fiji, Papua New Guinea, Vanuatu and Solomon Islands) own some of the best natural resources in the region. Except Fiji, all other Melanesian countries are agrarian societies heavily dependent on agriculture as a source of income and livelihood, while they also experience a very high population growth rate.

The Fijian economy has become reasonably diversified since the 1970s, and accordingly agriculture's contribution to total GDP declined from 24 per cent in 1970 to 12 per cent in 2010. Yet, agriculture remains a significant contributor to Fiji's economy in terms of its importance to the informal sector in this country. Nevertheless, Fiji's agriculture sector which experienced one of the strongest growths in the 1980's performed poorly over the last two decades. Growth of agricultural production was 4.3 per cent in the period 1980-1990 and thereafter, it experienced negative growth rates of 0.28 and 1.8 per cent in the periods 1991-2000 and 2001-2010 respectively. The strong performance in the early period can be attributed to the strong performance of the sugar industry, government support provided to the agriculture sector and the relatively stable domestic economic environment. The rice production in Fiji increased from 17846 tonnes in 1980 to 31827 in 1989 when it achieved 66 per cent self-sufficiency and thereafter, it gradually declined (Prasad and Narayan, 2005). The average rice production in the period 1980-1990 was 23567 tonnes per annum, but it declined to 18000 and 13107 tonnes over 1991-2000 and 2001-2010 respectively, mainly due to the withdrawal of government support and the non-renewal of some of the land leases by landowners in the later period. A similar decline was also noticed in meat, coconut and milk production, which declined by 3, 1.8 and 0.25 per cent per annum respectively in the period 1990-2000. These industries experienced a moderate positive growth rate in the period 2001-2010; however, any such gain was offset by a huge decline in the sugar industry due to the expiry of land leases and gradual removal of preferential prices.

Unlike Fiji, other Melanesian countries generally experienced a positive agricultural growth rate over all periods, except for Vanuatu which had a slight negative growth rate in the period 1991-2000. Papua New Guinea, which is the largest of all Melanesian countries in terms of population and natural resources, experienced positive agricultural growth rates of 1.8, 2.98 and 1.95 per cent per annum over the periods 1980-1990, 1991-2000 and 2001-2010 respectively. A similar trend was also experienced by the Solomon Islands which achieved increasing positive growth rates of 1.25, 2.37 and 4.1 per cent over the same three periods respectively. Vanuatu experienced a positive growth rate of 3.6 per cent per annum in the period 1980-1990, then a negative growth rate of 0.85 per cent in 1991-2000, before experiencing a positive growth rate of 1.79 per cent per annum in the period 2001-2010.

Out of the two Polynesian countries, Samoa experienced a negative growth rate of 1.8 per cent in the period 1980-1990 and thereafter, it managed to achieve increasing positive growth rates of 0.39 and 3.1 in the periods 1991-2000 and 2001-2010 respectively. Similarly, Tonga experienced a negative growth rate of 3.1 per cent per annum in 1980-1990, then positive growth rates of 1.78 and 1.28 per cent per annum over the periods 1991-2000 and 2001-2010 respectively.

While most of the countries under study have made some progress in agriculture output growth, there is a lack of innovation in terms of producing new crops, commodities and processing. Also, due to the lack of genetic diversity, many agricultural commodities are extremely vulnerable to biotic and abiotic stresses, and generally fail to produce desired results when under stress (Singh, Ghodake and Quartermain, 2007).

Poorly defined property rights, particularly those relating to land, are also seen as a major hindrance to any innovative investment in the agriculture sector. Except for Fiji, about 80-90 per cent of land in the region is customarily owned and cannot be easily accessed by outside developers. Moreover, over the last two decades political instability has negatively contributed to agricultural growth in the Melanesian countries (Duncan and Chand, 2002). There was a significant decline in the availability of agricultural labour in Samoa and Tonga over the last two decades. In addition, poor rural infrastructure is a major constraint to agriculture development (Manning, 2007).

LITERATURE REVIEW

There are a number of studies which attempt to analyse and decompose agricultural productivity in developed and developing countries. These studies found mixed evidence of total factor productivity progress, and factors contributing to TFP progress/regress varied across studies. For instance, Mugera and Ojede (2014) examined technical efficiency in African agriculture using recent advances in bootstrap DEA over the period 1966-2001. The study found evidence of technical inefficiency in the cases of many African countries, and in fact, technical efficiency declined over the period under study.

Tipi and Rehber (2006) examined the technical efficiency and total factor productivity in agriculture for South Marmara region of Turkey within a data envelopment analysis framework during the period 1993-2002. The study found evidence of total factor productivity progress, and technical efficiency was driving TFP progress. Swinnen and Vrankan (2010) examined the effect of reform on agricultural productivity in Central and Eastern Europe and Former Soviet Republics for 1989-2005 within a data envelopment analysis framework. The study found all countries experienced a decline in total factor productivity in the initial stage of the transition, and then a productivity progress in the later stage. There was some observed variation in the length and depth of productivity regress and progress across the countries. Rezitis (2010) investigated agricultural productivity and convergence for European countries and the United States using the Window Malmquist index for 1973-1993. The study found evidence of TFP progress across these countries; however, there was a wide variation of total factor productivity progress in the agriculture sector across the countries. The study further found evidence of β-convergence and absence of σ-convergence. Ajetomobi and Odeniyi (2011) used a non-parametric analysis approach and examined productivity growth in the Economic Community of West African States (ECOWAS) agriculture sector during 1971-2007. The study, however, found that generally there was a decline in TFP over the whole period with fluctuations. Chen et al. (2008) examined the total factor productivity growth in China's agriculture sector using the Malmquist index and sequential technologies. Using the province level data, the study found that total factor productivity increased by 1.5 per cent annually and it was driven by technical progress. Further analysis revealed that technical progress was driven by tax cuts, public investment on research and development, infrastructure, and mechanisation.

In some of the earlier studies, Nin, Arndt and Preckel (2003) examined agriculture productivity in developing countries using a modified nonparametric approach. The study found that most of the countries under study experienced a positive productivity growth over the period under study, and that it was mainly driven by technical change.

COMPUTATION OF PRODUCTIVITY MEASURES

An investigation of impacts of productivity growth requires a quantification of productivity. Productivity in this study refers to total factor productivity, which includes pure technical efficiency, scale efficiency, and technology. The first part of this section describes briefly the method to be used to quantify productivity measures, followed by a description of data required for such quantification. The third part presents the computed growth rates of total factor productivity and its components.

THE MALMQUIST INDICES

The construction of the Malmquist index is based on the non-parametric data envelopment analysis of the frontier production function, which is widely used in the literature on productivity. According to pioneering studies such as Caves *et al*. (1982) and Färe *et al*. (1994), for each time period $t = 1, 2, \ldots, T$, the production technology F^t models the transformation of inputs, $x^t \in R_+^N$, into outputs, $y^t \in R_+^M$, i.e., $F^t = \{(x^t, y^t) : x^t \text{ can produce } y^t\}$.

The output distance functions are defined as

(1) $$D_o^t(x^t, y^t) = \inf\{\theta : (x^t, y^t/\theta) \in F^t\} = (\sup\{\theta : (x^t, \theta y^t) \in F^t\})^{-1}$$

where θ measures technical efficiency. Thus the distance functions are the reciprocal of the 'maximum' proportional expansion of the output vector y^t, given inputs x^t. They completely characterize the technology. In particular, note that $D_o^t(x^t, y^t) \leq 1$, if and only if $(x^t, y^t) \in F^t$. In addition, $D_o^t(x^t, y^t) = 1$, if and only if (x^t, y^t) is on the boundary or frontier of technology. A similar definition is given by $D_o^{t+1}(x^{t+1}, y^{t+1})$, the distance at period $t+1$ relative to the technology at $t+1$.

Färe *et al*. (1994) specify the output-based Malmquist productivity change index as follows:

(2) $$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \cdot \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}\right)\right]^{1/2}$$

The ratio outside the brackets measures an economy's efficiency relative to the best performer's efficiency (that is, the change in the distance of observed production from maximum potential production) and therefore, captures the 'catching-up' progress to the frontier. We denote efficiency index by *EFF*. The geometric mean of the two ratios inside the brackets measures technology level relative to the best performer's technology level. We denote technology index by *TECH*. TFP index is the product of efficiency and technology measures ($TFP = EFF \cdot TECH$).

All three indices will be measured compared to value 1. A Malmquist index greater than 1 represents improvements in TFP, while an index of less than 1 signals deterioration in TFP performance. Improvements in any of the components are also associated with component indices greater than 1 and deterioration is associated with component indices of less than 1. Annual growth rates of TFP and its elementary components (denoted by *TFPG*, *EFFG* and *TECHG*) can be obtained by subtracting the corresponding Malmquist index by 1:

(3) $$TFPG = (TFP - 1) \cdot 100$$

(4) $$EFFG = (EFF - 1) \cdot 100$$

(5) $$TECHG = (TECH - 1) \cdot 100$$

Following Krüger (2003), relative levels of efficiency, technology and TFP can be obtained accordingly:

(6)

(7) $$CUMEFF_k^{t+N} = D_k^t(x_k^t, y_k^t) \cdot \prod_{t+1}^{t+N} EC_k^{t+N}$$

(8) $$CUMTECH_k^{t+N} = D_k^t(x_k^t, y_k^t) \cdot \prod_{t+1}^{t+N} TC_k^{t+N}$$

$$CUMTFP_k^{t+N} = D_k^t(x_k^t, y_k^t) \cdot \prod_{t+1}^{t+N} TFPC_k^{t+N}$$

The Malmquist indices are widely used in the measurement of productivity since Färe et al. (1994) applied the DEA approach in computation of distance functions to form the Malmquist indices. Moreover, studies such as Lovell (1996) found that the Malmquist indices provide more satisfactory reorientation towards productivity measurement compared to parametric-stochastic frontier analysis. Another advantage of the DEA approach is that it allows further decomposition of TFP into technical efficiency and technology. This decomposition is important as it helps to quantify sources of productivity and evaluate the effect of productivity sources on production growth.

DATA

The sample for the current analysis covers 15 Pacific Island countries (Cook Islands, Fiji, French Polynesia, Kiribati, Marshall Islands, Micronesia (Federated States of), Nauru, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu) over 1980-

2012. The series required for computing the Malmquist indices include:

Net production value in agriculture (constant 2004-2006, USD million);

Net capital stock in agriculture (constant 2005 prices, US$ million). This series includes data on land development, livestock (fixed assets), livestock (inventory), machinery & equipment, plantation crops, and structures for livestock;

Total economically active population in agriculture (estimated & projected, unit: 1000 persons); and

Arable land (unit: Ha).

These four series' data are obtained from the database of Food and Agriculture Organization (FAO) of the United Nations.

There are some missing values in this database, which are handled as follows. Firstly, missing values in the total economically active population in agriculture for Marshall Islands, Micronesia (Federated States of) and Tuvalu are estimated by means of multiple imputation using data on total population at the country level. Secondly, the missing values in net production are interpolated based on a log-linear relationship between net production and economically active population in agriculture. Thirdly, two linear relationships (between arable land and economically active population, and between arable land and agriculture production) are used in the interpolation of arable land, and missing values in arable land are the average of two interpolated values. Lastly, two log-linear relationships (between net capital stock and net production, and between capital stock and economically active population in agriculture) are used in the interpolation of net capital stock, and missing values in net capital stock are the average of two interpolated values. The country level data are summarized in Table 1.

TABLE 1: *Agriculture production, capital stock and population by country over 1980-2012*

	Net Production Value (constant 2004-2006 prices, USD million)				Net capital stock (constant 2005 prices, USD million)			
Country	1980-1990	1991-2000	2001-2006	2007-2012	1980-1990	1991-2000	2001-2006	2007-2012
Cook Islands	6.8	4.5	3.0	2.4	23.3	18.3	8.1	7.7
Fiji	215.4	228.1	221.2	203.7	798.9	974.2	977.8	676.0
French Polynesia	21.2	20.5	23.0	24.6	86.1	87.6	88.4	87.9
Kiribati	15.3	16.1	20.2	26.7	223.4	210.8	197.0	241.2
Marshall Islands	2.2	3.0	2.2	4.1	21.7	26.9	30.7	32.1
Micronesia (Fed.State of)	19.9	12.5	10.8	10.9	128.6	83.8	76.0	90.5
Nauru	0.4	0.6	0.6	0.6	10.3	14.2	14.0	16.1
New Caledonia	18.3	20.9	22.5	22.5	571.0	596.7	577.8	345.8
Palau	2.3	2.8	3.5	2.6	5.2	5.3	6.7	4.7
Papua New Guinea	1516.9	1911.5	2279.2	2676.0	1802.5	2114.7	2370.9	2388.7
Samoa	52.7	40.8	45.6	51.0	402.9	305.2	327.2	364.2
Solomon Islands	65.2	78.2	92.5	115.6	158.6	174.1	185.6	203.6
Tonga	25.4	24.4	24.5	34.0	130.0	123.2	118.5	143.6
Tuvalu	0.7	0.8	0.8	0.9	15.4	16.2	13.3	13.2
Vanuatu	59.8	63.0	58.8	70.3	447.6	543.9	593.6	498.9

TABLE 1 *(continued)*

	Economically active population (1000 persons)				Land (1000 Ha)			
Country	1980-1990	1991-2000	2001-2006	2007-2012	1980-1990	1991-2000	2001-2006	2007-2012
Cook Islands	3.0	2.7	2.0	2.0	2	2	2	1
Fiji	108.5	121.9	122.9	128.4	120	176	170	152
French Polynesia	30.8	34.2	34.1	32.4	2	3	3	4
Kiribati	9.0	9.9	10.3	11.0	2	2	2	3
Marshall Islands	5.9	6.9	6.2	5.9	1	1	1	2
Micronesia (Fed.State of)	12.4	13.9	12.4	11.8	8	3	3	2
Nauru	1.0	1.0	1.0	1.0	24	24	23	23
New Caledonia	26.7	31.3	32.0	32.2	8	8	7	7
Palau	1.8	2.0	2.0	2.0	3	1	1	1
Papua New Guinea	1239.0	1571.2	1841.1	2102.4	182	196	229	292
Samoa	26.0	23.3	19.9	18.6	17	17	12	9
Solomon Islands	78.6	106.3	128.0	145.8	12	12	16	18
Tonga	11.8	12.9	12.0	11.4	16	16	15	15
Tuvalu	1.0	1.0	1.0	1.0	24	23	24	24
Vanuatu	28.1	31.7	34.6	37.0	20	20	20	20

Source: FAO of the United Nations and authors' estimation.

GROWTH RATES OF PRODUCTIVITY MEASURES

Annual technical efficiency growth (*EFFG*), pure technical efficiency growth (*PEG*), scale efficiency growth (*SEG*), technological growth (*TECHG*) and TFP growth (*TFPG*) are obtained by subtracting the corresponding Malmquist indices by 1 and then multiplying them by 100. Relationships among these five growth indices include: summation of annual *PEG* and annual *SEG* gives the annual *EFFG*; and summation of annual *EFFG* and annual *TECHG* gives the annual *TFPG*. Annual growth rates of productivity measures are presented in Table 2.

To summarize, in terms of technological growth, technological regress was experienced in many PICs over 1981-1990, except for Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu; most PICs, except Fiji, French Polynesia and Kiribati, had rapid technological progress over 1991-2000; over 2001-2006 most PICs continued experiencing rapid technological progress, except for Cook Islands, Fiji, French Polynesia and Kiribati; and over 2007-2012 all PICs under study experienced technological regress.

With respect to pure technical efficiency, over 1981-1990 deterioration in pure technical efficiency was seen in most PICs except for Samoa, Solomon Islands and Tonga; over 1991-2000 improvement in pure technical efficiency was seen in most PICs except for French Polynesia, Kiribati, Marshall Islands and Samoa; over 2001-2006 PICs experienced either deterioration or negligible improvement in pure technical efficiency; and over 2007-2012, there still lacked evidence of improvement in pure technical efficiency in PICs, except for Tuvalu and Vanuatu.

With regard to scale efficiency, Vanuatu was the only PIC which made noticeable progress in scale efficiency over 1981-1990; over 1991-2000, most PICs made more or less progress in scale efficiency except for Tonga, Tuvalu and Vanuatu; scale efficiency deteriorated in most PICs over 2001-2006 except for Nauru, New Caledonia, Tuvalu and Vanuatu. Over 2007-2012, apart from Marshall Islands, Nauru, New Caledonia, Samoa, Tuvalu and Vanuatu, the other PICs made more or less progress in scale efficiency.

In terms of total factor productivity, PICs as a whole experienced evident deterioration in TFP over 1981-1990 and 2007-2012; while significant enhancement and slight enhancement were seen in 1991-2000 and 2001-2006 respectively.

Over the whole period 1981-2012, PICs as a whole experienced a slight decline in pure technical efficiency with an average growth rate of -0.3 per cent per annum, stagnancy in scale efficiency, little progress in technology with an average growth rate of 0.5 per cent per annum, and consequently, little improvement in total factor productivity with an average growth rate of 0.2 per cent per annum.

TABLE 2: *Computed annual productivity growth by country over 1981-2012*

Series	Period	Cook Islands	Fiji	French Polynesia	Kiribati	Marshall Islands	Micronesia (Fed. States of)	Nauru	New Caledonia	Palau	Papua New Guinea	Samoa	Solomon Islands	Tonga	Tuvalu	Vanuatu
Technical efficiency growth (per cent)	1981-1990	-8.5	-10	-11.8	-18.5	-11.7	-4.6	-9.1	-7.8	-5.9	-3.4	2.2	1	2.5	-2.9	-1.3
	1991-2000	9.4	11	13.3	22.2	13.1	4.6	9.7	8	5.9	3.4	0	0.8	1	7.5	7.2
	2001-2006	0	-0.1	-0.9	-0.4	-0.6	-0.9	0.5	0.4	-2.1	-1.6	-0.9	-1.8	-0.4	-3.5	-4.6
	2007-2012	0	-2.4	-2.5	-2.2	-4.4	-3	-4.3	-4.2	-2.2	-2.2	-1.5	-2.4	1.1	2.1	4.9
Technological growth (per cent)	1981-1990	-17.6	-12.3	-13.4	-12.6	-10.6	-10.2	-8	-7.4	-5.5	2.7	4.7	4.9	8.5	9	12.7
	1991-2000	1.8	-1.4	-2.8	-0.2	6.7	8.2	8	13.1	8.8	13.6	10.2	9	13.2	15.3	15.7
	2001-2006	-14.9	-14.3	-14.3	-0.1	0.1	0.3	10	10.3	11.6	8.8	8.5	9.3	10.1	10.2	11.3
	2007-2012	-10.6	-10.5	-11.6	-9.8	-7.8	-7.7	-4.6	-4.9	-2.3	-0.3	1.7	-2.5	0.5	-1.6	-0.4
Pure technical efficiency growth (per cent)	1981-1990	-7.1	-9.3	0	0	0	-3.8	-8.4	-7	-5.1	-2.5	2.2	1	2.4	-3.1	-7
	1991-2000	7.6	10.2	-0.1	-0.4	-0.2	3.7	8.8	7.3	5.3	2.6	0	0.8	1.1	7.6	7.5
	2001-2006	0	0	-0.7	0.1	0	0.3	0.4	0.1	0.2	0.1	0	-0.5	0.5	-3.6	-4.9
	2007-2012	0	-2.5	-2.5	-2.6	-4.3	-3.6	-3.7	-3.4	-3.6	-3	0	-2.6	0	3.2	5
Scale efficiency growth (per cent)	1981-1990	-1.6	-0.8	-11.8	-18.5	-11.8	-0.8	-0.8	-0.8	-0.8	-0.8	0	0	0.1	0.1	6.1
	1991-2000	1.6	0.7	13.4	22.7	13.4	0.9	0.7	0.6	0.6	0.8	0	0	-0.1	-0.1	-0.3
	2001-2006	0	-0.1	-0.2	-0.4	-0.5	-1.2	0.1	0.3	-2.3	-1.6	-0.9	-1.4	-1	0.2	0.3
	2007-2012	0	0.2	0	0.4	-0.1	0.7	-0.7	-0.9	1.5	0.8	-1.5	0.2	1.1	-1	-0.1
Total factor productivity growth (per cent)	1981-1990	-24.6	-21.1	-23.6	-28.7	-21.1	-14.4	-16.3	-14.7	-11.1	-0.8	7.1	6	11.1	5.8	11.2
	1991-2000	11.4	9.4	10.2	22	20.7	13.1	18.5	22.2	15.2	17.4	10.3	9.8	14.3	24	24.1
	2001-2006	-14.9	-14.4	-15.1	-0.5	-0.4	-0.7	10.5	10.8	9.3	7.1	7.6	7.3	9.6	6.4	6.2
	2007-2012	-10.6	-12.6	-13.8	-11.8	-11.8	-10.5	-8.7	-8.9	-4.4	-2.6	0.2	-4.8	1.6	0.5	4.4

Source: *Authors' computation based on the data envelopment analysis approach.*

IMPACTS OF TOTAL FACTOR PRODUCTIVITY ON PRODUCTION GROWTH

This section presents the models and estimators based on which impacts of productivity growth are quantified. This is followed by panel integration tests and panel data regression findings.

THE MODEL AND ESTIMATORS

Impacts of productivity growth on production growth in the agriculture sector of PICs are estimated based on the following two panel data regression models:

$$\begin{aligned} \Delta \ln Y_{it} &= \beta_0 + \beta_1 \Delta \ln K_{it} + \beta_2 \Delta \ln P_{it} + \beta_3 \Delta \ln L_{it} \\ &+ \beta_4 PEG_{it} + \beta_5 SEG_{it} + \beta_6 TECHG_{it} + \sum \phi_p DUM_{p,it} + \gamma_i + u_{it} \end{aligned} \tag{9}$$

$$\begin{aligned} \Delta \ln Y_{it} &= \delta_0 + \delta_1 \Delta \ln K_{it} + \delta_2 \Delta \ln P_{it} + \delta_3 \Delta \ln L_{it} \\ &+ \delta_4 TFPG_{it} + \sum \varphi_p DUM_{p,it} + \lambda_i + v_{it} \end{aligned} \tag{10}$$

where

Y = net agricultural production, and $\Delta \ln Y$ is annual growth of agricultural production (per cent);

K = net capital stock in agriculture, and $\Delta \ln K$ is annual growth of agricultural capital stock (per cent);

P = economically active population in agriculture, and $\Delta \ln P$ is annual growth of population in agriculture (per cent);

L = arable land, and $\Delta \ln L$ is annual growth of arable land (per cent);

PEG = growth of pure technical efficiency (per cent);

SEG = growth of scale efficiency (per cent);

$TECHG$ = growth of technology (per cent);

$TFPG$ = growth of total factor productivity (per cent);

DUM = a set of dummy variables to represent the occurrence of typhoons and cyclones, with value 1 to time spans when disasters were observed and 0 otherwise. These dummy variables are time and country variant. Some dummy variables are further combined based on Wald tests for parameter constraints.

γ and λ = country-specific heterogeneity. They can either be fixed effects or random effects in respective equations; and

u and v = independently and identically distributed error terms in respective equations.

The above two models are estimated based on a sample of 15 PICs over 1981-2012. To reduce short-term fluctuations' effects on obtaining robust estimation results, 4-yearly moving averages are used instead of annual data. Hence, the whole period 1981-2012 is divided into eight time spans: 1981-1984, 1985-1988, 1989-1992, 1993-1996, 1997-2000, 2001-2004, 2005-2008, and 2009-2012.

Data on net agricultural production are obtained from the World Bank database; data on net capital stock in agriculture, economically active population in agriculture, and arable land are from the FAO of the United Nations; data on growth of pure technical efficiency, growth of scale efficiency, growth of technology, and growth of total factor productivity are calculated by using the DEA approached presented in Section 4.1.

Given the number of time periods is less than the number of countries in the panel sample of the current study, the difference generalized method of moments (GMM-DIFF) and system generalized method of moments (GMM-SYS) estimators are employed to produce consistent estimation results. The GMM estimators separate fixed effects from idiosyncratic errors that are heteroskedastic and correlated within but not across individuals. These estimators instrument the differenced variables with all their available lags in levels, and instrument the untransformed variables with suitable lags of their own first differences (Arellano and Bond, 1998; Roodman, 2009). Furthermore, robust panel corrected standard errors are used to address the possibility of country-wise heteroskedasticity, and error autocorrelation is addressed by the employment of a second order autoregressive process.

INTEGRATION TESTS

Integration tests on individual panel variables are necessary in order to avoid the risk of obtaining spurious regression results. The Breitung panel integration test, testing the null hypothesis of non-stationary panels, yields test results as shown in Table 3.

TABLE 3: *Panel integration tests*

Variable	Time trend	Constant	Lambda	p-value
$\Delta \ln Y$	No	Yes	-3.3699	0.0004
$\Delta \ln K$	No	Yes	-3.9213	0.0000
$\Delta \ln P$	No	Yes	-2.9431	0.0016
$\Delta \ln L$	No	No	-6.2723	0.0000
TECHG	No	No	-6.8295	0.0000
PEG	No	No	-6.9335	0.0000
SEG	No	No	-8.6294	0.0000
TFPG	No	No	-6.9412	0.0000

Since the p-value in each Breitung test is less than the significance coefficient 0.01, the null hypothesis of non-stationarity is rejected at the 1 per cent significance level. This provides strong statistical evidence that all variables in Equations (9) and (10) are respectively integrated of order

0. The use of stationary variables does not lead to spurious regressions.

PANEL REGRESSION FINDINGS

The panel regression models as expressed in Equations (9) and (10) are each estimated by the GMM-DIF and GMM-SYS estimators. Estimation results are summarized in Table 4.

In general, all independent variables have expected effects on agriculture production growth; these independent variables are overall highly significant in all regressions; autocorrelation within countries is not evidenced as per the test results of the Arellano-Bond test for AR(2); overidentification of parameters in Equations (9) and (10) is confirmed by the Sargan test of overidentification; and exogeneity of instruments is evidenced by the difference-in-Sargan tests.

Focusing on independent variables' performance in the agriculture production growth models, the positive impact of $\Delta\ln K_{it}$ on $\Delta\ln Y_{it}$ is consistently evidenced across the four regressions with estimated coefficient ranging from 0.07 to 0.12. This suggests that, keeping other factors constant, a 10 percentage point increase in growth of net capital stock is associated with only around a rise of 1 percentage point in growth of net agriculture production. Also, such impact is statistically significant for at least the 10 per cent level. On the other hand, the negative impact of $\Delta\ln P_{it}$ on $\Delta\ln Y_{it}$, though consistent across the four regressions, is not statistically significant. The third factor input's growth, namely, growth of arable land $\Delta\ln L_{it}$, has a statistically significant and positive impact on growth of agriculture production; and the magnitude of such an effect is similar to that of net capital stock growth. Furthermore, typhoons and cyclones prove devastating to the agricultural sector. It is found that the occurrence of a natural disaster reduces the growth of agricultural production by 4 to 31 percentage points.

Turning to variables of interest, namely pure technical efficiency growth, scale efficiency growth, technological growth and total factor productivity growth, these productivity growth measures have expected positive coefficients in all regressions. More specifically, pure technical efficiency growth' positive impact is statistically significant at the 10 per cent level with an estimated magnitude of around 0.15. This suggests that a 10 percentage point rise in pure technical efficiency growth increases agriculture production growth by around 1.5 percentage points, other factors remaining fixed. Growth of the other efficiency component, that is, scale efficiency growth, also has a positive impact which is highly significant at the 1 per cent level. It is found that a 10 percentage point increase in scale efficiency growth is linked with an increase of around 1 percentage point in agriculture production growth, all else unchanged. As another component of productivity growth, technological growth proves important in contributing to agricultural production growth in Pacific Island countries. Technological growth's positive impact is less quantitatively significant than that of efficiency growth. The estimated coefficient of *TECHG*'s is around 0.05, suggesting that a 10 percentage point increase in technological growth is associated with an increase of 0.5 percentage points in growth of agricultural production (Columns 1 and 2 of Table 4). Total factor productivity, as the measure of productivity as a whole in the current study, its growth's impact on agricultural production growth is statistically evident. It is found that a rise of 10 percentage points in TFP growth would lead to a rise of around 0.6 percentage points in production growth in the agriculture sector of Pacific Island countries.

TABLE 4: *GMM Estimation of Impacts of Productivity Growth*

Dependent variable: $\Delta \ln Y_{it}$

Independent variable	Equation (9) GMM-DIF Coeff [z-stat]	Equation (9) GMM-SYS Coeff [z-stat]	Equation (10) GMM-DIF Coeff [z-stat]	Equation (10) GMM-SYS Coeff [z-stat]
Constant	-	-3.527 [-6.94] ***	-	-3.302 [-6.61] ***
$\Delta \ln K_{it}$	.070 [1.75] **	.122 [3.15] ***	.088 [2.18] **	.120 [3.32] ***
$\Delta \ln P_{it}$	-.273 [-1.21]	-.201 [-1.17]	-.253 [-1.04]	-.190 [-1.07]
$\Delta \ln L_{it}$	.111 [2.05] **	.084 [1.81] **	.106 [1.92] **	.080 [1.73] **
PEG_{it}	.158 [1.57] *	.128 [1.62] *		
SEG_{it}	.092 [3.23] ***	.109 [3.96] ***		
$TECHG_{it}$	.036 [1.63] *	.051 [3.05] ***		
$TFPG_{it}$			.047 [2.03] **	.060 [3.65] ***
$DUM1_{it}$	-21 [-13.08]***	-23 [-14.51] ***	-23 [-14.29]***	-21 [-12.91]***
$DUM2_{it}$	-25 [-10.78]***	-31 [-12.45] ***	-31 [-12.19]***	-25 [-10.62]***
$DUM3_{it}$	-10 [-12.05]***	-9 [-10.78] ***	-9 [-10.32]***	-10 [-11.38]***
$DUM4_{it}$	-6 [-9.11]***	-5 [-6.54] ***	-4 [-5.99]***	-6 [-8.15]***
Number of countries	15	15	15	15
Number of time spans	7	8	7	8
Wald chi-squared (*p*)	558.59 (0.000)	504.39 (0.000)	514.43 (0.000)	468.62 (0.000)
Number of instruments	17	23	17	21
Arellano-Bond for AR(1): z stat (*p*)	-4.12 (0.000)	-	-4.21 (0.000)	-1.08 (0.278)
Arellano-Bond for AR(2): z stat (*p*)	0.97 (0.331)	0.47 (0.638)	1.02 (0.306)	0.51 (0.607)
Sargan of overidentification chi-squared (*p*)	74.58 (0.302)	100.90 (0.130)	72.54 (0.244)	88.03 (0.332)
Difference-in-Sargan tests of exogeneity of instrument subsets				
Sargan test excluding group: chi-squared (*p*-value)	63.43 (0.291)	80.24 (0.083)	62.76 (0.194)	77.01 (0.128)
Difference (null H = exogenous): chi-squared (*p*)	11.15 (0.430)	20.67 (0.541)	9.78 (0.550)	11.02 (0.923)

Note: *, **, *** respectively represent significance at the 10 per cent, 5 per cent and 1 per cent levels. Significance level is decided by one-tailed hypothesis tests.

CONCLUSION AND POLICY SUGGESTIONS

The agrarian crisis in Pacific Island countries cannot be tackled if the factors that are responsible for creating the problems in agricultural growth are not well understood and the effective policies undertaken. A visionary plan is needed because agriculture contributes to development not only by providing good and raw materials to the population, but as productivity rises in agriculture, this sector also contributes to the supply of labor to the nonagricultural sectors, since higher rural income increases the demand for nonagricultural as well as agricultural products. Hence, understanding the pattern of agricultural productivity growth, which is the key component of long-run agricultural growth, is very important.

This study examines the impacts of productivity growth on production growth in the agriculture sector of Pacific Island countries. It clearly shows that there are differences in PICs' agricultural output growth, not only because these countries have accumulated different quantities of factors of production including capital, labor and arable land, but also because there is variation in the effectiveness with which they combine these factors of production to production output.

The above findings would generate more interest and discussion about the crucial aspect of technological progress that it allows agricultural economy to transcend the limitations imposed by diminishing returns. In addition, this study would also generate interest for further research to explore at the microeconomic level as to what could be the reasons of technical inefficiency in the agriculture sector resulting in sluggish growth in some PICs.

To boost sustainable agricultural development, policymakers in this region should,

(1) improve irrigation systems and road infrastructure to motivate agricultural producers;

(2) provide higher quality services such as efficient marketing arrangements to encourage commercial farming;

(3) improve quality and quantity of agricultural products; and

(4) develop the food processing industry to diversify agricultural products.

These will help agricultural producers explore new markets and expand production scale, and make it possible to reduce transportation costs of agricultural exports and shipping time. Consequently, scale efficiency would increase and agricultural producers would adopt advanced machinery and managerial skills.

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