Trade’s Impacts on Production Efficiency and Technology in Pacific Island Countries

Hong Chen, Biman Chand Prasad and Baljeet Singh

ABSTRACT

Pacific Island countries have relatively high level of openness measured by the trade-to-GDP ratio; yet they are faced with the difficulty of making progress in economic development. This raises the concern whether trade works effectively to enhance economic growth in PICs. Answer to this question is particularly important since these countries have limited domestic sources to boost economic growth. This study aims to provide an answer to the above question by assessing exports and imports’ impacts on production efficiency and technology. The non-parametric data envelopment analysis approach is employed to calculate efficiency and technology levels for seven Pacific Island countries over 1970-2009; this is followed by panel regression analyses to assess trade’s impacts on production efficiency and technology in these countries.

Key words: trade, total factor productivity, production efficiency, technology
INTRODUCTION

Economic expansion represents the sum of two sources of growth. On one side there are increases in ‘inputs’: growth in employment and in the stock of physical capital. On the other side are increases in the output per unit of input, i.e. productivity. As a measure of productivity, Total factor productivity is believed to be superior to labour productivity.\(^1\) The concept of TFP was firstly raised by Solow (1957), who identifies the changes in productivity with shifts in the production function. TFP, which is often referred to as the ‘Solow residual’ in the literature, addresses any effects in total output not explained by factor inputs and productivity. For instance, Solow (1957) defines TFP as a ‘sort of measure of our ignorance’; Abramovitz (1962) defines TFP growth as ‘the effect of “costless” advances in applied technology, managerial efficiency and industrial organisation’; and Denison (1967) regards TFP as ‘technological progress in the broadest sense’.\(^2\) Researchers such as Caves et al. (1982b) and Islam (1999) even distinguish TFP from technical advances; and some researchers such as Nishimizu and Page (1982) and Battese and Coelli (1995) further accurately decompose TFP into technological efficiency and technical progress.

Recent issues related to productivity improvement, new approaches to and adjustments in trade policies, the effect of trade on specialization, and the overall gains from trade, have led to an intense debate over trade liberalization and its impact on different economic variables. Using TFP instead of labour productivity allows us to assess the impact of trade on technological progress and efficiency improvement. The general consensus in trade theory maintains that trade results in a positive and sustained effect on economic growth due to increased efficiencies in the allocation of resources and economies of scale (Grossman & Helpman, 1991; Obstfeld & Rogoff, 1996). Trade theory also hypothesizes that trade expansion would lead to improved productivity (labour productivity as well as TFP) due to (1) gains stemming from economies of scale (Krugman, 1981; Grossman & Helpman, 1991). (2) Trade flows are an integral part of the process of opening up a country’s economy. Trade flows are considered as opportunities to boost economic activity. International trade allows the various countries to increase their productivity because it allows them to specialize according to their comparative advantages. (3) Recent advances in endogenous growth theory put the stress on the crucial importance of research and development and human capital for growth. According to this view, international trade and some other factors are considered as vectors allowing the diffusion of technical progress.

A number of empirical studies have confirmed the existence of a positive relationship between growth, or total factor productivity, and trade openness. Alcalá and Ciccone (2004), after looking at the effect of trade openness on labour productivity, conclude that trade has a significant and robust effect on labour productivity. Miller and Upadhyay (2000) contend that although no consensus has emerged, most past studies conclude that opening the economy to more trade enhances TFP. Coe and Helpman (1995) show that TFP in a given country depends not only on its domestic R&D stock, but also on the R&D stock of its trade partners. They show that the more open the country, the more important the relative role played by foreign R&D with respect to domestic R&D. Krueger (1997) strongly supports trade liberalization in DCs: comparing exports growth to GDP growth, she finds that the most open countries are, in the long run, also those who record the most impressive growth performances. Other empirical studies on the trade-

Despite the extensive debate on trade’s impact on growth, there is a limited literature on an explicit assessment of the relationship between trade, technological progress and efficiency improvement although the possibility has already been postulated in development theory (Marin, 1992; Ben-David & Loewy, 2003). In the empirical literature, findings of trade’s impact on TFP have been mixed. Cecchini and Lai-Tong (2008) find that international trade improves total factor productivity through technology transfer, while Abizadeh and Pandey (2009) and Liao and Liu (2010) found little evidence in support of the conventional export-led productivity hypothesis. The lack of consensus in empirical findings motivates our study of trade’s impact on TFP, in particular, for PICs.

PICs have generally achieved lower growth rates compared to other developing countries, and growth in the Pacific has been slower in the past two decades (Yang et al., 2013). Given the disadvantages of remoteness, smallness and limited natural resources, PICs are faced with a more difficult task of enhancing growth through incrementing factor inputs. Moreover, emigration of skilled workers is a common phenomenon in the Pacific, which though brings remittances but creates a huge loss of human capital. The other option left to promote growth is to seek increase in TFP.

PICs are generally open economies in terms of large ratio of trade-to-GDP. International trade plays an important role in regional and global integration process. On one hand it promotes efficiency in utilizing natural resources, scale of production and thus labour specialization; on the other hand it facilitates technology diffusion through flows of products and services. However, due to limited domestic sources, not all PICs have the competency of benefiting from international trade and hence improving production capacity. It is therefore important to assess whether international trade positively affects the Pacific small economies, particularly in the process of efficiency improvement and technological progress. By doing this, it not only identifies the channels through which trade contributes to economic development but also searches for feasibility of making appropriate policies and boosting growth for the Pacific region.

In this study we look at the effect of international trade on TFP evolution in ten PICs over 1970-2009. To measure TFP growth and its two components, namely technological progress and efficiency improvement, the non-parametric data envelop analysis approach is employed to calculate the Malmquist indices to serve our purpose. Compared with the traditional growth-accounting approach, the DEA approach avoids assumptions on production shares and returns to scale. It further avoids specifying functional forms and addressing estimation issues such as causality when compared with parametric regression analysis. This paper therefore makes an important contribution to the existing literature by filling the gap on the trade-TFP nexus analysis for PICs.

The present study is organized as follows. In Section 2, we explain the theoretical relationships between trade openness and TFP. A brief overview is given in Section 3 to discuss economic
performance and trade openness in PICs. Methodology and data are described in Section 4. In Section 5 we present calculated productivity indices. In section 6 impacts of exports and imports on productivity are respectively assessed by using regression analyses. Section 7 concludes and presents policy implications.

LITERATURE REVIEW

THE TRADE-PRODUCTIVITY NEXUS

The new endogenous growth models establish the links between long-run growth and technological progress, and provide a framework in which trade can permanently increase the rate of growth in the host country through technology transfer, diffusion and spillover effects. Romer (1994) points out that one benefit that trade brings is access to new ideas. Grossman and Helpman (1991) have constructed a theoretical model to show formally that trade in goods serves as a conduit for knowledge flows between countries. These flows in turn serve to increase the productivity of capital and labour, and hence increase growth rate of per capita output. In addition, the human capital building model as presented by Lucas (1988) may suggest that trade could enable inter-country technology transfers.

The benefits from free trade have been emphasised not only by traditional trade theory, but also by the new approaches that incorporate imperfect competition features. Wu (2003) examines the impact of trade openness on sources of growth and productivity in APEC economies. The study noted that openness not only improves technical efficiency but also the structure of technology. Butter, Mohlmann and Wit (2008) find that trade innovations play a crucial role in Netherlands by creating Total Factor productivity as well as technological innovations leading to productive efficiency. Kim et al. (2009) note that imports have considerably positive correlation on TFP growth in South Korea during 1980-2003. López (2005) and Wagner (2007) suggest that exporters can enhance productivity and growth through forward looking policies. Better access and exposure to foreign markets heighten productivity gains through ‘learning by exporting’.

Some papers, however, cast some doubt on the beneficial impacts from trade liberalization on development in developing countries. Wagner (2007) argues that exporting does not necessarily improve productivity. Iscan (1998) does not find any positive correlation of trade liberalization and productivity in Mexican manufacturing industries. Greenaway et al. (2002) make use of three different measures of liberalization and test a dynamic growth model on alternative developing country samples. They conclude that the beneficial impact of trade liberalization on per capita GDP may be realised but its size remains limited and it may come with a time lag. Choudhri and Hakura (2000) put the stress on the importance of the nature of specialization in developing countries: as long as the comparative advantage of developing countries probably lie in traditional sectors with low growth perspectives, unregulated international trade might restrict production to such sectors and eventually lead to lower productivity growth. Relying upon the ‘technological gap’ model of Krugman (1990), they conduct an empirical analysis on 33 developing countries and conclude that the stiffening of competition through higher imports promotes growth and global productivity only when this stiffening takes place in medium-growth
industries. In traditional industries (characterized by slower growth), as well as in high-tech sectors, a rise in imports has no impact on global productivity growth.

The abovementioned literature leads us to question the automatic nature of the beneficial effects from trade openness. In the light of mixed effects in both theoretical and empirical literature, examining trade’s impact on the second source of growth, i.e. TFP, becomes particularly important given limited sources of factor inputs in PICs.

THE MALMQUIST INDEX AND ITS APPLICATIONS

Several approaches to TFP studies have been found in the sophisticated literature since the emergence of this issue. Broadly the approaches can be classified into two categories: parametric and non-parametric approaches. Parametric approaches require model specification and econometric estimation but avoid assuming factor inputs shares. See, e.g. Islam (1999) demonstrating a panel-data regression and Lee and Cheng (2011) demonstration stochastic frontier production analysis. Non-parametric approaches generally avoid model specification and can be further classified into growth accounting approach which requires presumption on factor inputs shares (Kendrick, 1956; Solow, 1957; Denison, 1967; Abramovitz, 1993; Hall & Jones, 1999; and Abizadeh & Pandey, 2009) and non-parametric frontier production approaches which allow TFP to be generally decomposed into technological efficiency and technical progress (Krüger, 2003; Maudos et al., 2003; and Liao & Liu, 2010). Based on non-parametric frontier production analysis, researchers have built and developed a number of TFP indices such as Fisher ideal index, Divisia–Tornqvist index, Malmquist index and their variations. See Chen (2012) for summary on the types of approaches and their respective advantages and disadvantages.

The current analysis adopts calculating the Malmquist index, based on the data envelopment analysis of a frontier production function. The Malmquist index approach is widely applied in studies to measure productivity at the firm level, industry level and state level. Some of the studies on the Malmquist productivity growth index at the state and country levels are summarised in Table 1.

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample</th>
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<tr>
<td>Färe et al. (2006)</td>
<td>European Union (EU) area</td>
</tr>
</tbody>
</table>

international trade facilitates technological transfers is incorporated through the assumption that the technological gap of a given country in a given sector is inversely related to the openness rate in that sector. Long-run overall TFP growth rate is the production-weighted average of sector growth rates.
A number of empirical studies searching for determinants of productivity have also employed the Malmquist indices method. For instance, Maudos et al. (2000), who study convergence of productivity, find that technical change has worked against labour productivity convergence. Maudos et al. (2003), who investigate the role of human capital in the productivity gains of the OECD countries in the period 1965-1990, find that rich countries with greater endowment of human capital have higher rates of technical change. Yörük and Zaim (2005) find the evidence that international protocols help to reduce global emissions and country-specific effects on Malmquist–Luenberger productivity measures. Färe et al. (2006), who analyse the determinants of labour productivity in the European Union (EU) area, find that human capita plays a fairly minor role in enhancing productivity in the EU countries, and that there was more than one convergence clubs within the EU area. Chen and Singh (2012), based on a study for 11 Asian and Pacific countries over 1986-2007, find that important impacts of human capital augmented population and remittances on TFP are mainly through improving workers’ production efficiency. While using the Malmquist indices in regression analyses is popular, the current analysis will add contribution to the literature by assessing trade’s impacts on production efficiency and technology in the South Pacific region.

PACIFIC OVERVIEW ON GROWTH AND TRADE

PICs generally suffer from a high level of volatility due to their environmental vulnerability. Average growth rate of per capita GDP at 2005 constant prices in the Pacific varied from 2.61 percent per year over the decade 1970-1979 to 0.79 percent per year over the decade 1990-1999 (see Table 2). Volatility has also been evident within each Pacific Island country. Among the 10 PICs under study, Tuvalu, Marshall Islands and Kiribati are seen as the most volatile countries with highest ranges of real per capita GDP growth per year over the four decades (1970-1979, 1980-1989, 1990-1999 and 2000-2009) being 21.68, 8.68 and 8.36 percent respectively, while Fiji and Papua New Guinea are the least volatile countries with lowest ranges of real per capita GDP growth per year over the four decades being 3.29 and 3.33 percent respectively.

Table 2: Growth of Real per capita GDP in PICs over 1970-2009 (% constant 2005 prices)

<table>
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<tr>
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<tbody>
<tr>
<td>Fiji</td>
<td>3.69</td>
<td>0.40</td>
<td>2.15</td>
<td>0.41</td>
</tr>
<tr>
<td>Kiribati</td>
<td>2.64</td>
<td>-5.72</td>
<td>1.90</td>
<td>-0.04</td>
</tr>
<tr>
<td>Papua New</td>
<td>-1.09</td>
<td>-1.18</td>
<td>2.15</td>
<td>0.40</td>
</tr>
<tr>
<td>Samoa</td>
<td>3.06</td>
<td>-0.59</td>
<td>0.55</td>
<td>3.19</td>
</tr>
<tr>
<td>Solomon</td>
<td>5.58</td>
<td>-1.47</td>
<td>1.33</td>
<td>-1.19</td>
</tr>
<tr>
<td>Tonga</td>
<td>1.35</td>
<td>5.92</td>
<td>1.58</td>
<td>0.78</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>5.02</td>
<td>2.11</td>
<td>1.10</td>
<td>1.13</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>2.89</td>
<td>-0.08</td>
<td>1.54</td>
<td>0.67</td>
</tr>
</tbody>
</table>

Data source: authors’ calculation based on data from World Bank database.
The sample is chosen based on data availability.

Trade-to-GDP ratio in the Pacific as a whole has increased substantially over the last four decades (see Table 3). However, international trade in the Pacific lacks technology diffusion, since import products are mainly for household consumption while export products are mainly natural resources based.

Table 3: Growth of Real Imports, Exports and Trade in PICs (%)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Fiji</td>
<td>7.90</td>
<td>5.34</td>
<td>6.43</td>
<td>5.06</td>
</tr>
<tr>
<td>Kiribati</td>
<td>7.77</td>
<td>8.57</td>
<td>7.05</td>
<td>3.66</td>
</tr>
<tr>
<td>PNG</td>
<td>-0.09</td>
<td>12.71</td>
<td>3.76</td>
<td>1.45</td>
</tr>
<tr>
<td>Samoa</td>
<td>3.92</td>
<td>3.97</td>
<td>3.94</td>
<td>2.73</td>
</tr>
<tr>
<td>Solomon</td>
<td>13.41</td>
<td>24.67</td>
<td>17.46</td>
<td>11.29</td>
</tr>
<tr>
<td>Tonga</td>
<td>10.44</td>
<td>5.53</td>
<td>8.56</td>
<td>5.46</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>8.30</td>
<td>8.30</td>
<td>8.30</td>
<td>3.55</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>7.38</td>
<td>9.87</td>
<td>7.93</td>
<td>4.74</td>
</tr>
</tbody>
</table>

Source: authors’ calculation based on data from World Bank database.

Apart from the similarities of disadvantages discussed above, PICs differ from each other to a large extent in terms of culture, political and social environment, geographical feature and economic structure. The following context provides a brief discussion on background information of PICs under study.

Papua New Guinea is the largest country amongst the 14 Forum Island countries with significant natural resources. It has been able to achieve growth rates of more than 6 percent in the last four years mainly on the strength of exploiting mineral resources and the investment being undertaken in anticipation of the start of the LNG gas production. In addition, Papua New Guinea has benefited in the last several years from high commodity prices for its exports crops (coffee, cocoa and palm oil). It has also enjoyed high prices for its timber exports, gold, copper and petroleum. The recovery in the global economy in 2010 may have been temporary as the Eurozone crisis could further dampen consumer demand for these products and have an adverse impact on PNG’s economy and other Pacific Island economies. Fiji economic growth problems have been exacerbated by three factors in the last twenty five years. The average growth since 1987 has been around 2 percent. The military coup in December 2006 created a major shock to the economy. This shock plus the ill-conceived contractionary fiscal policy of the government in 2007 caused a negative 6.6 percent growth (Narayan & Prasad, 2008). The level of investment has also not increased in the last twenty five years. Over 2006-2012, the average investment to GDP ratio was only 15.6 percent (Asian Development Bank, 2013). The lack of confidence in the economy has been a major factor in explaining the low levels of investment. The plans for elections in 2014 under a new Constitution can inspire confidence in the economy and therefore the forecast for 2013 and 2014 could be better. The government has forecasted that the economy will grow by 2.7 percent in 2012. This may be an optimistic forecast given that the overall level of investment has been low.
Solomon Islands experienced growth rates of 5.4 and 6.4 percent in 2007 and 2008 respectively. The sources of growth mainly came from the exports of logs for which the prices have been rising. Vanuatu has over the past few years invested in the tourism infrastructure especially on the island of Santo. The result has been an increase in the number of tourist arriving in Vanuatu. In 2007 for example, tourism sector contribution to its GDP was 38.8 percent and provided 34.9 percent of total employment in the country. Vanuatu’s future growth will continue to be driven by tourism but there is also potential for small scale manufacturing dealing with value to the production from the agricultural sector. Vanuatu has recently developed a national trade policy framework which provides for policy intervention to improve production for export (Prasad & Giacomelli, 2012).

Both the Samoan and Tongan economies are showing signs of significant stress. In 2007 and 2008, the Samoan economy grew at a rate of 3.5 and 3 percent respectively. However, the projection for 2009 is negative 1 percent and in 2010 negative 0.1 percent. The forecast for the Tongan economy for 2011 was 4.7 percent and this has been revised downwards for 2012 to 1.3 percent. The Samoan economy has been affected by changes in the domestic front due to the impact of the global crisis. The tourism industry which was expected to drive growth in the Samoan economy is somewhat on the decline. The 2011 forecast was 2.1 and for 2012 it has been revised downwards to just 1 percent. Kiribati is severely affected by climate change. It has little natural resources and export potential. Remittances and foreign aid are becoming more and more important for this nation.

METHODOLOGY AND DATA

COMPUTATION OF THE MALMQUIST INDEX

The construction of the Malmquist index is based on the non-parametric data envelopment analysis (DEA) of the frontier production function, which was first introduced by Caves et al. (1982a) as a productivity index and has since been developed and used by, for example, Färe et al. (1994), and Krüger (2003).

Färe et al. (1994) construct the output-based Malmquist index of TFP change by assuming that for each time period \( t = 1, \ldots, T \), the production technology \( F_t \) models the transformation of inputs, \( x_t \in \mathbb{R}_+^N \), into outputs, \( y_t \in \mathbb{R}_+^M \),

\[
F_t = \{(x_t', y_t') : x_t' \text{ can produce } y_t' \}. \tag{1}
\]

The output distance functions are defined as

\[
D_o^t(x_t', y_t') = \inf\{\theta : (x_t', y_t' / \theta) \in F_t^t\} = (\sup\{\theta : (x_t', \theta y_t') \in F_t^t\})^{-1} \tag{2}
\]

where \( \theta \) 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 \( (x_t', y_t') \in F_t^t \). 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. In
the terminology of Farrell (1957), \( D^+_o(x', y') = 1 \) occurs when production is technically efficient. A similar definition is given by \( D^{+1}_o(x^{+1}, y^{+1}) \), the distance at period \( t + 1 \) relative to the CRS technology at \( t + 1 \).

In Figure 1, which exhibits variable returns to scale (henceforth ‘VRS’, i.e. increasing, constant or decreasing returns to scale), a scalar input is used to produce a scalar output. In the figure, observed production at \( t \) is interior to the boundary of technology at \( t \); that is, we say that \((x', y')\) is not technically efficient. The distance function seeks the reciprocal of the greatest proportional increase in the output, given the inputs, such that output is still feasible. In the diagram, maximum feasible production, given \( x' \), is at \((y'/\theta')\). The value of the distance function for our observation in terms of the distances along the y-axis is \( oa/ob \), which is less than 1. More generally, one may write the value of the distance function for observation \((x', y')\) as \( \|y'\|/\|y'/\theta'\| \).

\[
\text{Figure 1: The Malmquist output-based index and output distance functions}
\]

\[
\begin{align*}
F^+_t & = \left[ \frac{D^+_t(x^+, y^+)}{D^+_o(x^+, y^+)} \right] \left[ \frac{D^+_t(x', y')}{D^+_o(x', y')} \right]^{1/2} (3)
\end{align*}
\]

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

\[
M_o(x^{+1}, y^{+1}, x', y') = \frac{D^{+1}_o(x^{+1}, y^{+1})}{D^+_o(x', y')} \left[ \left( \frac{D^+_t(x^{+1}, y^{+1})}{D^+_o(x^{+1}, y^{+1})} \right) \left( \frac{D^+_t(x', y')}{D^+_o(x', y')} \right) \right]^{1/2}
\]

The ratio outside the brackets measures the change in relative efficiency (that is, the change in the distance of observed production from maximum potential production) between \( t \) and \( t + 1 \) and therefore captures the ‘catching-up’ progress to the frontier.

\[
\text{Source: Authors’ improvement based on Färe et al. (1994)}
\]
EC = \frac{D_o^{t\rightarrow t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}, \quad (4)

where \( EC \) represents the efficiency change.

The geometric mean of the two ratios inside the brackets captures the shift in technology between the two periods evaluated at \( x^t \) and \( x^{t+1} \) and therefore quantifies ‘innovation’ or technical change,

\[
TC = \left[ \left( \frac{D_o^t(x^t, y^t)}{D_o^{t\rightarrow t+1}(x^{t+1}, y^{t+1})} \right) \left( \frac{D_o^{t\rightarrow t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})} \right) \right]^{1/2} \quad (5)
\]

where \( TC \) represents technical change. Hence, as we have seen, TFP-change is represented by the Malmquist index and it is the product of efficiency change and technical change:

\[ M_o(x^{t+1}, y^{t+1}, x^t, y^t) = TFPC = EC \cdot TC \quad (6) \]

In terms of the distances along the y-axis in Figure 1, which exhibits technologies of variable returns to scale, the Malmquist index (3) is

\[ M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \left( \frac{od}{of} \right) \left( \frac{ob}{oa} \right) \left[ \left( \frac{of}{oe} \right) \left( \frac{oc}{ob} \right) \right]^{1/2} \quad (7) \]

In Equation (7), \( od / of \) represents the distance at period \( t + 1 \) relative to the same period CRS DEA frontier, i.e. technical efficiency rate at \( t + 1 \); \( oa / ob \) represents the distance at period \( t \) relative to the same period CRS DEA frontier, i.e. technical efficiency rate at \( t \). The ratio of the two efficiency rates captures the change in technical efficiency, i.e. whether production is getting closer to or further from the frontier. The first ratio inside the brackets in Equation (7), \( of / oe \), represents the shift in technology at input level \( x^{t+1} \); and the second ratio, \( oc / ob \), the shift in technology at input level \( x^t \). The geometric mean of those two shifts measures technical change.

Turning to the interpretation of the Malmquist index and its two components, a Malmquist index greater than 1 represents improvements in TFP, while a Malmquist 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.

In order to apply this theoretical device to real data for inputs and output and to calculate TFP-change and its two components, we need to quantify the four distance functions under the VRS technology for each country in each year: \( D_o^t(x^t, y^t), D_o^{t\rightarrow t+1}(x^{t+1}, y^{t+1}), D_o^{t\rightarrow t+1}(x^{t+1}, y^{t+1}), D_o^{t+1}(x^{t+1}, y^{t+1}) \).

On the basis of Equations (3), (4) and (5), all the indices of TFP-change and its elementary components (\( EG, TG \) and \( TFPG \)) can be obtained as follows:
5.1 Productivity Growth

Looking at growth of productivity changes at the regional level (last column of Table 4), efficiency in the seven countries as a whole grew most significantly over the decade 1990-2000 with a rate of 1.13 per cent per annum, while over 1970-1980 efficiency decreased severely at an average rate of 2.09 per cent per annum. There was hardly technology progress in the seven countries as a whole; instead, technology on average decreased by 0.17 per cent per annum over the entire 1970-2009 time period. These overall averages are geometric means since Malmquist indices are defined as the geometric average of the distance from the CRS DEA frontier to the production frontier over a period of time.

The country-level data needed to calculate TFP-change and its components come from World Bank database. The sample covers 7 Pacific island countries over the period 1980-2009. Series required for the analysis include:

In terms of the distances along the y-axis in Figure 1, which exhibits technologies of variable returns to scale, it is evident that the DEA frontier is not parallel to the production frontier. Both are parallel, however, to the CRS DEA frontier. The first ratio inside the brackets in Equation (7), the output elasticity with respect to each factor, is greater than 1 and deterioration is associated with component indices of less than 1.

\[ EG = \left( \prod_{t=t_1}^{t_2} EC_{yr}^{t} \right)^{1/(t_2 - t_1 + 1)} - 1 \cdot 100 \]  
\[ TG = \left( \prod_{t=t_1}^{t_2} TC_{yr}^{t} \right)^{1/(t_2 - t_1 + 1)} - 1 \cdot 100 \]  
\[ TFPG = \left( \prod_{t=t_1}^{t_2} TFP_{yr}^{t} \right)^{1/(t_2 - t_1 + 1)} - 1 \cdot 100 \]

Cumulated levels of efficiency, technology and TFP can be obtained accordingly:

\[ CUMEFF_{k}^{t+N} = D_{k}^{t}(x_{k}^{t}, y_{k}^{t}) \cdot \prod_{t+1}^{t+N} EC_{k}^{t+N} \]  
\[ CUMTECH_{k}^{t+N} = D_{k}^{t}(x_{k}^{t}, y_{k}^{t}) \cdot \prod_{t+1}^{t+N} TC_{k}^{t+N} \]  
\[ CUMTFP_{k}^{t+N} = D_{k}^{t}(x_{k}^{t}, y_{k}^{t}) \cdot \prod_{t+1}^{t+N} TFP_{k}^{t+N} \]

DATA

The country-level data needed to calculate TFP-change and its components come from World Bank database. The sample covers 7 Pacific island countries over the period 1980-2009. Series required for the analysis include:

GDP, the output variable, measured by real GDP at constant 2005 prices.

Pop, the labour input. Due to limited data on labour force and population of age 15-64, together with the fact that the informal sector plays an important role in the Pacific economies, total population is used for the labour input.

K, the capital input. This series is calculated by means of the perpetual inventory method, based on data on gross fixed capital formation at constant 2005 prices I, the capital stock at year 1970 approximated by \[ I_{1980} \times 10 \] and used as the benchmark capital stock, and capital stock depreciation rate of 6 percent.
PRODUCTIVITY INDICES

PRODUCTIVITY GROWTH

Instead of presenting the disaggregated results for each country and year, we provide a summary description of the average performance of each country and the Pacific region as a whole over the entire 1970-2009 time period. These overall averages are geometric means since Malmquist indices are multiplicative.

Looking at growth of productivity changes at the regional level (last column of Table 4), efficiency in the seven countries as a whole grew most significantly over the decade 1990-2000 with a rate of 1.13 per cent per annum, while over 1970-1980 efficiency decreased severely at an average rate of 2.09 per cent per annum. There was hardly technology progress in the seven countries as a whole; instead, technology on average declined over the first three decades 1970-2000. Over the whole period 1970-2009 TFP in the seven countries declined at an average rate of 0.54 per cent per annum, mainly contributed by negative technology growth. These findings suggest that economic development in the Pacific region was mainly contributed by factor inputs.

Turning to country-specific discussion, sluggishness, variation and turbulence are main features of these small economies. Fiji’s best performance over the past four decades was seen in the first decade 1970-1980 with TFP growth of 0.6 percent per annum, while the least progress was seen in the second decade 1980-1990 with TFP growth of -0.3 percent per annum – a decade with high levels of political instability and high frequency of natural disasters. Variation in TFP growth is mainly caused by variation in technological progress, and it is interesting to note that Fiji didn’t make any progress in production efficiency over 1970-2009.

Kiribati is the country which suffers the most severe productivity downturn among the seven countries under study. Kiribati experienced severe decline in efficiency over 1970-1980, followed by recovery of efficiency improvement over 1980-2000. Technology grew slowly in Kiribati over 1970-1980 and 2000-2009 while there was severe decline in efficiency over 1980-2000. On average, production efficiency in Kiribati declined by 0.6 per cent and technology declined by 0.4 per cent per annum over 1970-2009.

TFP growth in Papua New Guinea fluctuates significantly over the last four decades – it was negative before 1990 and turned positive after 1990; so was efficiency growth. There was hardly technology progress in Papua New Guinea; negative technology progress was even seen over 1980-2000. On average, production efficiency in Papua New Guinea declined by 0.13 per cent and technology declined by 0.63 per cent per annum over the whole period 1970-2009.

TFP progress and efficiency improvement in Samoa were similar to those in Papua New Guinea – they were negative before 1990 and turned positive after 1990. Technology decline was seen over the four decades 1970-2009. On average, production efficiency in Samoa declined by 0.13 per cent and technology declined by 0.48 per cent per annum over the whole period 1970-2009.

Solomon Islands is another economy which suffers from TFP worsening. There was neither efficiency improvement nor technology progress in this country before 2000. Production efficiency and technology grew slowly at rates of 0.9 and 0.2 per cent per annum respectively in
the new millennium 2000-2009. On average, production efficiency in Solomon Islands declined by 0.25 per cent and technology declined by 0.55 per cent per annum over the whole period 1970-2009. This implies that achievement in economic development in Solomon Islands was mainly contributed by exploiting natural resources.

Tonga is known by its relatively high education level in the Pacific. However, the Tongan economy does not benefit from this advantage – reason could be found from the severe loss of skilled people due to emigration. Despite the highest average economic growth rate of 2.41 percent per annum over 1970-2009 among the seven PICs, Tonga’s TFP deteriorated with an average rate of -0.53 percent per annum over the same period. Efficiency drop and technology downturn equally explained productivity recession.

Vanuatu has the second fastest economic growth with an average rate of 2.34 percent per annum over the entire period. It is interesting to note that the first decade 1970-1980 witnessed the highest economic growth rate of 5.02 percent and at the same time the most severe production efficiency and technology, suggesting an overwhelming contribution to the economic development comes from increments of factor inputs. Production efficiency over 1980-1990 grew at a rate of 1 per cent, followed by stagnant efficiency improvement in the last two decades. Technology declined in the first three decades and grew at a low rate of 0.2 per cent per annum in the new millennium. On average, production efficiency in Vanuatu was stagnant while technology declined by 0.38 per cent per annum over the whole period 1970-2009.

In terms of productivity’s contribution to economic growth, out of seven countries under study, Fiji has seen the significant contribution of TFP. With the facility of technological diffusion brought by international trade, TFP contributed to 17.8 per cent of total economic growth over 1970-2009. The other six countries were all found to suffer from productivity downturn and therefore had converse contribution from efficiency and technology.
Table 4: Growth of Efficiency, Technology and TFP over 1970-2009 (%)

<table>
<thead>
<tr>
<th>Period</th>
<th>Variable</th>
<th>Fiji</th>
<th>Kiribati</th>
<th>Papua New Guinea</th>
<th>Samoa</th>
<th>Solomon Islands</th>
<th>Tonga</th>
<th>Vanuatu</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>EG</td>
<td>0</td>
<td>-7.8</td>
<td>-3.5</td>
<td>-1.4</td>
<td>0</td>
<td>-0.9</td>
<td>-1</td>
<td>-2.09</td>
</tr>
<tr>
<td></td>
<td>TG</td>
<td>0.6</td>
<td>0.6</td>
<td>0</td>
<td>-0.8</td>
<td>0</td>
<td>-0.5</td>
<td>-0.6</td>
<td>-0.10</td>
</tr>
<tr>
<td></td>
<td>TFPG</td>
<td>0.6</td>
<td>-7.3</td>
<td>-3.5</td>
<td>-2.2</td>
<td>0</td>
<td>-1.4</td>
<td>-1.5</td>
<td>-2.19</td>
</tr>
<tr>
<td>1980</td>
<td>EG</td>
<td>0</td>
<td>2</td>
<td>-0.5</td>
<td>-1.4</td>
<td>-1</td>
<td>0.1</td>
<td>1</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>TG</td>
<td>-0.3</td>
<td>-1.4</td>
<td>-0.7</td>
<td>-0.2</td>
<td>-0.9</td>
<td>0.4</td>
<td>-0.5</td>
<td>-0.51</td>
</tr>
<tr>
<td></td>
<td>TFPG</td>
<td>-0.3</td>
<td>0.6</td>
<td>-1.2</td>
<td>-1.6</td>
<td>-1.9</td>
<td>0.5</td>
<td>0.5</td>
<td>-0.49</td>
</tr>
<tr>
<td>1990</td>
<td>EG</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>1.5</td>
<td>-0.9</td>
<td>0.3</td>
<td>0</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>TG</td>
<td>0.2</td>
<td>-1</td>
<td>-2</td>
<td>-0.5</td>
<td>-1.5</td>
<td>-0.4</td>
<td>-0.6</td>
<td>-0.83</td>
</tr>
<tr>
<td></td>
<td>TFPG</td>
<td>0.2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>-2.3</td>
<td>-0.1</td>
<td>-0.6</td>
<td>0.31</td>
</tr>
<tr>
<td>2000</td>
<td>EG</td>
<td>0</td>
<td>-0.6</td>
<td>0.5</td>
<td>0.8</td>
<td>0.9</td>
<td>-0.5</td>
<td>0</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>TG</td>
<td>0.5</td>
<td>0.2</td>
<td>0.2</td>
<td>-0.4</td>
<td>0.2</td>
<td>-0.5</td>
<td>0.2</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>TFPG</td>
<td>0.5</td>
<td>-0.4</td>
<td>0.7</td>
<td>0.4</td>
<td>1</td>
<td>-1.1</td>
<td>0.2</td>
<td>0.19</td>
</tr>
<tr>
<td>1970</td>
<td>EG</td>
<td>0.00</td>
<td>-0.60</td>
<td>-0.13</td>
<td>-0.13</td>
<td>-0.25</td>
<td>-0.25</td>
<td>0.00</td>
<td>-0.19</td>
</tr>
<tr>
<td></td>
<td>TG</td>
<td>0.25</td>
<td>-0.40</td>
<td>-0.63</td>
<td>-0.48</td>
<td>-0.55</td>
<td>-0.25</td>
<td>-0.38</td>
<td>-0.35</td>
</tr>
<tr>
<td></td>
<td>TFPG</td>
<td>0.25</td>
<td>-1.03</td>
<td>-0.75</td>
<td>-0.60</td>
<td>-0.80</td>
<td>-0.53</td>
<td>-0.35</td>
<td>-0.54</td>
</tr>
</tbody>
</table>

Note: EG = efficiency growth; TG = technology growth; and TFPG = TFP growth.

Cumulated productivity levels are further calculated by using Equations (11), (12) and (13) to exhibit trends of production efficiency, technology and TFP over time. Note that the three productivity indices are in comparison of benchmark unity. A value less than 1 suggests downturn in efficiency, technology or TFP, which is equivalent to a negative growth rate in changes of these three measures.

Given varied productivity growth across the seven countries as discussed in Section 5.1, cumulated productivity levels should vary significantly as well across PICs. Cumulated efficiency, technology and TFP level indices are respectively presented in diagrams in Figure 2. We clearly see that, Fiji is most efficient among PICs with the cumulated efficiency index of 0.99, followed by Vanuatu (0.97), Tonga (0.91), Solomon Islands (0.9), Samoa (0.84), Papua New Guinea (0.81) and Kiribati (0.71) in the order of cumulated efficiency level.

With respect to the cumulated technology level, we see from diagrams in Figure 3 that Fiji had the highest cumulated technology level among the seven PICs with the average index of 1.11, followed by Tonga (1), Kiribati (0.96), Vanuatu (0.95), Samoa and Solomon Islands (0.93), and Papua New Guinea (0.92). The indices show that only Fiji made slight technological progress over the entire period, while the other six countries suffered from either technology stagnancy or recession.
Figure 2: Indices of Cumulated Efficiency Level over 1970-2009
Figure 3: Indices of Cumulated Technology Level over 1970-2009
Figure 4: Indices of Cumulated TFP Level over 1970-2009

- Cumulated TFP - Papua New Guinea
- Cumulated TFP - Tonga
- Cumulated TFP - Kiribati
- Cumulated TFP - Solomon Islands
- Cumulated TFP - Vanuatu
- Cumulated TFP - Fiji
- Cumulated TFP - Samoa
Evolution of cumulated TFP levels is the combination of cumulated efficiency and cumulated technology levels distributions. Diagrams in Figure 4 show all of the seven countries suffered from severe fluctuations in total factor productivity over the entire period. Except for Fiji and Tonga, the remaining five countries generally experienced productivity downturn.

**TRADE’S IMPACT ON PRODUCTIVITY**

To assess trade’s impacts on efficiency and technology, exports and imports’ impacts are individually considered in the following panel framework:

\[
Y_{i,t} = \beta_{i,0} + \beta_1 L\text{EXPORT}_{i,t} + \beta_2 L\text{IMPORT}_{i,t} + \epsilon_{i,t}
\]

where \(Y\) is a vector including cumulated efficiency (\(CUMEFF\)), cumulated technology (\(CUMTECH\)) and cumulated TFP (\(CUMTFP\)); \(L\text{EXPORT}\) is natural logarithmic real exports of goods and services; \(L\text{IMPORT}\) = natural logarithmic real imports of goods and services; and subscripts \(i\) and \(t\) respectively denote country and year. In this panel framework country specific heterogeneity is captured by the fixed effects, \(\beta_{i,0}\).

The Levin-Lin-Chu (LLC) unit-root test is used to test for stationarity of productivity indices and trade variables, followed by the generalized method of moments (GMM) estimation. In the LLC unit root tests, one lag is included to address potential autocorrelation in test regressions and panel-specific means are included. The LLC test results, based on dataset covering seven countries over 1971-2009, are summarized in Table 5. Since all \(p\)-values are less than, say 5% significance level, the null hypothesis that panels contain unit roots is rejected, leading to the conclusion that all the five variables, namely, cumulated efficiency, cumulated technology, cumulated TFP, logarithmic export and logarithmic import, are stationary at the 5% significance level. This allows us to run regressions involving the five variables without the risk of producing spurious regression results.

**Table 5: The Levin-Lin-Chu Unit Root Tests**

<table>
<thead>
<tr>
<th>Variable</th>
<th>CUMEFF</th>
<th>CUMTECH</th>
<th>CUMTFP</th>
<th>LEXPORT</th>
<th>LIMPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjusted (t) stat</td>
<td>-3.5788</td>
<td>-4.2493</td>
<td>-2.4564</td>
<td>-3.2084</td>
<td>-2.3078</td>
</tr>
<tr>
<td>(p)-value</td>
<td>0.0002</td>
<td>0.0000</td>
<td>0.0070</td>
<td>0.0007</td>
<td>0.0105</td>
</tr>
</tbody>
</table>

In the GMM estimation of Equation (14), the first and second order differences of explanatory variables are used as external instrumental variables to control for potential endogeneity of explanatory variables. The Hansen J statistic is employed to test for validity of instrumental variables and overidentification of parameters, and Hausman test statistic is employed to test for exogeneity of explanatory variables that are instrumented. Regression results as summarized in Table 6.
Table 6: Estimation of Trade’s Impacts on Production Efficiency and Technology

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>1. CUMEFF</th>
<th>2. CUMTECH</th>
<th>3. CUMTFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanatory variable</td>
<td>Coeff. (p-value)</td>
<td>Coeff. (p-value)</td>
<td>Coeff. (p-value)</td>
</tr>
<tr>
<td>LEXPORT</td>
<td>.382 (2.50)**</td>
<td>.176 (1.20)</td>
<td>.558 (2.21)**</td>
</tr>
<tr>
<td>LIMPORT</td>
<td>.351 (1.32)</td>
<td>.248 (0.95)</td>
<td>.556 (1.17)</td>
</tr>
<tr>
<td># of countries</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Root MSE</td>
<td>.2890</td>
<td>.2732</td>
<td>.5038</td>
</tr>
<tr>
<td>Hansen $\chi^2$ stat (p-value)</td>
<td>0.761 (0.6834)</td>
<td>0.455 (0.7964)</td>
<td>0.620 (0.7335)</td>
</tr>
<tr>
<td>Hausman $\chi^2$ stat (p-value)</td>
<td>24.810 (0.0000)</td>
<td>14.918 (0.0006)</td>
<td>33.406 (0.0000)</td>
</tr>
</tbody>
</table>

Note: ** denotes significance at the 5% level.

Since all p-values from Hansen J tests are greater than, say 5% significance level, the null hypothesis of valid instruments and overidentification of parameters is not rejected. And all p-values from Hausman tests are greater than 5% significance level; the null hypothesis of exogeneity of explanatory variables is rejected, leading to the conclusion that LEXPORT and LIMPORT are endogenous and the GMM estimation of Equation (14) avoid biased estimates caused by endogeneity.

According to regression results in Table 6, exports significantly promote production efficiency in PICs; exports’ positive impact on technology is not statistically significant (Column 1). Imports have positive impacts on production efficiency and technology; however such impacts are not statistically significant (Column 2). To summarize, exports significantly enhance total factor productivity, while there lacks statistical evidence that imports are helpful in promoting total factor productivity in the seven PICs (Column 3).

CONCLUSION

As small economies limited generally by scarce resources, distant from major markets, PICs have generally experienced difficulty in boosting economic growth. Our analysis shows that that production efficiency and technology have deteriorated in the Pacific as a whole, with the exception of Fiji which made a limited technological progress. Given that most PICs have limited domestic sources for growth, exploring ways to improve total factor productivity is essential for sustainable economic growth.

Our analysis suggests that there is significant potential for PICs to raise production efficiency through increasing exports; and governments of these economies should make greater efforts to import products which are helpful in promoting technological spillover in productive sectors. This calls for speeding up the progress towards a deeper and meaningful regional integration and inter-regional integration to enhance trade volume of PICs. While some progress has been made under the Pacific Island Countries Trade Agreement (PICTA) where an agreement has
been signed in trade in services, that involving trade in goods remains under discussion and could remain a constraint for enhancing trade in the future.

The membership of the WTO of some PICs in this study also provides opportunities for enhancing trade through carefully sourcing aid-for-trade to improve trade facilitation and build capacity in these countries for export. Contribution of the services sector to GDP in PICs provides significant opportunity for economic growth. Apart from tourism, PICs could enhance the export of other kinds of services and these could include ‘weightless’ products such as accounting services, engineering services, editorial services etc. For these, PICs would need to enhance their Information, Communication and Technology infrastructure to support investment in the services sector.

NOTE

1 Partial productivity measures have long been criticised for their incomplete picture of performance, thereby causing misleading analysis. It would be difficult to distinguish whether labour productivity being high in a sector is because of a high degree of technological efficiency or because of a large stock of physical capital, given that labour productivity fails to capture all of the influences on productivity. TFP growth, on the other hand, measures the ratio of output to the sum of all basic inputs, and therefore, mitigates the impact of factor substitution and scale economies (Liao & Liu 2010).

2 Hall and Jones (1996), however, equalize TFP to labour productivity.

3 Endogenous growth theory considers this possibility. Grossman and Helpman (1991, chaps. 18 and 19) set out several cases where free trade leads to lower productivity growth in technologically backward countries.

4 There are three sectors, and each of them has its own constant rate of technical progress (one sector has slow technical progress, another one has medium technical progress and the third one has fast technical progress). Least developed countries have access to the best technologies, but with a longer time lag. They have, therefore, a comparative disadvantage in those sectors where productivity growth is the strongest. The idea according to which international trade facilitates technological transfers is incorporated through the assumption that the technological gap of a given country in a given sector is inversely related to the openness rate in that sector. Long-run overall TFP growth rate is the production-weighted average of sector growth rates.

5 For a description of how political instability may have caused poor economic performance see Prasad (2012).
REFERENCES


