8-2016

# The Association of Southeast Asian Nations Agricultural Total Factor Productivity, 1961-2011

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# The Association of Southeast Asian Nations Agricultural Total Factor Productivity, 1961-2011

by

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A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Agricultural Economics

Under the Supervision of Professor Lilyan E. Fulginiti

Lincoln, Nebraska

August, 2016

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University of Nebraska, 2016

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This article estimates agricultural total factor productivity (TFP) growth in eight Southeast Asian nations over the time period of 1961-2011, using panel data. This study is concerned with investigating whether the recent slowdown in agricultural productivity growth exhibited by affluent societies extends to this region. Three approaches for measuring agricultural total factor productivity growth are used. First, a non-parametric Simple TFP, output, and input index is calculated. Second, a non-parametric non-stochastic Malmquist index is calculated using data envelopment analysis techniques. Finally, an econometric true fixed effects stochastic frontier model is estimated using a maximum likelihood procedure. Aggregate measures of TFP over the study period for the Simple index, Malmquist index, and stochastic frontier were found to be 2.65%, -0.31%, and 0.98% growth respectively. Through these three methods of measuring agricultural total factor productivity growth our results are inconclusive and need further examination.

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**Introduction**

According to the Population Reference Bureau (PRB), the current global population is 7.3 billion and is estimated to reach a population of 9.8 billion by 2050 (PRB, 2015). 852 million of those currently living on the planet, or roughly one out of eight, are undernourished (FAO, 2015). This figure, published by the Food and Agriculture Organization (FAO), while large is actually a significant improvement over the previous estimate. From 1990-92 and 2000-12, the number of hungry people in the world decreased by 132 million, or fell from 18.6% to 12.5% of the global population (FAO, 2015). This is an encouraging improvement, however, it is clear there is still much work to be done before global malnourishment is remedied.

The task of feeding the world's current population of 7.3 billion is great, but with another 2.5 billion added by 2050, the feelings of trepidation start to sink in. This additional 2.5 billion people will not have the same consumer preferences as previous generations. The new populace will demand larger amounts of meats in their diet, meaning increasing demand for feed and consequently demand for agricultural production.

Agricultural productivity on regional, national, and global scales has been a popular topic of conversation in academia. The growth rates of agricultural productivity are of special interest for two reasons. First, to feed an increasing population, the world will need to produce more food. An increase in food production must come from either increases in productivity or expansion of production; with global warming and other environmental concerns becoming more relevant each day, it would be more

advantageous to realize this increase in production through the former rather than the latter. The second reason agricultural productivity growth rates are of special interest is because many studies have identified decreases in yield growth rates for high and middle-income countries during the last few decades (Alston et al., 2010, Fuglie, 2010, and World Bank Development Report, 2007). Alston et al. also identify decreases in total factor productivity (*TFP*) growth rates in advanced economies. Slower productivity growth rates could lead to growth in demand outstripping growth in supply causing consequences for both food prices and food security. Feeding the estimated addition of 2.5 billion people by 2050 will be increasingly difficult if this slowdown in agricultural productivity extends to developing nations.

Growth in productivity accounts for growth in output not attributable to growth in inputs. Increases in inputs do lead to increases in output; however, it is innovation that leads to sustainable increases in output. Agricultural productivity is usually measured by changes in *TFP*, with *TFP* being defined as the ratio of outputs to all inputs (Trindade & Fulginiti, 2014).

The main objective of this paper will be to identify if the slowdown in agricultural productivity observed in developing countries extends to nations in the Southeast Asian region of the world. This region of the world was chosen because it is lacking in agricultural productivity research present in many other regions of the world. To the best of my knowledge, there have been no recent studies done on this region concerning agricultural *TFP*.

The Association of Southeast Asian Nation's (ASEAN) is composed of 10 member states: Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic

Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam. However, this paper does not include the nations of Singapore and Brunei Darussalam. These two nations were excluded because they have insignificant agricultural production when compared to other nations in the region.

This paper uses three different approaches to measure changes in agricultural *TFP* from 1961-2011 and examines whether there is a slowdown in agricultural productivity growth rates in the region. First, a Simple *TFP* index is calculated and compared with results from Fuglie's work. Second, a non-parametric, non-stochastic Malmquist index is found. Finally, an econometric maximum likelihood stochastic frontier (MLSF) method is implemented.

I would also like to note that this paper is based upon two previous works. The Simple *TFP* index is predominately based on Fuglie (2008). The Malmquist and Stochastic Frontier approaches follow Trindade and Fulginiti (2014). This paper follows the procedures and structure present in these two papers very closely, and this is meant to suffice as a general acknowledgement to the authors.

**Models**

This paper is focused on the potential of a decrease in the rates of productivity growth in the most recent years of the time series data, which has been observed by other authors in high and middle-income countries. There are advantages and limitations to every method of estimating productivity growth; this paper uses three methods to compare results across methods and provides for a check of results.

*Simple Index*

Two types of productivity measure are partial and multifactor indices. Partial productivity indices relate output to a single input. In agriculture, a partial productivity index would relate output to a single input, such as fertilizer or machinery. While these types of measures are useful to indicate factor-saving biases in technical change, they are likely to overestimate the overall improvement in efficiency since they do not consider changes in other inputs. A measure of *TFP* that relates output to all inputs used in production, gives a better indication of efficiency than partial indices of productivity.

*TFP*, in this section, is defined as the ratio of total output to total inputs. Letting total output be represented by *Y* and total inputs by *X*, *TFP* can be written as:

$$TFP = \frac{Y}{X} \qquad (1).$$

However, we are concerned with changes in *TFP* over time. This can be found by comparing the rate of change in total output with the rate of change in total inputs. Expressing equation (1) in logarithmic form changes in *TFP* over time can be written as:

$$\frac{dln(TFP)}{dt} = \frac{dln(Y)}{dt} - \frac{dln(X)}{dt} \qquad (2).$$

This equation states that the rate of change in *TFP* is the difference between the rate of change in outputs to inputs.

Agricultural output is composed of a multitude of commodities that are produced by a multitude of inputs. This means that *X* and *Y* are vectors, not singular variables. In his 1988 paper, Chambers shows that when the underlying technology can be represented by a Cobb-Douglas production function, and where (i) producers maximize profits so that output elasticities equal input shares in total cost and (ii) markets are in long-run

competitive equilibrium so that total revenue equals total cost, then equation (2) can be written as:

$$\ln\left(\frac{TFP_t}{TFP_{t-1}}\right) = \sum_i R_i \ln\left(\frac{Y_{i,t}}{Y_{i,t-1}}\right) - \sum_j S_j \ln\left(\frac{X_{j,t}}{X_{j,t-1}}\right) \qquad (3),$$

where $R_i$ is the revenue share of the $i$-th output and $S_j$ is the cost share of the $j$-th input.

Output growth is found by summing the growth rate of each commodity, weighted by revenue shares. Input growth is found by summing the growth rate of each input, weighted by its cost share. From equation (3), *TFP* is the difference between the growth in aggregate output and aggregate input. In this index, *TFP* revenue and cost shares are held constant. Using fixed revenue and factor shares could potentially allow for the occurrence of 'index number bias' in cases where revenue or cost shares are changing significantly. Furthermore, cost shares are partially dependent upon output prices since a part of agricultural production is used as factors of production.

A significant limitation of equation (3) is that data on input cost shares for most countries is nonexistent. It is not possible to make international comparisons of input prices since there is no internationally comparable data, especially in the case of non-traded inputs. To combat this issue, this paper uses the cost share values Fuglie (2008) develops for Southeast Asia. The cost share values that Fuglie and this paper use for Southeast Asia were found by the procedure outlined by Avila and Evenson (2004).

In summation, the Simple *TFP* productivity index assumes that producers maximize profits so that the elasticity of output with respect to each input is equal to its' factor share. Furthermore, this index assumes that markets are in long-run equilibrium, meaning that total revenue equals total cost. If the underlying production function is

indeed Cobb-Douglas, then our index is a representation of Hicks-neutral technical change.

To obtain aggregate measures of output, input, and *TFP* growth rates for the ASEAN region countries' annual growth rates are weighted by annual output share for the region, the summation of these weighted values is then found to realize the aggregate growth rates for the entire study region.

*Input cost/factor shares*

As mentioned above Fuglie follows the approach developed by Avila and Evenson (2004) when finding cost shares. Input cost share estimates are carefully constructed using representative farm survey data. Estimates are not found for every country, so it is assumed that cost shares are representative of agricultural production for similar groups of countries. For Southeast Asia, the cost shares applied are derived from Indonesia and are as follows: 0.254 for land, 0.222 for livestock, 0.012 for machinery, 0.051 for fertilizer, and 0.461 for labor.

It may seem tenuous to apply the same factor shares to different countries facing different conditions. However, as Fuglie (2008) discusses, the remarkable degree of congruency among cost shares found for similar countries lends the method credibility. For example, of the four developing nations (India, Indonesia, China, and Brazil) that shares were found for, shares ranged from 0.40 to 0.46 for labor, 0.22 to 0.25 for land, and 0.14 to 0.25 for livestock. Factor shares for fertilizer and machinery were less than 14% of total output. Even though these four countries are very different among many different criteria, the ranges of the share values are very small. In effect, it should be safe to assume that nations facing similar conditions will have similar factor shares of inputs.

In general, factor shares found for one nation may be applied to other nations as long as they face similar factors of production. While it is true that the applied factor shares may not be exactly correct, they will be close.

There are some limitations of these calculations that need to be mentioned. First, only rates of change in *TFP* are calculated, meaning that the *TFP* values found cannot be compared across countries. Another limitation is that revenue and cost shares are held constant over time. Finally, this paper does not make adjustments for input quality changes for any of the inputs.

*Malmquist Index-Data Envelopment Analysis (DEA)*

Another method of measuring *TFP*, a Malmquist index, can be created through data envelopment analysis (DEA). DEA takes advantage of linear programming techniques to construct a non-parametric piecewise frontier over data. This allows for calculations of efficiencies relative to the frontier calculated for the data in question. Farrell (1957) proposed that the efficiency of a decision making unit (DMU) is made up of two components: technical efficiency, which is a measure of the DMUs ability to obtain the maximum amount of output from a given set of inputs, and allocative efficiency, which is a measure of the DMUs ability to use inputs in optimal proportions (Coelli, 1996). Changes in productivity may be due to either technological change, a shift in the production possibility frontier, or to change in technical efficiency, the distance from the production possibility frontier (Fulginiti and Perrin, 1994).

The Tornqvist-Theil share-weighted indexing procedure is the traditional empirical measure of productivity. If price ratios reflect measures of marginal productivity and production is technically efficient, this method will result in valid

measures of technological change. However, if price ratios are not representative of marginal productivity, this share-weighted index approach will not yield valid measures of productivity change. Furthermore, if price data is unavailable, which is typical for less developed countries, the Tornqvist-Theil indexing approach is not possible. Since price data is unavailable for the entire study period for some of the nations in our study and completely unavailable for others, a nonparametric quantity-based approach is utilized. As mentioned previously, this approach will allow *TFP* change to be seperated into change due to changes in technology and efficiency (Fulginiti and Perrin, 1994).

The quantity-based Malmquist index estimated in this paper follows procedures outlined by Fare et al. (1994), measuring productivity change as the geometric mean of two Malmquist productivity ratios. The production technology $S^t$ models the way in which inputs, $x^t$, are transformed into output, $y^t$,

$$S^t = \{(x^t, y^t): x^t can\ produce\ y^t\} \qquad (4).$$

Equation (4) represents that technology consists of all feasible input and output combinations within the data set. We assume that the technology, $S^t$, is nonempty, closed, convex, and both inputs and output are freely disposable (Fulginiti and Perrin, 1994). The output distance function at time *t*, is defined as

$$D_i^t(x^t, y^t | C, S) = \inf\left\{\theta: \left(x^t, \frac{y^t}{\theta}\right) \epsilon S^t\right\} \qquad (5),$$

where $D_0^t$ is the distance function at time *t,* and $\theta$ is the ratio of the current periods output to the maximum obtainable output given the current periods level of inputs (Trindade and Fulginiti, 2014). Finding a value of $D^t(x^t,y^t)$=1 indicates that production is technically efficient and occurs if and only if $(x^t,y^t)$ lies on the frontier of the technology set, a value of less than one indicates technically inefficient production.

To define the Malmquist index we need to compare output at one period with the technology of another period by defining distance functions such as:

$$D^t(x^{t+1}, y^{t+1}) = \inf\left\{\theta : \left(x^{t+1}, \frac{y^{t+1}}{\theta}\right) \epsilon S^t\right\} \qquad (6).$$

Here we are considering the technology set at period *t* with input and output observations at period *t+1*. This distance function then measures the maximum proportional change in outputs required to make ($x^t$,$y^t$) possible with the technology available at period *t* (Fulginiti and Perrin, 1994). The Malmquist productivity ratio with reference to the technology set at time *t* is defined as:

$$m^t = \frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \qquad (7).$$

Similarly we can define another Malmquist ratio using the technology available at time *t+1* as:

$$m^{t+1} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)} \qquad (8).$$

Following the procedure laid out by Fare et al., in their 1994 paper; the Malmquist productivity change index is defined as the geometric mean of the two indices above; one referencing the technology set available in period *t* and the other referencing technology at time *t+1*. Fare et al. define this Malmquist productivity index as:

$$m^{t+1} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}\right]^{\frac{1}{2}} \qquad (9).$$

This represents the productivity of the production point ($x_{t+1}$, $y_{t+1}$) relative to the production point ($x_t$, $y_t$). A value greater than one indicates positive *TFP* growth from period *t* to period *t+1*. The first ratio on the right side of the equation outside of the brackets represents efficiency change (EC), or the distance from the production

possibility frontier. The term within brackets on the right side of the equation represents technical change (TC), or the shift in the production possibility frontier (Fulginiti and Perrin, 1994).

Aggregate growth rates of the ASEAN region for the Malmquist index, are found in the same fashion as in the Simple index approach. This paper uses national annual percentage contribution to the entire study region's gross agricultural output as a weighting factor.

*Maximum Likelihood Stochastic Frontier (MLSF)*

Agricultural technology is approximated with a translog production function specification, and the estimation of the agricultural productivity growth rate is obtained using an econometric stochastic frontier (SF). While econometric estimation techniques provide standard errors that allow for tests of hypotheses, this approach may add specification error (Greene, 2005). Following Greene (2005), the standard stochastic frontier model is written as:

$$y_{it} = f(\boldsymbol{x}_{it}, \boldsymbol{z}_i) + v_{it} \pm u_{it} = \alpha + \boldsymbol{\beta}'\boldsymbol{x}_{it} + \boldsymbol{\gamma}'\boldsymbol{z}_i + v_{it} \pm u_{it},$$

$$i = 1, \dots, N, \quad t = 1, \dots, T, \quad u_{it} \geq 0, \qquad (10),$$

where, $y_{it}$ is the logarithm of output of the $i$-th country during the time period $t$, $\boldsymbol{x}_{it}$ is a vector of the logarithm of inputs for the $i$-th country, in time period $t$, and $z_i$ is a vector of unknown country specific parameters. The error term is broken into two components, $v_{it}$ and $u_{it}$, which will be revisited in more detail. Incorporating the time invariant term, $\boldsymbol{\gamma}'\boldsymbol{z}_i$, into $\boldsymbol{\beta}'\boldsymbol{x}_{it}$, the model can be written as:

$$y_{it} = \alpha + \boldsymbol{\beta}'\boldsymbol{x}_{it} + v_{it} \pm u_{it} \qquad (11.1).$$

The true fixed effects stochastic frontier model defined by Greene (2005) is written as:

$$y_{it} = \alpha_i + \boldsymbol{\beta}'\boldsymbol{x}_{it} + v_{it} + u_{it}, \qquad (11.2),$$

$$v_{it} \sim N[0, \sigma_v^2], \qquad (11.3),$$

$$u_{it} = |U_{it}| \; where \; U_{it} \sim N[\mu, \sigma_u^2], \qquad (11.4),$$

where $v_{it}$ are random errors which are assumed to be iid $N(0, \sigma_v^2)$ and independently distributed from $u_{it}$, and where $u_{it}$ are non-negative random variables assumed to be iid $N(\mu, \sigma_u^2)$ where $\mu$ is associated with inefficiency of countries over time. The sign of the inefficiency term will be positive since the frontier describes a production function. This means that variables within the inefficiency term with greater positive numerical values indicate greater inefficiency. The fixed effects, country dummy variables, enter into the stochastic frontier in the term $\alpha_i$. Any latent heterogeneity is either not present, contained within the production function, or absorbed by $\alpha_i$.

Following Jondrow et al. (1982) estimation of the efficiency term can be conducted as follows:

$$Efficiency_{it} = u_{it} = E[u_{it}|\varepsilon_{it}] = \frac{\sigma\lambda}{1+\lambda^2}\left[\frac{\phi(\alpha_{it})}{1-\boldsymbol{\phi}(\alpha_{it})} - \alpha_{it}\right] \qquad (12),$$

where $\sigma = [\sigma_v^2 + \sigma_u^2]^{1/2}$, $\lambda = \frac{\sigma_u}{\sigma_v}$, $\alpha_{it} = \pm\frac{\mu_i}{\sigma\lambda} - \frac{\varepsilon_{it}\lambda}{\sigma}$, and $\phi(\alpha_{it})$ is the standard normal density evaluated at $\alpha_{it}$ and $\boldsymbol{\phi}(\boldsymbol{\alpha_{it}})$ is the standard normal cumulative density function (CDF) evaluated at $\alpha_{it}$, and $Efficiency_{it}$ represents the efficiency level of each respective country. Efficiency change (EC) is then found by finding the change in efficiency levels over time.

As mentioned previously, a translog production function is estimated using the true fixed effects model of Greene, 2005, in a MLSF setting. Imposing symmetry, the production function estimated is:

$$y_{it} = a_0 + \sum_{j=1}^{5} b_j x_{ijt} + \frac{1}{2}\sum_{j=1}^{5} c_{jj} x_{jj}^2 + \sum_{j=1}^{5}\sum_{k>j}^{5} c_{jk}\, x_{ijt} x_{ikt} + b_t t + \frac{1}{2} b_{tt} t^2 + \sum_{j=1}^{5} b_{jt} x_{ijt} t$$

$$+ v_{it} + u_{it}, \qquad (13),$$

where again, $y_{it}$ is the logarithm of agricultural output for country *i* during year *t*, *x's* are the inputs variables, *t* represents time and is a proxy to measure technical change; *a, b,* and *c* are parameters to be estimated; $v_{it}$ and $u_{it}$ are the random error term and the inefficiency term respectively.

The first derivative of (13) with respect to *t* represents the rate of *TC*:

$$TC_{it} = b_t + b_{tt} t + \sum_{n=1}^{5} b_{nt} x_{int}\, t, \qquad (14).$$

*TC* is growth due to advancements in technology or innovations, or the shift in the production possibility frontier. The frontier shifts out or away from the origin when *TC* is positive and in or towards the origin when *TC* is negative.

*EC* is growth due to countries catching-up to the most efficient input using country. *EC* is the rate at which a country moves away or toward the most efficient input using countries production possibility frontier. The efficiency measure takes a value ranging from zero to one, where a value of one indicates that the country is fully efficient, or the country setting the frontier. Efficiency is captured by equation (12) when a frontier approach is used. Changes in the efficiency level over time can then be found using

equation (15). Given the definition of $u_{it}$, the mean of the technical efficiency component, $\mu$, is defined as:

$$Efficiency_{it} = \mu_{it} = \delta\, \boldsymbol{r}_{it},$$

$$EC_{it} = Efficiency_{it} - Efficiency_{it-1}, \qquad (15),$$

where, $\boldsymbol{r}_{it}$ is a (1xp) vector of explanatory variables that are associated with the efficiency of countries over time (institutional, quality). In this model, $\mu_{it}$ will account for differences in the efficiencies of input use across countries. *TFP* is found by aggregating *TC* and *EC* as follows:

$$TFP_{it} = TC_{it} + EC_{it}, \qquad (16).$$

Properties such as monotonicity were also tested for by finding input elasticities. Input elasticities were found by taking the first derivative of the logarithm of the production function with respect to the logarithm of each input variable, $x_i$:

$$\frac{dy_{it}}{dx_{it}}, \qquad (17).$$

All calculations were carried out in STATA. The sfpanel program add-in developed by Belotti et al., for STATA was used to simultaneously estimate the parameters of equations (13) and (12). Aggregate measures of *TFP* were found in the same fashion as the two previous approaches.

**Data**

The FAO publishes annual data on agricultural outputs and inputs and serves as the primary data source for finding agricultural productivity over the time period of 1961 to 2011 for the nations of Cambodia, Indonesia, Lao People's Democratic Republic,

Malaysia, Myanmar, Philippines, Thailand, and Viet Nam. This paper supplements data from the FAO with data from the USDA ERS when necessary.

For output, the FAO takes data on production of crops and livestock and aggregates them into a production index. This production index uses a common set of commodity prices based on the 2004-2006 period. Notably, FAO index of output does not include forage production, but does include production of crops that may be used for livestock feed.

For inputs in agricultural production, FAO publishes data on cropland (rainfed and irrigated), permanent pasture, total economically active individuals in agriculture, heads of animals, number of tractors in use, and consumption of fertilizer. FAO data is not used for the inputs of fertilizer and machinery; data from the USDA ERS is instead used for these inputs. In the case of fertilizer, this was done because the FAO has missing data for the nation of Lao People's Democratic Republic. For machinery FAO data was not used because no data was collected after 2003. These data sources are continuous and complete from 1961-2011.

Agricultural inputs are divided into five main factors of production: agricultural land is the area in permanent crop production, annual crop production, and permanent pasture; farm labor is the total number of economically active individuals (males and females) in agriculture; fertilizer is the amount of major inorganic nutrients applied to agricultural land annually, measured as metric tons of N, $P_2O_5$, and $K_2O$ nutrients; farm machinery is an aggregation of 4-wheel riding tractors, 2-wheel pedestrian tractors, and power harvester-threshers in use; and livestock is the aggregate of animals present expressed in the units of 'cattle equivalents.'

The ERS aggregates fertilizer quantities using annual average nutrient prices for N, P2O5, and K2O fertilizers from the International Monetary Fund. Expressing fertilizer consumption in terms of metric tons of "N-fertilizer equivalents," the aggregation weights (relative price of one metric ton of nutrient) are 1.00 for N, 1.36 for $P_2O_5$, and 0.85 for $K_2O$ (ERS, 2014). Farm machinery is an aggregation of 4-wheel riding tractors, 2-wheel pedestrian tractors, and power harvester-threshers. Using metric horsepower (CV) machinery is expressed in '40-CV tractor-equivalents' (ERS, 2014). The aggregate livestock input variable includes: cattle, water buffalos, horses, camels and other equine species (donkeys, mules, and hinnies), small ruminants (sheep and goats), pigs, rabbits, and poultry (chickens, ducks, and turkeys), with each species weighted to 'cattle equivalents'. The weights used for this aggregation are based on the findings of Hayami and Ruttan (1985), and are as follows: 1.25 for water buffalo and horses, 1.38 for camels, 1.00 for cattle and other equine species, 0.13 for small ruminants, 0.25 for pigs, 25 per 1,000 rabbits, and 12.50 per 1,000 head of poultry.

Although there are many other inputs involved in agricultural production, these five major inputs account for the majority of total agricultural input usage and should suffice for this analysis. Summary statistics of the data can be seen in Table 1.

*Efficiency Variables*

Former research by economists has used broad panel data of countries to discover the determinants of economic growth- see for example, Barro (1991, 2000) Barro and Sala-i-Martin (2003, Ch. 12). A general conclusion can be made from this literature that to successfully explain economic performance, one must go beyond measures of economic variables and encompass political and social characteristics as well. In

summary, these studies reveal that government policies and public institutions present have important influences on economic growth (Barro et al., 2003).

As government plays an important role, this paper uses efficiency variables to explain the differences in performance observed between nations. The efficiency variables of national religion, life expectancy, and freedom were chosen to explain the differences in efficiency between countries. National religion is used as a variable because it affects economic outcomes. Religion affects economic outcome by fostering religious beliefs that influence individuals' character traits like work ethic, honesty, frugality, and charity. For example, belief in an afterlife such as heaven or hell may affect character traits by creating perceived rewards and punishments associated with lifetime 'good' and 'bad' behavior (Barro et al., 2003). National religion is represented as a dummy variable, 1 indicating that the nation has an established national religion or 0 if it has none. Data on national religion was gathered for the study period from the Central Intelligence Agency (CIA) Factbook. The nations of Cambodia, Malaysia, and Thailand have established national religions, while the remaining nations do not.

The second efficiency variable selected, freedom, is also used to explain the differences in performance observed between nations. By including this variable, this paper is able to recognize a connection between agricultural growth and economic liberties (Haan and Sturm, 1999). A large amount of empirical research indicates that economic freedom may be important in explaining the differences in economic performance between countries (de Vanssay and Spindler, 1994; Alesina, 1998; de Haan and Siermann, 1998; Nelson and Singh, 1998). The degree to which economies and their subsequent markets operate freely may have a distinct effect on economic growth.

Freedom is also represented as a dummy variable, 1 indicating that a country is not completely free and 0 if it is free. Data for this variable was collected from the Freedom House Freedom in the World index. This annual report looks at various numerical indicators of political rights and civil liberties, categorizing the country as free, partly free, or not free, based on the aggregate score. The report's methodology largely follows the Universal Declaration of Human Rights, adopted by the United Nations (UN) General Assembly in 1948 (Freedom House, 2016). The Freedom in the World index is based on the premise that the standards outlined by the UN apply to all countries, irrespective of geographical location, religious and ethnic composition, or the level of economic development. Data from the Freedom in the World index starts in 1972 and is continuous to the end of the study period. For periods prior to 1972, data from Freedom House's prior freedom report, Balance Sheet of Freedom, and other various sources are used. In this paper, partly free and not free are combined into a single variable, labeling countries classified as partly free or not free as 'non-free.'

The final efficiency variable, life expectancy, is included as a measure of healthiness of the population within a country. Life expectancy can be used as a measure of general health within a nation, since we expect a higher level of healthiness to be positively correlated with life expectancy. A higher level of economic growth may be associated with healthier workers for many reasons. Healthier workers are more robust physically and mentally, more productive, earning higher salaries, and less likely to be absent from work due to illness. Illness and disability reduce hourly wages substantially, with the effect especially strong in developing nations where a higher proportion of the

work force is engaged in manual labor when compared to developed nations (Bloom et al., 2004).

Life expectancy as a proxy for health has appeared in many empirical cross-country growth studies. It is generally found that health has a significant positive effect on the rate of economic growth (see Bloom and Canning, 2000, 2003). Life expectancy was obtained from the World Bank's World Development Indicators database, and is continuous over the entire study period. The World Bank measures life expectancy as the number of years a newborn would live if the prevailing patterns of mortality at the time of birth stay the same throughout the infant's life (World Bank, 2016).

The complete data set used for this paper can be found in *The Association of Southeast Asian Nations Agricultural Total Factor Productivity* supplementary materials.

**Estimation and Results**

Agriculture in the selected nations of ASEAN is largely dominated by four nations: Indonesia, Philippines, Thailand, and Viet Nam. Over the 1961-2011 time period, the four nations account for 80% of the total agricultural output in the region. Table 2 and Figure 2 show that these countries dominate not only output shares but input shares as well, especially in the extreme case of machinery. Furthermore, the region's remaining 20% of agricultural output over this time period primarily comes from only two other countries. Myanmar and Malaysia account for 9% and 8% respectively of agricultural output over the 1961-2011 time period; the remaining nations, Lao People's

Democratic Republic and Cambodia, only contribute about 2% to agricultural output over the study period.

Lao People's Democratic Republic has very little agricultural area, and therefore represents a small portion of the region's agricultural production. Lao People's Democratic Republic's percent share in agricultural area hovered just below 2%, and it's output share was 0.85% over the entire study period. Conversely, the last nation yet to be mentioned, Cambodia, has a slightly more significant agricultural area. Over the study period, Cambodia's percentage share of agricultural area in the ASEAN region was 3.87% while its output share was 1.70%. Figure 1 shows the cumulative frequency distribution of the growth rates of inputs and output for the region. Highlighted by this figure is the large increase in fertilizer input during the 1961-2011 period; most nations used very little fertilizer at the start of the analysis. The median growth rate is approximately 3% but about 20% of observations show decreases of 10% or higher and 20% show increases of 20% or higher.  Figure 3 presents an index of the evolution of input usage and agricultural output for the study region with 1961=1.

The largest input usage change occurs in machinery and is followed by fertilizer. The large growth in machinery usage occurs because of the mechanization present over the study period. Beginning in 1961, there was very little mechanization present in agricultural production in the ASEAN region. However, the study period includes the Green Revolution, which allowed for rapid technology adoption in the form of agricultural mechanization. Rapid increases in mechanization are apparent at the country level beginning around the 1980's. Most prominently, the nations of Thailand and the Philippines lead the region in machinery input usage growth. Country level figures of

evolution for output and the five inputs used can be viewed in Appendix B (Figures 11-18).

*Simple Index*

Following a brief and general overview of the significance of agriculture to different members of the ASEAN region, let us now examine growth rates. The decade averages for the Simple index of output, inputs, and *TFP* growth are presented in Table 3. Examining the estimates of the Simple index shown in Table 3 agricultural *TFP* growth actually appears to have been accelerating since 1980. In the most recent decade, average output growth at the country level varies from Thailand at the low end with a value of 3.02% growth, to Myanmar at the high end with a 7.17% output growth rate.

Cambodia achieved both the highest and lowest decade average growth rates in output with values of -11.16%(all table values reported in red are negative values) and 11.53% in the 1970's and 1980's, respectively. This dramatic swing between the two decades was caused by conflict in the region. Starting in the 1970's, the Cambodian government was overthrown, and five years later basic freedoms were curtailed. All forms of religion were banned, and hundreds of thousands of people in the educated middle-class were tortured and executed. These events initiated what is known as Cambodia Year Zero. Over the next three years, the death toll climbed to an estimated 1.7 million (BBC, 2015).

Cambodia's negative percent growth rate for output during the 1970's is the only negative decade average found for output growth using the Simple index approach. The weighted aggregate measure of output growth is observed to accelerate from 2.97% in the

1960’s to 3.98% growth in the 1980’s. This aggregate measure then decreases in the 1990’s to 2.95% growth, but quickly rebounds in the 2000’s to 3.21% growth.

Continuing to present the Simple index results shown in Table 3, input growth appears to be consistently decreasing over the study period. This could be attributed to producers either learning to use inputs more efficiently, or, due to technological innovation. Agricultural innovations such as new genetic hybrids can result in agriculture requiring less input usage while still obtaining prior levels of output or possibly even higher levels of output. Cambodia again exhibits the largest decrease in this growth measure in the 1970’s with a value of -3.76% growth in inputs. This reduction in input use was also caused by the previously discussed conflict in the region. The largest decade-average value for input growth was obtained by the Lao People’s Democratic Republic in the 1960’s with a value of 4.46% growth.

The nations of Malaysia, Myanmar, the Philippines, and Thailand all exhibit continual reductions in input usage over the study period. In the most recent decade-average, the 2000’s, all nations except for Indonesia and Thailand are found to have decreasing input growth rates when compared to the 1990’s. However, the aggregate ASEAN measure of input growth is shown to increase from 1.14% in the 1990’s to 1.20% growth in the 2000’s. Indonesia and Thailand’s large percentage contribution to the region's total agricultural output causes the increase in the aggregate input usage measure by outweighing the decrease in input use apparent in the other six nations.

Aggregate *TFP* growth in the Simple index is shown to be positive for the entire study period, first increasing from 0.87% in the initial decade to 2.04% growth in the 1970’s. Aggregate *TFP* growth then decreases to 1.53% percent in the 1980’s and

continually increases until the most recent decade, where it achieves a *TFP* value of 3.21% growth. Using this approach, all nations exhibit increasing *TFP* growth rates in the most recent decade average when compared to the 1990's. Most notably, a substantial increase in the agricultural *TFP* growth rate of 1.58% (2.86%-1.28%) in Indonesia, the study's largest agricultural producer, is found between the 1990's and 2000's.

The last row in Table 3 presents Findings from Fuglie (2008). Fuglie's study uses data from 1970-2006, but this paper also includes Fuglie's most recent estimate in the 2000-2009 columns for the sake of readability. As such, the reader should keep in mind that when comparing the last decade's results, Fuglie's most recent estimate only includes the years of 2000-2006. However, the aggregate findings of this paper are consistent with Fuglie's. In general, the results show consistency in the magnitude of growth rates estimated. For example, when examining the 1970's, Fuglie's estimate of output growth for the region is 3.68% while this paper's corresponding result was found to be 3.59%; a negligible difference of 0.09%. Input growth measures are also consistent in this time period, with Fuglie's estimate being 1.67% and this paper's being 1.54%, a difference of 0.13%. Again, *TFP* growth in the 1970's is consistent with Fuglie's estimate being 2.01% and this paper's being 2.04% growth for the same period, a difference of 0.03%. When comparing this paper's Simple index results with those of Fuglie (2008), they follow the same general changes in magnitude and direction of change in unison for output, input, and *TFP* growth rates. Fuglie and this papers result's are not entirely the same due to the use of different data sets, and adjustments for the quality of inputs. For example, Fuglie conducts a quality adjustment for land and adjusts output with a Hodrick-Prescott filter with a lambda value of 6.25 to smooth short run fluctuations. The congruency in results,

however, leads me to believe that this paper's estimates are indeed indicative of what is occurring in the agricultural sector of this region.

Looking to the corresponding graph of Table 3, Figure 4, one can view the ten-year moving average values of this approach. Output growth rates are first observed to increase until 1981, then appear to regress for a significant portion of the study. It is not until the mid to late 2000's that output growth recovers to 1981 levels. Input growth rates, for the region first accelerate until the mid 1980's and then decline in more recent time periods. As mentioned previously, the annual growth rate of ASEAN agricultural *TFP* increased from 1.53% in the 1980's to 3.21% over the 2000-2009 period. This roughly doubling of the regions *TFP* growth rate over the 1980's to more recent time periods was able to maintain output growth while the rate of growth in inputs was declining. This indicates that technological innovation, rather than increases in input use, drives productivity growth in the later time periods.

*Malmquist Index*

In the next estimation technique using the Malmquist index, the reader should turn their attention to Table 4 and Figure 5. When looking at Table 4, the aforementioned characteristic of the Malmquist index, sensitivity to extreme values, caused by being based on two consecutive time periods only, is apparent. Even using decade averages extreme values are still returned, such as Cambodia's value of 24.36% *TFP* growth for the 1980-1989 period. This high average *TFP* growth rate is due to an extreme outlier for Cambodia in 1988. This is mainly due to a rapid increase in output and a simultaneous decrease in fertilizer use from 1987 to 1988. During this time, output increased and fertilizer use decreased by approximately 20% and 80% respectively. I am skeptical of

these values for Cambodia during this time period, and inaccurate reporting may cause these extreme values. Furthermore, I am surprised to see a positive and large estimate of *TFP* growth for Cambodia during the 1970's because of the conflict present in the region, as previously discussed. The results of this method are inconsistent with the Simple index and the MLSF approaches for most of the study period. For example, the Malmquist index indicates negative *TFP* growth rates for the majority of the study period and does not become positive until the most recent decade average. This method also indicates technological regression over the majority of the study period; *TC* only becomes positive in the 2000's. The Southeast Asian region in my study may not be well suited for measures such as the Malmquist index because of the volatility present in the region. For instance, Myanmar is involved in armed conflict for the entire study period; Malaysia has the least amount of conflict over the study period, with seven years of conflict occurring during the study period. The remaining nations not yet mentioned- Cambodia, Indonesia, Lao People's Democratic Republic, the Philippines, Thailand, and Viet Nam- have 33, 36, 17, 42, 22, and 23 years respectively with conflict present over the study period. The shocks from armed conflict may be over magnified by the Malmquist index since it relies on two time periods only for estimates returned.

This approach returned fully efficient efficiency estimates for the majority of the countries over the entire time period. There is not a sole nation that predominantly sets the frontier. *TFP* in this model is almost entirely driven by *TC* as can be seen in Table 4 and Figure 5, *TC* and *TFP* mirror each other almost perfectly. Discouraging as these results may be for the entire study period, in more recent time periods the Malmquist index indicates positive *TFP* growth. The ending decade of 2000-2009 is estimated to

have a *TFP* growth rate of 3.17%, which is consistent with the 3.21% *TFP* growth rate found using the Simple index approach.

The sharp decrease in the aggregate *TFP* growth rate starting in the 1980's and not returning to positive values until the 2000's, can partially be attributed to the global financial climate during that time period. Armed conflict present in the region over this period is also a factor to consider. The global financial crises of the 80's and 90's limited the amount of capital available to farmers for investment in new agricultural innovations; as depicted by the sharp drop of *TC* in Figure 5. This sharp decrease in *TC* accounts for farmers not being able to invest in new technologies. Furthermore, the financial crises at this time also caused demand for agricultural exports from the ASEAN region to decrease. This decrease in the *TFP* growth rate is also apparent in the Simple index approach. Although growth does not become negative, as in the Malmquist index, a significant and long lasting decrease in the rate of *TFP* growth is seen (see Figure 4) starting in the 1980's and not fully recovering until the 2000's. The MLSF approach exhibits the influence of the financial climate over the 1980-2000 period to a lesser extent. Looking at Figure 6, a slight recession or stagnation of *TFP* growth starting in the 1980's and continuing through the decade is observed. The MLSF approach also indicates a stagnation or plateau of growth for the 1990's and extends into the 2000's. These differences are due in part to the difference in nature of the estimation approaches and to the inclusion of country dummy and efficiency variables in the econometric approach.

Unfortunately, to the best of my knowledge, there have not been any other recent studies conducted on this region concerning agricultural productivity that use a

Malmquist index approach. This is unfortunate because I am skeptical of the validity of the Malmquist index results and would greatly benefit from being able to compare my results to others.

The DEAP program used and complementary output can be found in the supplementary materials.

*MLSF*

The results for the final estimation technique, the MLSF, can be seen in Table 5 and Figure 6. This estimation technique consistently returned positive values of *TFP* growth for the weighted aggregate measure after 1980. Consistent with the Malmquist index, *TC* is the driving force behind *TFP* growth. *EC* seems to play a larger role in this model than the Malmquist index, but is still small compared to *TC*. The larger portion of *TFP* growth being attributed to *EC* in the MLSF model, as compared to the Malmquist index approach, can be attributed to the inclusion of country specific inefficiency variables as well as country dummy variables. The country dummies and efficiency variables, not present in the Malmquist index approach, capture differences in country efficiencies in the MLSF, which causes more fluctuation in the *EC* measure.

The *TC* growth rate using the MLSF approach is estimated to increase over the study period for all of the ASEAN nations chosen. Viet Nam exhibits the largest value of *TC* growth in the most recent decade with a value of 3.60%. Viet Nam also exhibits the most statistically significant estimates with all decade averages being significant at the 99% level for *TC*. The nations of Cambodia, Indonesia, Lao People's Democratic Republic, and Malaysia all report negative *TC* growth rates for earlier and mid time

periods in the study, depending on the respective nation. For instance, Malaysia exhibits negative *TC* growth rates for all decade except for the 1980's and 2000's.

It is hard to imagine that some of these nations experienced negative *TC* growth rates over the earlier time periods. I find this especially hard to believe because agricultural innovation and technology adoption was booming over this time period. Viet Nam, Thailand, Philippines, Myanmar, and the Philippines all exhibit statistically significant estimates over the 1980-2000's decade averages; these estimates also exhibit increasingly significant *TC* growth rates in more recent time periods. All of the aforementioned nations (Viet Nam, Thailand, Philippines, Myanmar, Philippines) *TC* estimates become significant at the 99% level in the 1990's and onward. Malaysia is the only nation that does not return any positive statistically significant results for the measure of *TC*, using the MLSF approach.

The weighted ASEAN *TC* growth rate estimates are observed to increase in magnitude and significance over the study period. Starting in the 1960's, *TC* is estimated to be negative with a value of -0.24% reported and is statistically insignificant. The aggregate measure of *TC* growth rates becomes statistically significant at the 99% level in the 1980's, and continues to return values at that significance level over the remainder of the study period. The ASEAN *TC* growth rate is estimated to be 2.12% in the most recent decade. Comparing this to the Malmquist's aggregate measure of *TC*, 3.19% for the same time period, both return plausible rates of *TC*.

Cambodia, predominately sets the production possibility frontier using the MLSF approach. However, Cambodia's technical change is not an accurate indicator of the entire regions technical change. *EC* under this approach is much more variable than when

using the Malmquist index. Cambodia provides evidence that the country dummy variables and efficiency variables are capturing differences between our eight ASEAN nations. The value of 3.15% returned for *EC* in the 1970's, and the decline in the 1980's to a value of -3.46% for Cambodia, indicates that the conflict associated with Year Zero is being captured. This encourages the conclusion that the efficiency and country dummy variables used are doing a decent job of explaining the differences in agricultural productivity observed between nations.

Aggregate *TFP* growth rates steadily increase over the entire study period and end at a value of 1.90% for the 2000-2009 period. The weighted aggregate measure of *TFP* growth is -0.74%, in the 1960's, and then steadily climbs to the value of 1.90% previously mentioned. This result is lower than the estimates returned from the two previous approaches for the same time period. Decade averages of *TFP* growth rates are shown to be increasing over more recent time periods of the 1990's and 2000's. Indonesia, Philippines, and Viet Nam consistently exhibit increasing *TFP* growth rates over the entire study period ending with values of 2.31%, 1.81%, and 3.60% respectively, in the 2000's.

To check for properties such as monotonicity input elasticities and associated standard errors were found and are presented in Table 7. All elasticities were found to be positive and statistically significant except for the elasticity of labor, which was found to be highly insignificant. The efficiency variables of national religion and life expectancy were found to be statistically significant while the variable of non-free was found to be insignificant. The presence of a national religion is shown to have a negative effect on agricultural productivity and increases in life expectancy were found to increase

agricultural productivity. National religion having a negative effect on agricultural productivity could be due to funds being allocated to the national religion. If a national religion was not present, funds traditionally allocated to religion could be used to increase agricultural productivity through subsidy or assistance programs.

As with the Malmquist index, I am currently unaware of any recent literature that estimates agricultural productivity growth, in the ASEAN region, using a MLSF approach. Estimation output for the MLSF can be found in Appendix: A. The STATA code and complete estimation output for this approach can be found in the supplementary materials.

**Conclusions**

A summary of the results from the three approaches can be viewed in Table 6, or graphically in Figure 7. In Figure 7, the Simple index and MLSF approaches return similar results over the 1990's-2000's. After the year 2000 the MLSF indicates a stagnation of growth while the Simple Index depicts an acceleration of *TFP* growth.

The Malmquist index diverges from the other two measures of *TFP* for the majority of the study period. However, the results are more homogeneous from 2004 to 2011. In Table 6, the Simple index estimates positive *TFP* growth rates for all eight nations individually, as well as the aggregate measure for the entire study period. The stochastic approach shows negative TFP growth rates for Cambodia and Malaysia and positive growth rates for the remaining nations for the study period. The MLSF predicts a positive value for *TC* while the Malmquist index does not.

Since this paper is primarily concerned with a recent slowdown in agricultural *TFP* we look to Figures 8-10 in Appendix B, which show annual results since 2000 to the most recent time period. Figures 8 and 9, the Simple and Malmquist indices, show a reduction in the growth rate of agricultural *TFP* in the most recent time periods. An increase in *TFP* is indicated by both methods from 2010 to 2011, the most recent study period. Figure 10, the MLSF approach, shows an increasing trend of *TFP* over the most recent time periods. However, in the most recent year, 2011, the stochastic frontier's *TFP* measure suffers a significant reduction of almost an entire percent from 2010 to 2011.

Figures 19-26 found in Appendix B show country level ten-year moving average comparisons of the three *TFP* growth measures conducted. Figure 20 shows *TFP* growth rates for the regions largest agricultural producer, Indonesia. *TFP* growth is positive and increasing in the most recent time periods for all three measures conducted. Also, Figure 20 shows that for the Simple index and MLSF approaches, *TFP* is estimated to be positive over the entire study period since 1976. Figures for Cambodia, Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, and Viet Nam all depict generally increasing rates of *TFP* growth since 2000.

I conclude that the Malmquist index approach is not measuring agricultural productivity growth accurately for the chosen eight ASEAN nations. Most likely, the Malmquist index behaves poorly because it cannot account for volatility in the region related to armed conflict. The Malmquist index is not the tool for the job; the Malmquist does provide information on the presence of extreme values in the data.

With the evidence presented on national and the regional levels, I conclude that the slowdown in agricultural productivity observed in middle and high-income countries,

indicated by Alston et al. (2010), Fuglie (2010), and the World Bank Development Report (2007), cannot be confirmed or denied with the results found. While the ten year moving average approach does show a general trend of increasing *TFP* over the study period; when looking at annual data the increasing trend is less apparent. The methods applied see a pattern of oscillation between high and low values of productivity growth when observing annual data. This oscillation is partially due to the conflict, governmental structures, institutions, and possibly reporting errors present in the region.

This region of the world needs to be monitored closely as more detailed and reliable data becomes available in the future. Updating the data set used for this study to more current time periods will help identify if a slowdown in agricultural productivity growth rates is occurring in this region of the world. With the current data and methods used in this paper, I cannot conclude definitively if a slowdown in agricultural *TFP* growth is occurring or not within the selected ASEAN nations.

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**Table 1. Summary Statistics Output and Inputs**
**Region: Southeast Asia – Period: 1961 to 2011**

**Output – Thousands of constant 2004-2006 I$ - Source: FAO**

| Country | Mean | Max | Min. | SD |
|---|---|---|---|---|
| Cambodia | 1,475,067 | 4,305,677 | 399,176 | 867,025 |
| Indonesia | 28,164,928 | 61,926,309 | 10,233,862 | 14,973,638 |
| Lao's PDR | 738,281 | 1,910,174 | 249,339 | 453,025 |
| Malaysia | 6,947,500 | 15,121,526 | 1,909,582 | 3,829,691 |
| Myanmar | 8,043,161 | 20,952,564 | 3,080,488 | 5,031,646 |
| Philippines | 11,856,862 | 21,172,999 | 4,916,040 | 4,808,339 |
| Thailand | 17,646,671 | 33,106,707 | 6,512,112 | 7,753,411 |
| Viet Nam | 12,096,125 | 30,193,093 | 4,573,274 | 7,830,601 |
| **ASEAN** | **86,968,595** | **188,321,783** | **32,534,902** | **45,000,617** |

**Livestock – Thousands of Cattle Equivalents – Source: FAO**

| Country | Mean | Max | Min. | SD |
|---|---|---|---|---|
| Cambodia | 3,519,100 | 5,410,928 | 1,278,950 | 1,188,879 |
| Indonesia | 23,505,817 | 42,714,248 | 13,185,988 | 9,264,624 |
| Lao's PDR | 2,453,676 | 4,170,292 | 1,062,025 | 876,341 |
| Malaysia | 2,695,579 | 4,978,229 | 1,322,590 | 1,109,626 |
| Myanmar | 13,439,844 | 23,743,207 | 6,945,719 | 4,078,458 |
| Philippines | 10,075,365 | 13,111,798 | 7,621,237 | 1,648,226 |
| Thailand | 13,622,678 | 17,204,548 | 11,372,878 | 1,405,159 |
| Viet Nam | 11,751,441 | 20,332,091 | 6,856,196 | 4,414,203 |
| **ASEAN** | **81,063,499** | **126,156,232** | **51,593,374** | **21,830,257** |

**Fertilizer – Tons of Nitrogen-Equivalents – Source: USDA ERS**

| Country | Mean | Max | Min. | SD |
|---|---|---|---|---|
| Cambodia | 12,248 | 71,207 | 85 | 15,415 |
| Indonesia | 1,922,987 | 5,105,220 | 84,818 | 1,417,713 |
| Lao's PDR | 5,029 | 19,298 | 50 | 6,358 |
| Malaysia | 776,387 | 2,034,369 | 75,046 | 559,430 |
| Myanmar | 95,120 | 220,642 | 6,781 | 61,706 |
| Philippines | 450,530 | 845,798 | 87,989 | 238,621 |
| Thailand | 890,138 | 2,304,869 | 20,638 | 730,900 |

**Labor – Thousands of Persons– Source: FAO and USDA ERS**

| Country | 3,154 | 5,137 | 2,148 | 899 |
|---|---|---|---|---|
| Cambodia | 37,519 | 49,888 | 25,604 | 8,703 |
| Indonesia | 1,473 | 2,515 | 839 | 471 |
| Lao's PDR | 1,867 | 2,049 | 1,539 | 129 |
| Malaysia | 14,438 | 20,522 | 8,731 | 3,799 |
| Myanmar | 10,122 | 13,497 | 6,211 | 2,355 |
| Philippines | 17,529 | 21,087 | 11,681 | 2,846 |
| Thailand | 21,519 | 30,310 | 14,085 | 5,389 |

| Country | Mean | Max | Min. | SD |
|---|---|---|---|---|
| Viet Nam | 985,836 | 2,688,957 | 101,881 | 896,291 |
| **ASEAN** | **5,138,275** | **12,823,494** | **460,671** | **3,760,829** |

| Country | Mean | Max | Min. | SD |
|---|---|---|---|---|
| Viet Nam | 107,621 | 141,690 | 71,016 | 23,891 |
| **ASEAN** | **3,154** | **5,137** | **2,148** | **899** |

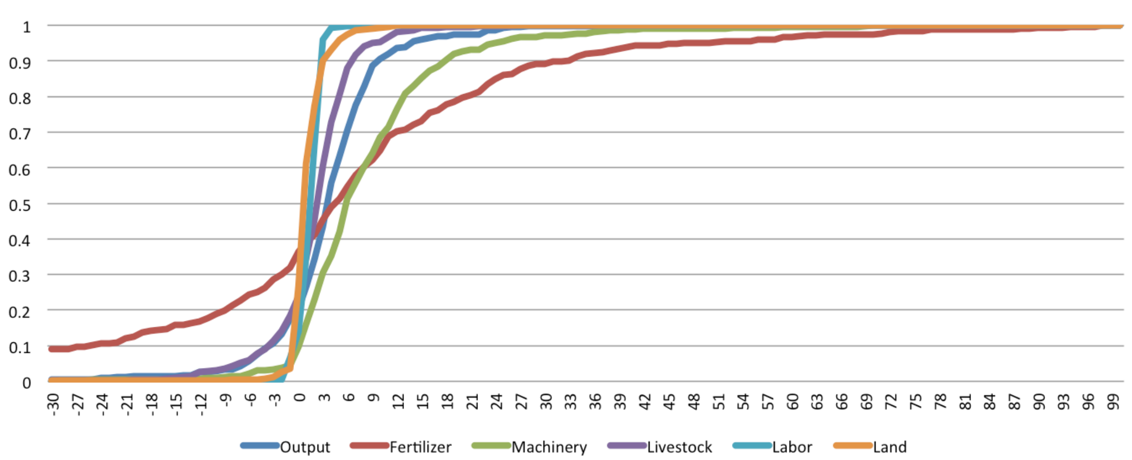
**Machinery – 40 CV Tractor Equivalents – Source: USDA ERS**

| Country | Mean | Max | Min. | SD |
|---|---|---|---|---|
| Cambodia | 4,234 | 19,655 | 621 | 5,054 |
| Indonesia | 23,219 | 59,241 | 831 | 22,402 |
| Lao's PDR | 707 | 1,316 | 30 | 399 |
| Malaysia | 22,239 | 49,608 | 1,600 | 18,130 |
| Myanmar | 19,435 | 86,200 | 1,419 | 19,212 |
| Philippines | 251,455 | 795,260 | 5,355 | 229,448 |
| Thailand | 497,488 | 1,702,701 | 10,516 | 559,218 |
| Viet Nam | 112,297 | 290,957 | 13,675 | 110,678 |
| **ASEAN** | **931,076** | **3,002,306** | **34,046** | **953,966** |

**Land – Thousands of Hectares – Source: FAO**

| Country | Mean | Max | Min. | SD |
|---|---|---|---|---|
| Cambodia | 3,909 | 5,655 | 2,450 | 1,055 |
| Indonesia | 42,886 | 56,500 | 37,052 | 5,766 |
| Lao's PDR | 1,721 | 2,447 | 1,450 | 255 |
| Malaysia | 5,647 | 7,627 | 3,119 | 1,468 |
| Myanmar | 10,760 | 12,558 | 10,322 | 589 |
| Philippines | 10,278 | 12,230 | 7,713 | 1,378 |
| Thailand | 18,348 | 21,516 | 11,653 | 3,061 |
| Viet Nam | 7,532 | 10,793 | 6,292 | 1,430 |
| **ASEAN** | **101,081** | **128,870** | **82,875** | **13,234** |

**Figure 1. Cumulative Frequency Percentage Growth Rates of Output and Inputs in Agricultural Production Region: Southeast Asia 1961-2011**



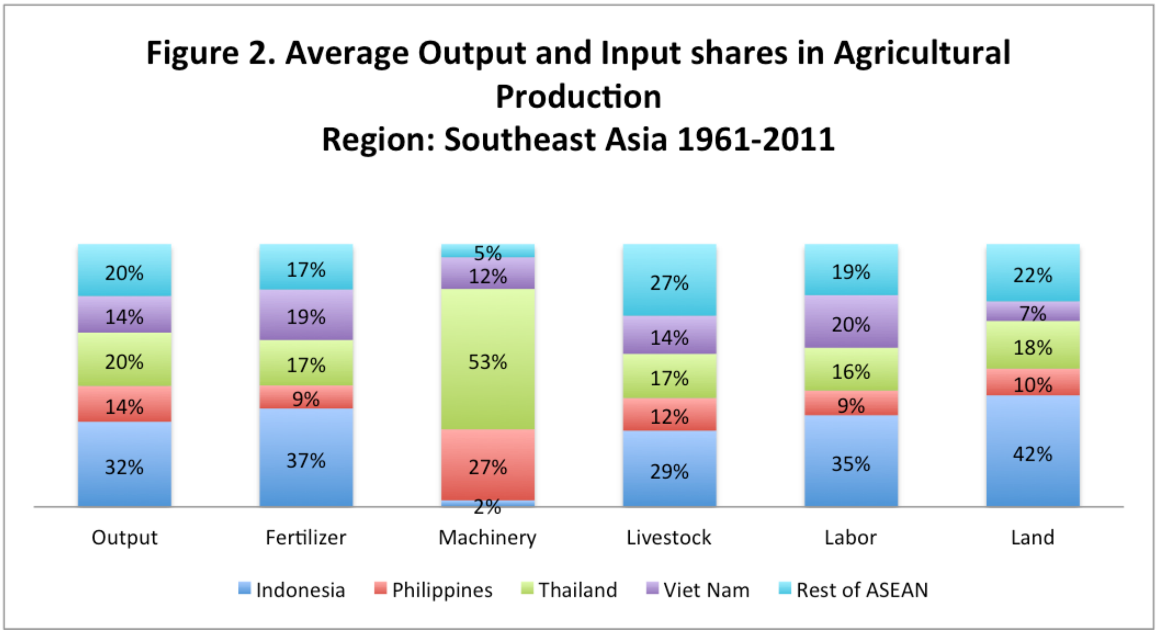



**Table 2. Average Percentage Output and Inputs Shares**
**Region: Southeast Asia 1961-2011**

| Country | Output | Fertilizer | Machinery | Livestock | Labor | Land |
|---|---|---|---|---|---|---|
| Cambodia | 1.70 | 0.24 | 0.45 | 4.34 | 2.93 | 3.87 |
| Indonesia | 32.39 | 37.42 | 2.49 | 29.00 | 34.86 | 42.43 |
| Lao's PDR | 0.85 | 0.10 | 0.08 | 3.03 | 1.37 | 1.70 |
| Malaysia | 7.99 | 15.11 | 2.39 | 3.33 | 1.73 | 5.59 |
| Myanmar | 9.25 | 1.85 | 2.09 | 16.58 | 13.42 | 10.65 |
| Philippines | 13.63 | 8.77 | 27.01 | 12.43 | 9.41 | 10.17 |
| Thailand | 20.29 | 17.32 | 53.43 | 16.80 | 16.29 | 18.15 |
| Viet Nam | 13.91 | 19.19 | 12.06 | 14.50 | 20.00 | 7.45 |

**Figure 3. Evolution of Output and Inputs (index 1961=1)**
**Region: Southeast Asia 1961-2011**

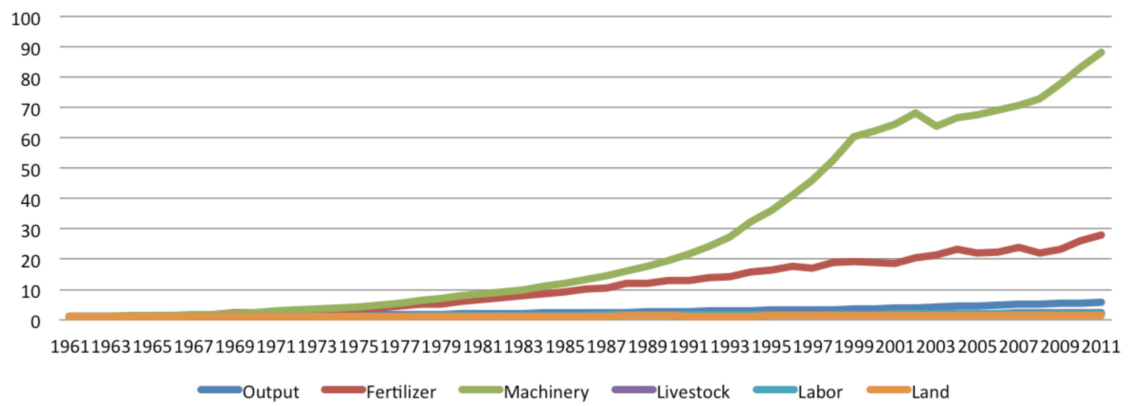



**Table 3. Simple Index average TFP, Input, and Output Percentage Growth Rates by Decade**
**Region: Southeast Asia 1961-2011**

| Country | Output Growth | | | | | Input Growth | | | | | TFP | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 62-69 | 70-79 | 80-89 | 90-99 | 2000-09 | 62-69 | 70-79 | 80-89 | 90-99 | 2000-09 | 62-69 | 70-79 | 80-89 | 90-99 | 2000-09 |
| Cambodia | 1.78 | -11.16 | 11.53 | 3.84 | 6.24 | 2.46 | -3.76 | 3.38 | 3.93 | 2.87 | -0.67 | -7.40 | 8.15 | -0.09 | 3.37 |
| Indonesia | 2.68 | 3.37 | 4.92 | 2.34 | 4.64 | 0.81 | 1.38 | 3.60 | 1.07 | 1.78 | 1.87 | 1.99 | 1.32 | 1.28 | 2.86 |
| Lao's PDR | 5.87 | 0.56 | 4.22 | 4.41 | 5.34 | 4.46 | -0.16 | 2.67 | 3.30 | 2.81 | 1.41 | 0.72 | 1.55 | 1.11 | 2.52 |
| Malaysia | 5.39 | 4.75 | 4.51 | 2.52 | 3.74 | 2.29 | 2.23 | 1.43 | 0.78 | 0.31 | 3.10 | 2.52 | 3.08 | 1.74 | 3.43 |
| Myanmar | 2.32 | 2.83 | 2.47 | 4.46 | 7.17 | 2.88 | 1.99 | 1.29 | 1.62 | 1.24 | -0.56 | 0.84 | 1.18 | 2.84 | 5.93 |
| Philippines | 3.06 | 4.63 | 1.62 | 2.48 | 3.26 | 2.68 | 1.58 | 1.50 | 1.50 | 0.77 | 0.38 | 3.05 | 0.12 | 0.98 | 2.49 |
| Thailand | 3.94 | 3.99 | 3.53 | 1.95 | 3.02 | 3.37 | 2.26 | 2.14 | -0.39 | 0.22 | 0.57 | 1.73 | 1.39 | 2.34 | 2.79 |
| Viet Nam | 0.41 | 3.11 | 4.83 | 5.24 | 4.68 | 1.42 | 0.80 | 2.51 | 2.80 | 1.70 | -1.01 | 2.31 | 2.32 | 2.43 | 2.98 |
| **ASEAN (weighted)** | **2.97** | **3.59** | **3.98** | **2.95** | **3.21** | **2.10** | **1.54** | **2.45** | **1.14** | **1.20** | **0.87** | **2.04** | **1.53** | **1.81** | **3.21** |
| **Fuglie (2008)** | | **3.68** | **3.59** | **3.13** | **3.54** | | **1.67** | **2.63** | **1.52** | **1.37** | | **2.01** | **0.97** | **1.60** | **2.16** |

**Figure 4. Simple Index (weighted) 10 Year Moving Average Output, Inputs and TFP Percent Growth Rates**
**Region: Southeast Asia 1971-2011**

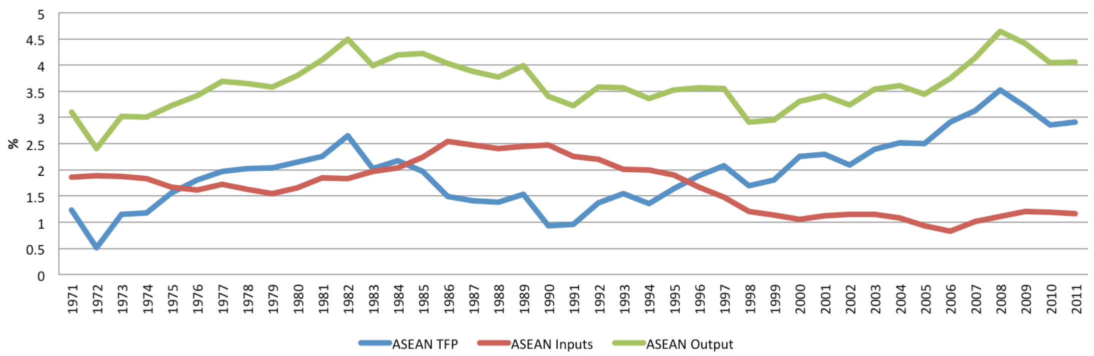



**Table 4. Malmquist Index average TFP, TC, and EC Percentage Growth Rates by Decade**
**Region: Southeast Asia 1961-2011**

| Country | TC | | | | | EC | | | | | TFP | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 62-69 | 70-79 | 80-89 | 90-99 | 2000-09 | 62-69 | 70-79 | 80-89 | 90-99 | 2000-09 | 62-69 | 70-79 | 80-89 | 90-99 | 2000-09 |
| Cambodia | -2.91 | 3.17 | 23.55 | -6.12 | 5.96 | 0.00 | 0.33 | 0.40 | 0.12 | -2.31 | -2.91 | 5.51 | 24.36 | -5.80 | 3.93 |
| Indonesia | -5.30 | -2.23 | -4.34 | -1.38 | 1.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -5.30 | -2.23 | -4.34 | -1.38 | 1.93 |
| Lao's PDR | -12.24 | 13.43 | 15.96 | -7.16 | 2.79 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -12.24 | 13.43 | 15.96 | -7.16 | 2.79 |
| Malaysia | 0.28 | -0.38 | 0.32 | -0.48 | 3.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.28 | -0.38 | 0.32 | -0.48 | 3.10 |
| Myanmar | -4.39 | -0.65 | 1.83 | 1.53 | 7.97 | 0.21 | 0.13 | 0.00 | 0.00 | 0.00 | -4.43 | -0.79 | 1.83 | 1.53 | 7.97 |
| Philippines | -1.46 | 1.79 | -0.53 | 0.65 | 2.94 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.46 | 1.79 | -0.53 | 0.65 | 2.94 |
| Thailand | -3.99 | -2.14 | -1.79 | -0.32 | 2.67 | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 | -3.99 | -2.14 | -1.79 | -0.07 | 2.67 |
| Viet Nam | -0.20 | 2.40 | 1.31 | -1.38 | 3.19 | -0.34 | 0.38 | 0.00 | 0.00 | 0.00 | -0.54 | 2.84 | 1.31 | -1.38 | 3.19 |
| **ASEAN (weighted)** | **-3.28** | **-0.40** | **-1.02** | **-0.77** | **3.19** | **-0.02** | **0.06** | **0.01** | **0.04** | **-0.03** | **-3.32** | **-0.33** | **-1.01** | **-0.72** | **3.17** |

**Figure 5. Malmquist Index (weighted) 10 Year Moving Average EC, TC, and TFP Percent Growth Rates**
**Region: Southeast Asia 1971-2011**

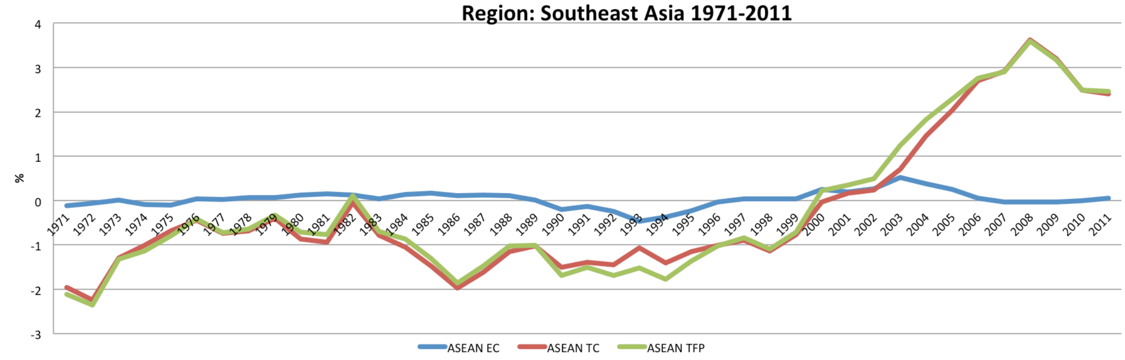



**Table 5. Maximum Likelihood Stochastic Frontier average TC, EC, and TFP Percentage Growth Rates by Decade**
**Region: Southeast Asia 1961-2011**

| Country | TC | | | | | EC | | | | | TFP | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 62-69 | 70-79 | 80-89 | 90-99 | 2000-09 | 62-69 | 70-79 | 80-89 | 90-99 | 2000-09 | 62-69 | 70-79 | 80-89 | 90-99 | 2000-09 |
| Cambodia | -1.32*** | -0.80* | -0.65 | 0.47 | 1.13*** | -0.23 | 3.15 | -3.46 | 0.12 | 1.01 | -1.42 | 2.24 | -4.06 | 0.77 | 0.18 |
| Indonesia | -0.52 | 0.06 | 1.29*** | 2.21*** | 2.46*** | -0.17 | -0.17 | -0.09 | 0.16 | -0.23 | -0.66 | -0.02 | 1.32 | 2.39 | 2.31 |
| Lao's PDR | -1.32* | -1.28** | -0.04 | 1.30** | 2.16*** | 0.94 | -1.07 | 0.12 | -0.25 | 0.23 | -0.18 | -2.39 | 0.21 | 1.21 | 2.47 |
| Malaysia | -1.43*** | -0.98** | -0.44 | -0.06 | 0.78 | -1.33 | -0.31 | 0.77 | -0.51 | -0.52 | -2.72 | -1.21 | 0.34 | -0.48 | 0.35 |
| Myanmar | -0.62* | 0.44 | 1.66*** | 2.10*** | 2.62*** | 0.98 | -0.57 | 0.27 | -0.50 | -0.53 | 0.48 | -0.02 | 1.98 | 1.69 | 2.10 |
| Philippines | 0.22 | 0.51 | 0.43* | 1.03*** | 1.76*** | -0.14 | -0.19 | 0.10 | 0.08 | 0.02 | 0.16 | 0.29 | 0.57 | 1.19 | 1.81 |
| Thailand | -0.04 | 0.36 | 0.53** | 1.01*** | 1.07*** | -2.84 | 0.22 | -0.27 | 0.52 | -0.58 | -2.77 | 0.58 | 0.30 | 1.54 | 0.54 |
| Viet Nam | 0.71** | 1.26*** | 1.93*** | 2.97*** | 3.49*** | 0.52 | -0.39 | -0.26 | 0.05 | 0.04 | 1.32 | 0.89 | 1.81 | 3.07 | 3.60 |
| **ASEAN (weighted)** | **-0.24** | **0.26** | **0.93*****| **1.66***** | **2.12***** | **-0.57** | **-0.17** | **-0.04** | **0.09** | **-0.29** | **-0.74** | **0.13** | **0.97** | **1.81** | **1.90** |

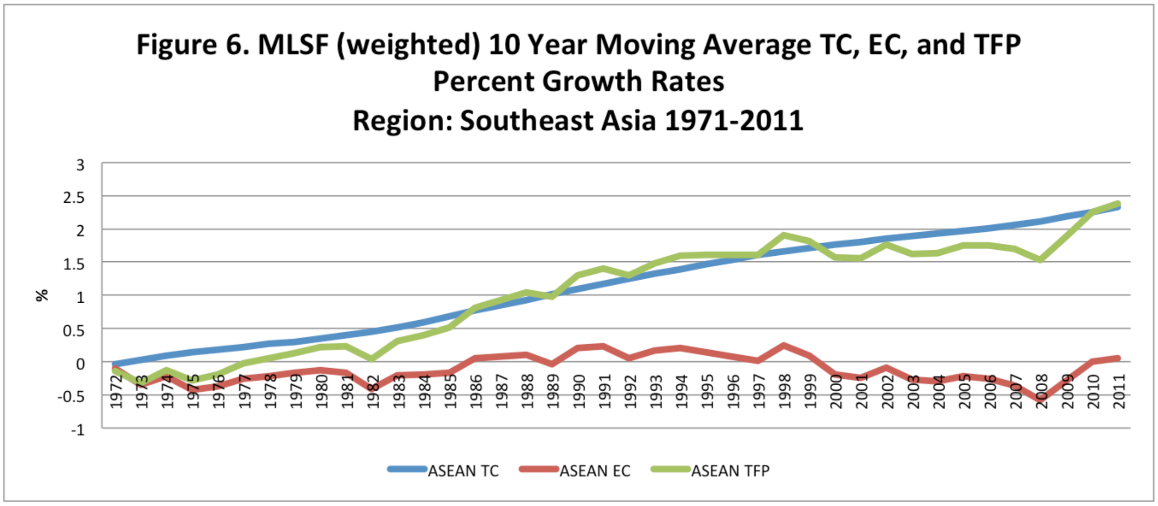
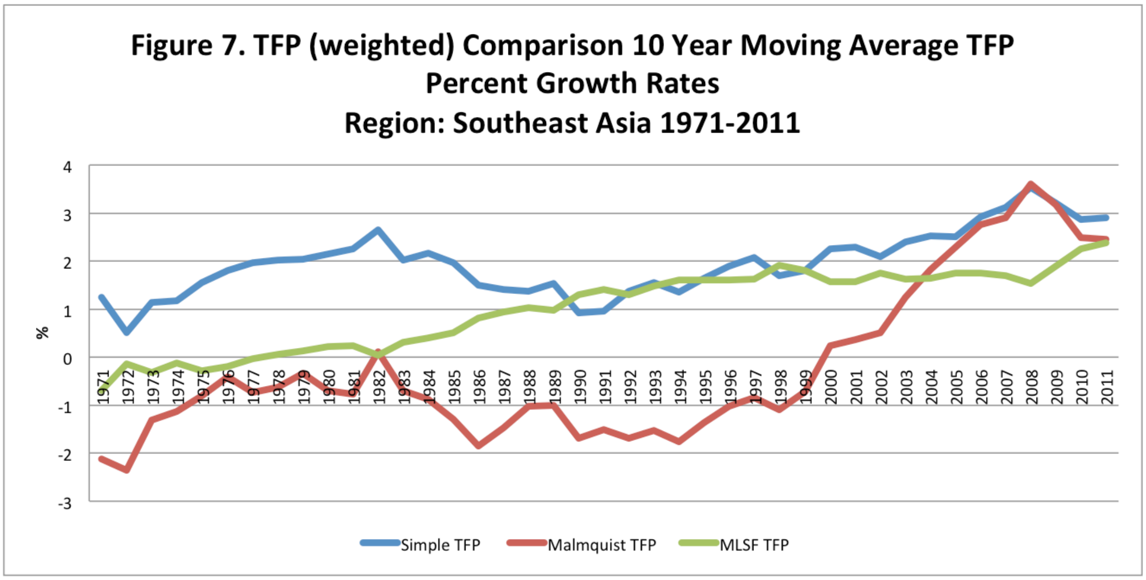



**Table 6. Average TFP Percentage Growth Rates in Agriculture**
**Region: Southeast Asia 1961-2011**

| Country | Simple Index | Malmquist Index | | | MLSF | | | Output |
|---|---|---|---|---|---|---|---|---|
| | TFP | TC | EC | TFP | TC | EC | TFP | |
| Cambodia | 1.06 | 4.67 | 0.36 | 5.58 | -0.09 | -0.36 | -0.42 | 2.78 |
| Indonesia | 1.84 | -2.05 | 0.00 | -2.05 | 1.28 | -0.07 | 1.24 | 3.61 |
| Lao's PDR | 1.49 | 3.21 | 0.00 | 3.21 | 0.37 | -0.03 | 0.39 | 4.13 |
| Malaysia | 2.78 | 0.52 | 0.00 | 0.52 | -0.28 | -0.17 | -0.43 | 4.01 |
| Myanmar | 2.01 | 1.14 | 0.06 | 1.11 | 1.41 | -0.01 | 1.44 | 3.64 |
| Philippines | 1.44 | 0.84 | 0.00 | 0.84 | 0.87 | -0.02 | 0.88 | 2.88 |
| Thailand | 1.87 | -0.95 | 0.04 | -0.90 | 0.65 | -0.48 | 0.19 | 3.25 |
| Viet Nam | 1.94 | 1.11 | 0.02 | 1.15 | 2.23 | -0.03 | 2.24 | 3.78 |
| **ASEAN (weighted)** | **2.65** | **-0.34** | **0.03** | **-0.31** | 1.09 | **-0.14** | **0.98** | **3.49** |




| Table 7. Input Elasticities<br>Region: Southeast Asia 1961-2011. | |
|---|---|
| Fertilizer (weighted) | 0.085<br>(0.027) |
| Land (weighted) | 0.276<br>(0.112) |
| Labor (weighted) | 0.015<br>(0.160) |
| Machinery (weighted) | 0.094<br>(0.031) |
| Livestock (weighted) | 0.309<br>(0.100) |

Appendix A:

**Greene 2005, True Fixed Effects Model**

**Region: Southeast Asia 1961-2011**

**Efficiency Variables:** National Religion (dummy), Non-free (dummy), Life expectancy

| ly | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| **Frontier** | | | | | | |
| lft | .0032187 | .0006016 | 5.35 | 0.000 | .0020396 | .0043978 |
| lmt | -.0026759 | .0008431 | -3.17 | 0.002 | -.0043282 | -.0010235 |
| llabt | .004394 | .0025371 | 1.73 | 0.083 | -.0005787 | .0093666 |
| llant | -.0168414 | .0022317 | -7.55 | 0.000 | -.0212154 | -.0124674 |
| llivt | .015809 | .0028141 | 5.62 | 0.000 | .0102935 | .0213246 |
| lf | 1.184218 | .2673855 | 4.43 | 0.000 | .6601519 | 1.708284 |
| lm | -.3333072 | .2904424 | -1.15 | 0.251 | -.9025637 | .2359494 |
| llab | -2.148623 | 1.499062 | -1.43 | 0.152 | -5.08673 | .7894837 |
| llan | 2.185673 | 1.087774 | 2.01 | 0.045 | .0536752 | 4.31767 |
| lliv | 2.91186 | 1.945686 | 1.50 | 0.135 | -.9016152 | 6.725334 |
| lf2 | .050747 | .0094686 | 5.36 | 0.000 | .0321888 | .0693052 |
| lm2 | .0362121 | .0144221 | 2.51 | 0.012 | .0079454 | .0644788 |
| llab2 | .3504829 | .1074058 | 3.26 | 0.001 | .1399714 | .5609945 |
| llan2 | .0011913 | .1184472 | 0.01 | 0.992 | -.2309611 | .2333436 |
| lliv2 | -.2793619 | .2156016 | -1.30 | 0.195 | -.7019333 | .1432094 |
| lflm | -.0446082 | .0080388 | -5.55 | 0.000 | -.0603639 | -.0288525 |
| lfllab | -.0607155 | .0297535 | -2.04 | 0.041 | -.1190313 | -.0023996 |
| lfllan | .127707 | .0259219 | 4.93 | 0.000 | .0769009 | .178513 |
| lflliv | -.1234706 | .0283674 | -4.35 | 0.000 | -.1790696 | -.0678715 |
| lmllab | .0180741 | .0325408 | 0.56 | 0.579 | -.0457047 | .0818529 |
| lmllan | .0423342 | .023654 | 1.79 | 0.073 | -.0040268 | .0886952 |
| lmlliv | .0077954 | .0265794 | 0.29 | 0.769 | -.0442993 | .0598901 |
| llabllan | -.4892635 | .0930886 | -5.26 | 0.000 | -.6717137 | -.3068132 |
| llivllab | .243831 | .1258056 | 1.94 | 0.053 | -.0027435 | .4904054 |
| llivllan | .0638386 | .1075285 | 0.59 | 0.553 | -.1469134 | .2745906 |
| t | -.1524181 | .034684 | -4.39 | 0.000 | -.2203975 | -.0844386 |
| t2 | .0004441 | .0001052 | 4.22 | 0.000 | .000238 | .0006503 |
| **Usigma** | | | | | | |
| non_free | .714969 | .5274915 | 1.36 | 0.175 | -.3188954 | 1.748833 |
| natlreligion | 1.429701 | .30596 | 4.67 | 0.000 | .8300304 | 2.029372 |
| lifeexp | -.0892652 | .0160298 | -5.57 | 0.000 | -.120683 | -.0578474 |
| _cons | -.6210563 | 1.085889 | -0.57 | 0.567 | -2.749359 | 1.507247 |
| **Vsigma** | | | | | | |
| _cons | -6.46763 | .2788215 | -23.20 | 0.000 | -7.01411 | -5.92115 |
| E(sigma_u) | .1098009 | | | | .0991412 | .1204607 |
| sigma_v | .0394069 | .0054937 | 7.17 | 0.000 | .0299851 | .0517891 |

Definitions of MLSF variables

- lft = natural log of fertilizer with a linear time trend interaction
- lmt = natural log of machinery with a linear time trend interaction
- llabt = natural log of labor with a linear time trend interaction
- llant = natural log of land with a linear time trend interaction
- llivt = natural log livestock with a linear time trend interaction
- lf = natural log of fertilizer
- lm = natural log of machinery
- llab = natural log of labor
- llan = natural log of land
- lliv = natural log of livestock
- lf2 = the geometric mean of the natural log of fertilizer
- lm2 = the geometric mean of the natural log of machinery
- llab2 = the geometric mean of the natural log of labor
- llan2 = the geometric mean of the natural log of land
- lliv2 = the geometric mean of the natural log of livestock
- lflm = interaction between the natural logs of machinery
- lfllab = interaction between the natural logs of fertilizer and labor
- lfllan = interaction between the natural log of fertilizer and land
- lflliv = interaction between the natural log of fertilizer and livestock
- lmllab = interaction between the natural logs of machinery and labor
- lmllan = interaction between the natural logs of machinery and land
- lmlliv = interaction between the natural logs of machinery and livestock
- llabllan = interaction between the natural logs of labor and land
- llivllab = interaction between the natural logs of livestock and labor
- llivllan = interaction between the natural logs of livestock and land
- t = linear time trend
- t2 = geometric mean of linear time trend
- non_free = dummy variable where any country classified as not free or partly free, according to the Freedom House Index, receives a 1 otherwise 0
- natlreligion = dummy variable for the presence of an established national religion, as according to the CIA Factbook, receives a 1 if a national religion is present 0 otherwise
- lifeexp = life expectancy measured as the number of years expected to live at birth, as according to the World Bank's, World Development Indicators
- _cons = constant
- E(sigma_u) = error term associated with the differences in agricultural efficiency observed across nations
- sigma_v = random error term

Appendix B:

**Figure 8. Simple Index (weighted) Input, Ouput, and TFP Percent Growth Rates Region: Southeast Asia 2000-2011**


**Figure 9. Malmquist Index (weighted) EC, TC, and TFP Percent Growth Rates Region: Southeast Asia 2000-2011**

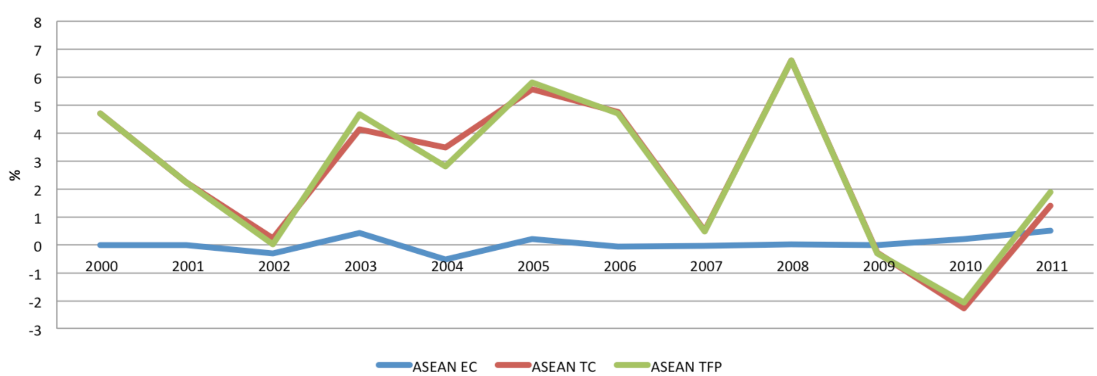



**Figure 10. MLSF (weighted) TC, EC, and TFP Percent Growth Rates Region: Southeast Asia 2000-2011**

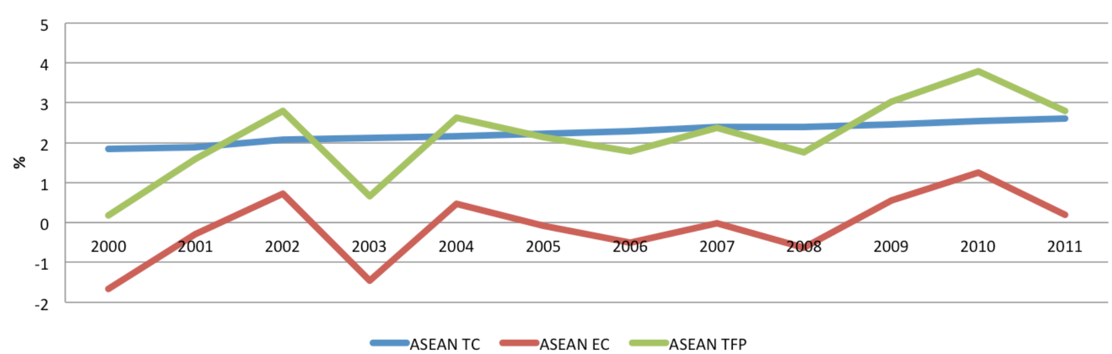


**Figure 11. Evolution of Output and Inputs (index 1961=1)**
**Region: Cambodia 1961-2011**

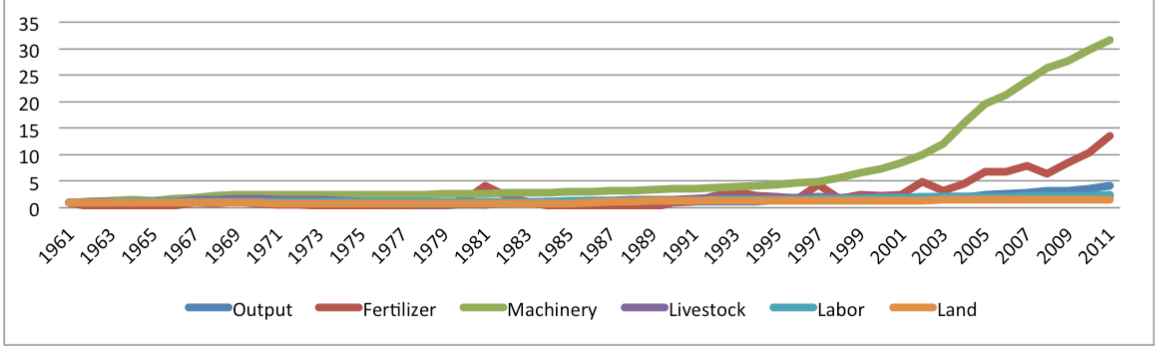



**Figure 12. Evolution of Output and Inputs (index 1961=1)**
**Region: Indonesia 1961-2011**

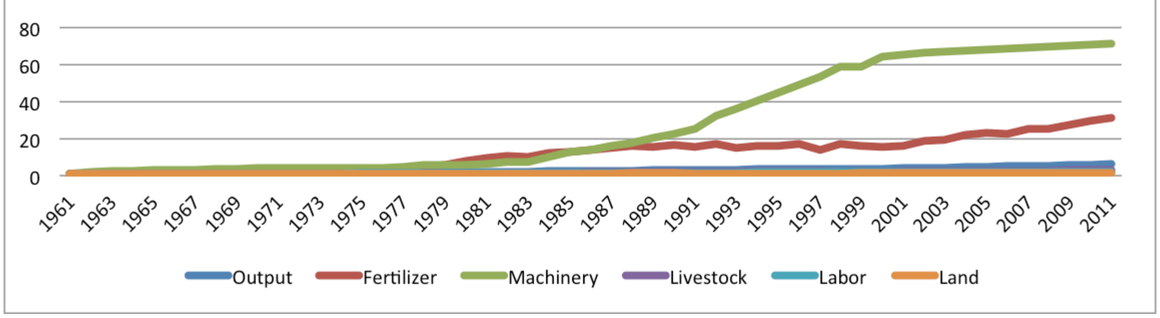
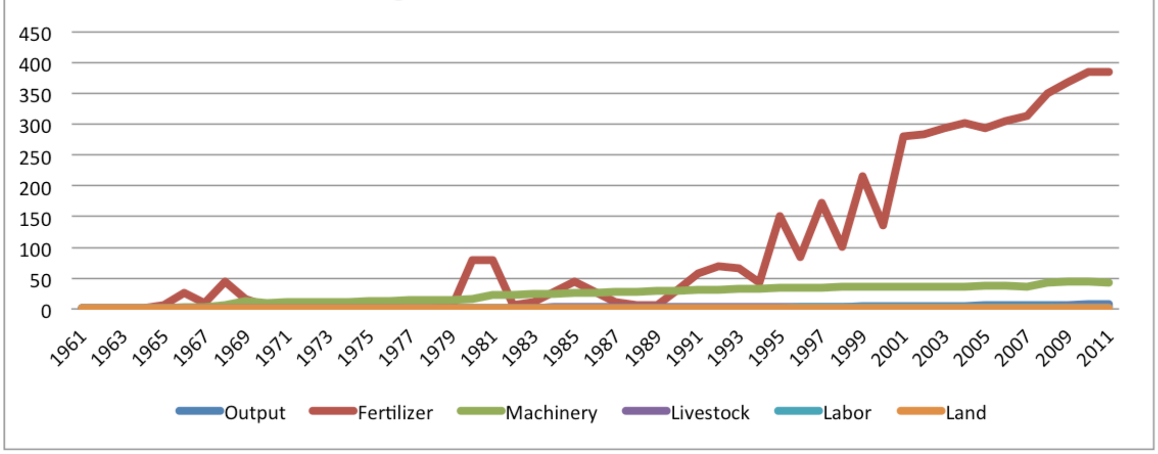



**Figure 13. Evolution of Output and Inputs (index 1961=1)**
**Region: Lao's PDR 1961-2011**



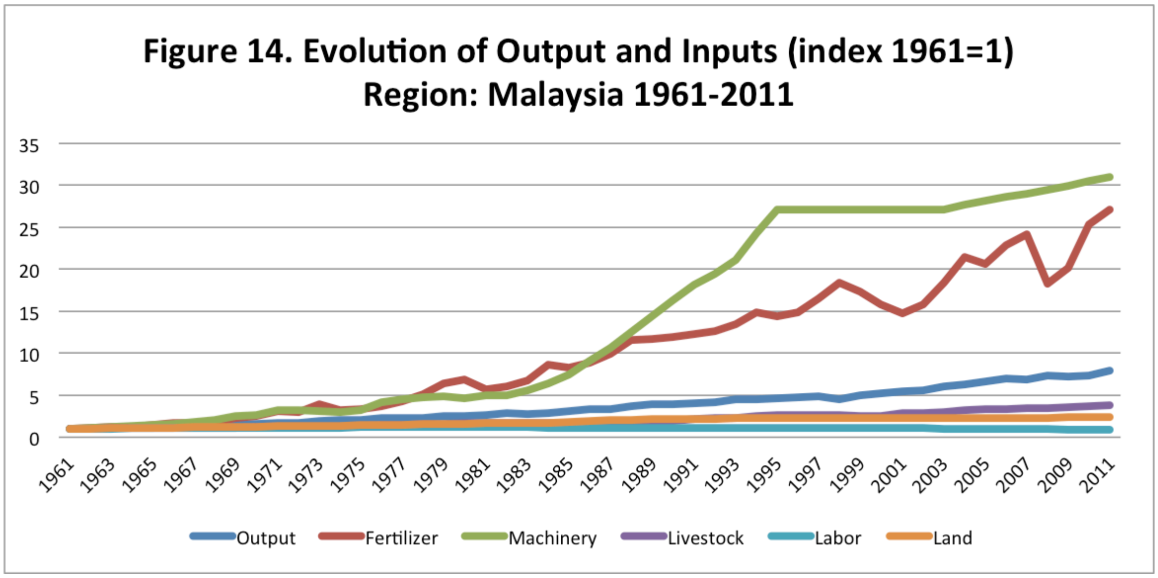


Figure 14. Evolution of Output and Inputs (index 1961=1)
Region: Malaysia 1961-2011
35
30
25
20
15
10
5
0
1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Output
Fertilizer
Machinery
Livestock
Labor
Land

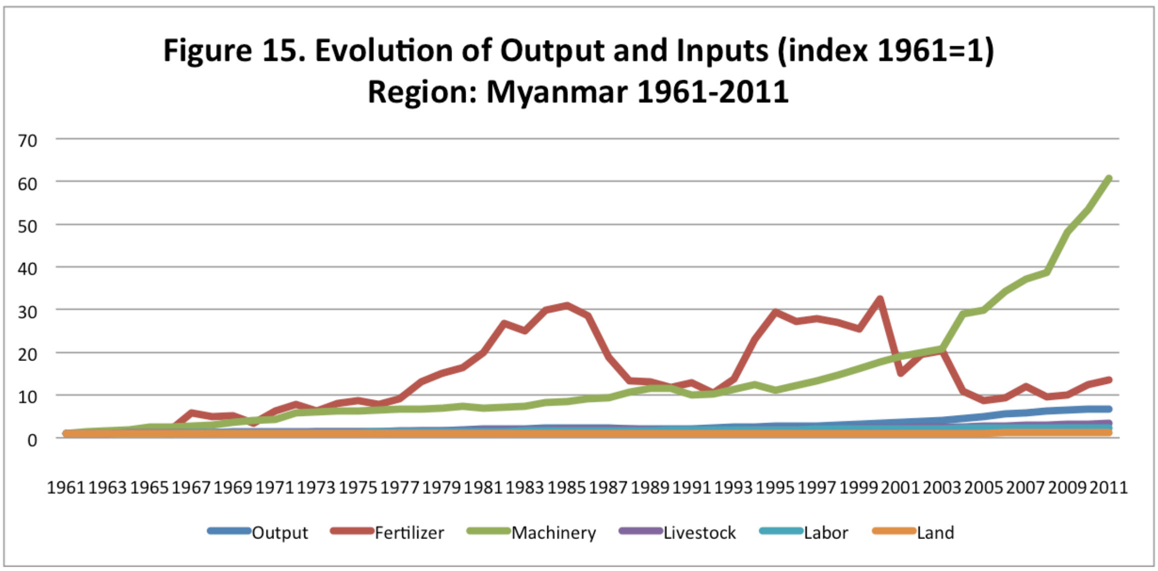


Figure 15. Evolution of Output and Inputs (index 1961=1)
Region: Myanmar 1961-2011
70
60
50
40
30
20
10
0
1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Output
Fertilizer
Machinery
Livestock
Labor
Land

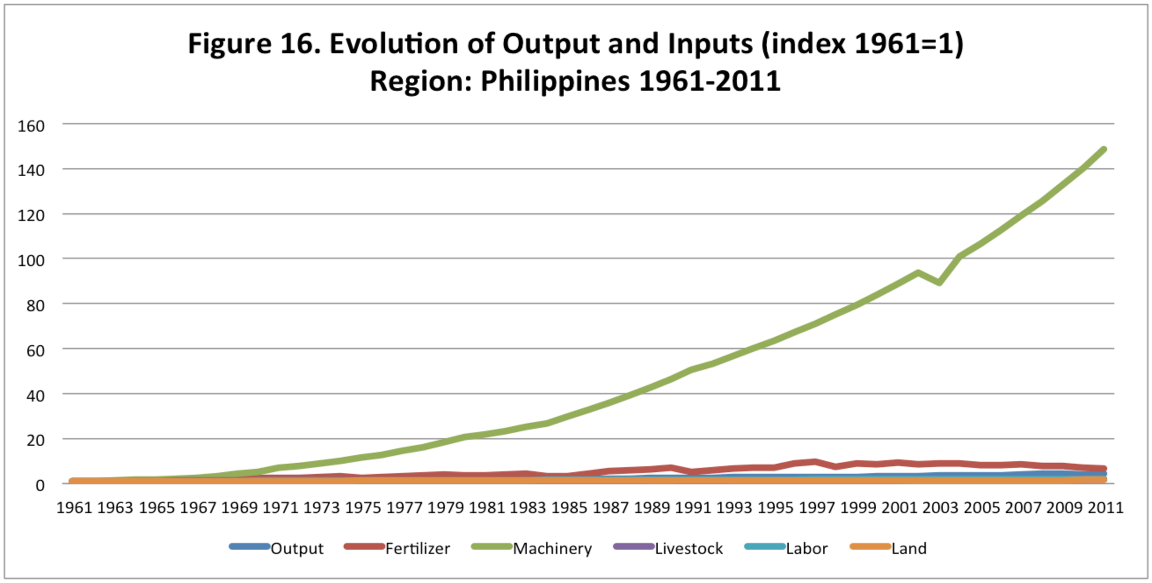


Figure 16. Evolution of Output and Inputs (index 1961=1)
Region: Philippines 1961-2011
160
140
120
100
80
60
40
20
0
1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Output
Fertilizer
Machinery
Livestock
Labor
Land

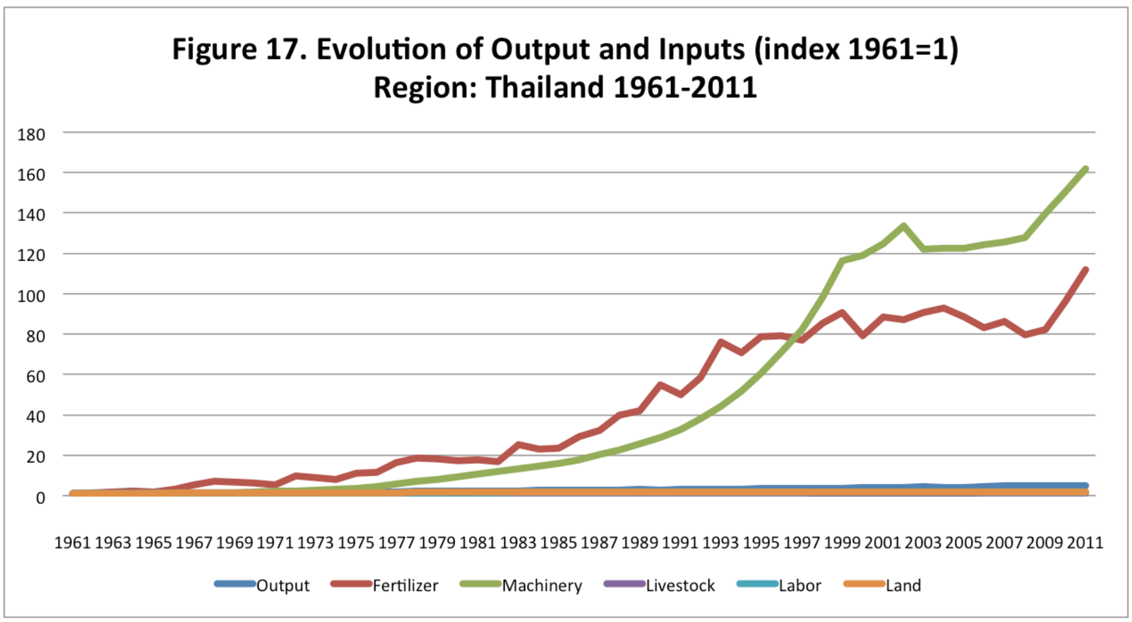


Figure 17. Evolution of Output and Inputs (index 1961=1)
Region: Thailand 1961-2011
180
160
140
120
100
80
60
40
20
0
1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Output
Fertilizer
Machinery
Livestock
Labor
Land

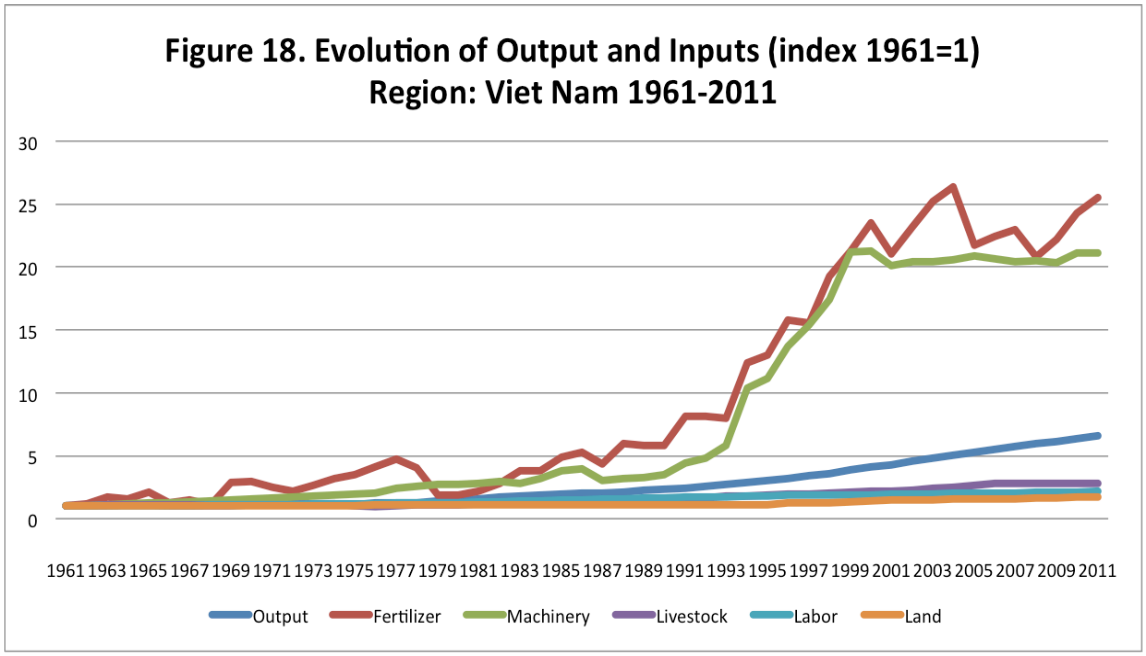


Figure 18. Evolution of Output and Inputs (index 1961=1)
Region: Viet Nam 1961-2011
30
25
20
15
10
5
0
1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Output
Fertilizer
Machinery
Livestock
Labor
Land

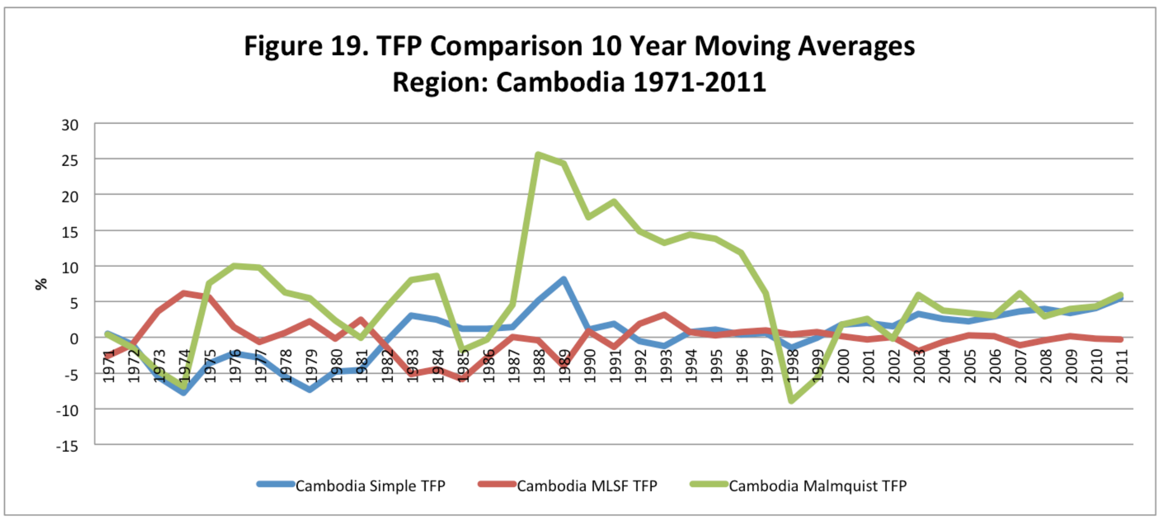


Figure 19. TFP Comparison 10 Year Moving Averages
Region: Cambodia 1971-2011
%
30
25
20
15
10
5
0
-5
-10
-15
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
Cambodia Simple TFP
Cambodia MLSF TFP
Cambodia Malmquist TFP

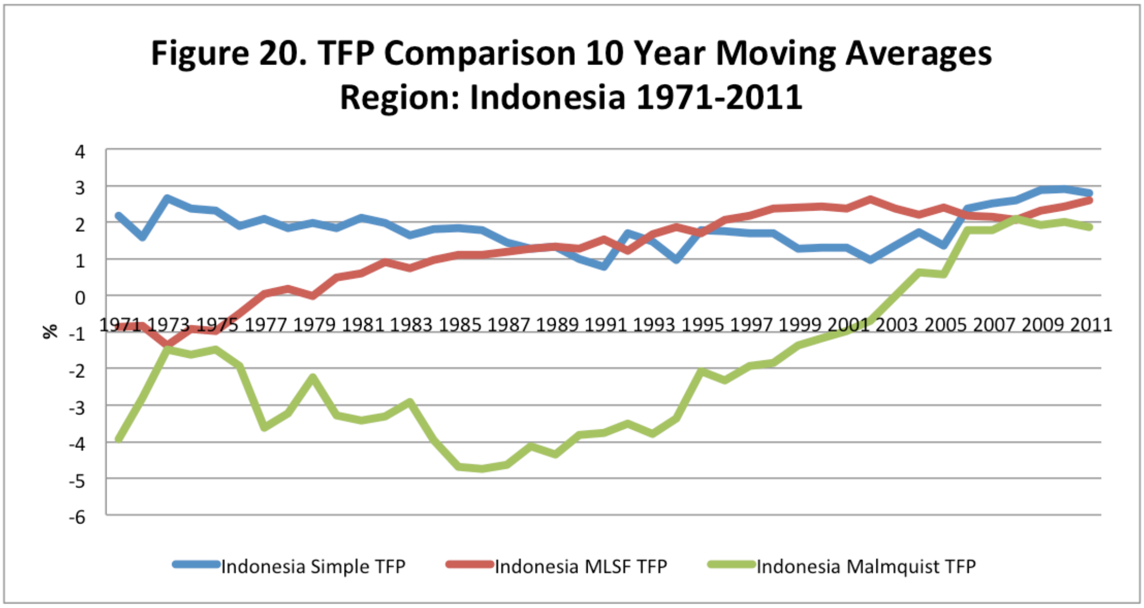


Figure 20. TFP Comparison 10 Year Moving Averages
Region: Indonesia 1971-2011
%
4
3
2
1
0
-1
-2
-3
-4
-5
-6
1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Indonesia Simple TFP
Indonesia MLSF TFP
Indonesia Malmquist TFP

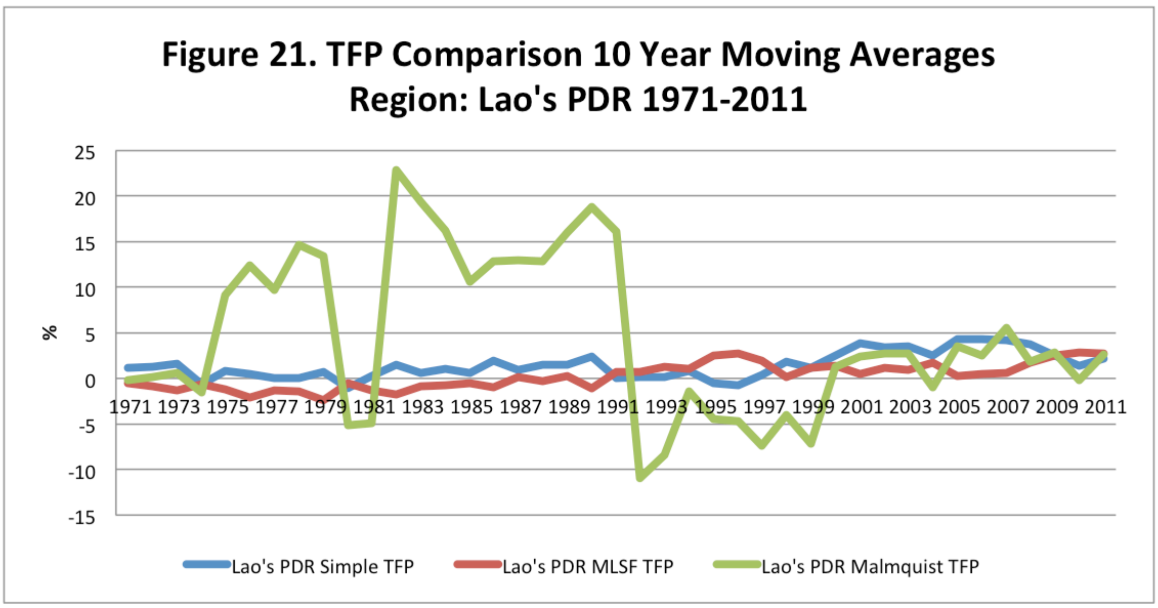


Figure 21. TFP Comparison 10 Year Moving Averages
Region: Lao's PDR 1971-2011
%
25
20
15
10
5
0
-5
-10
-15
1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Lao's PDR Simple TFP
Lao's PDR MLSF TFP
Lao's PDR Malmquist TFP

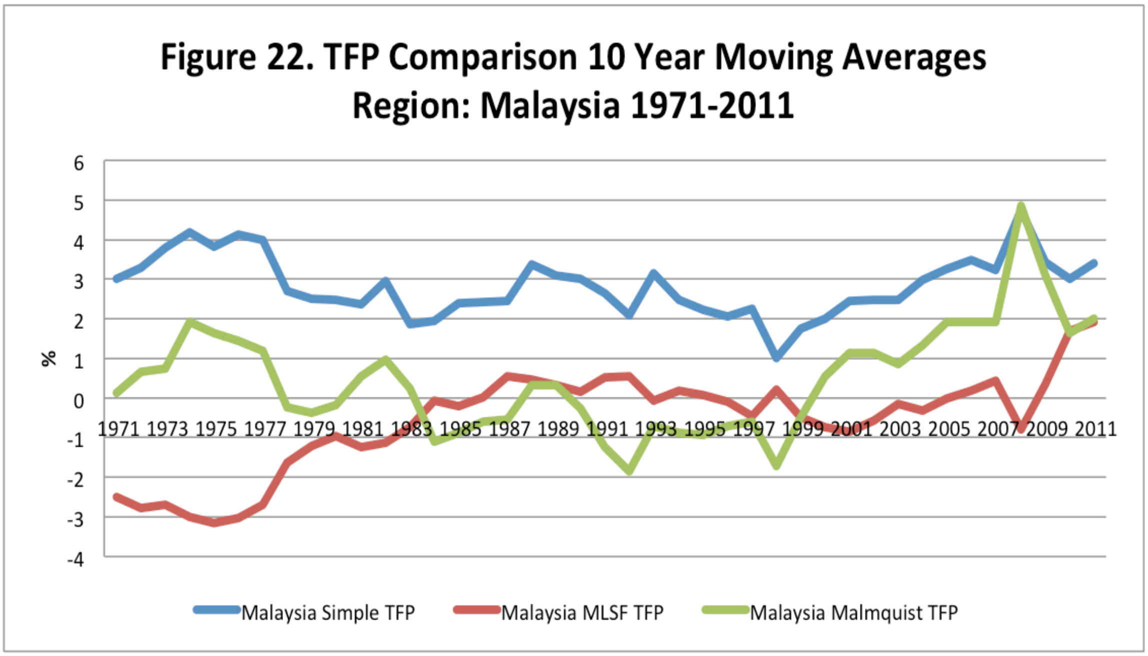


Figure 22. TFP Comparison 10 Year Moving Averages
Region: Malaysia 1971-2011
%
6
5
4
3
2
1
0
-1
-2
-3
-4
1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Malaysia Simple TFP
Malaysia MLSF TFP
Malaysia Malmquist TFP

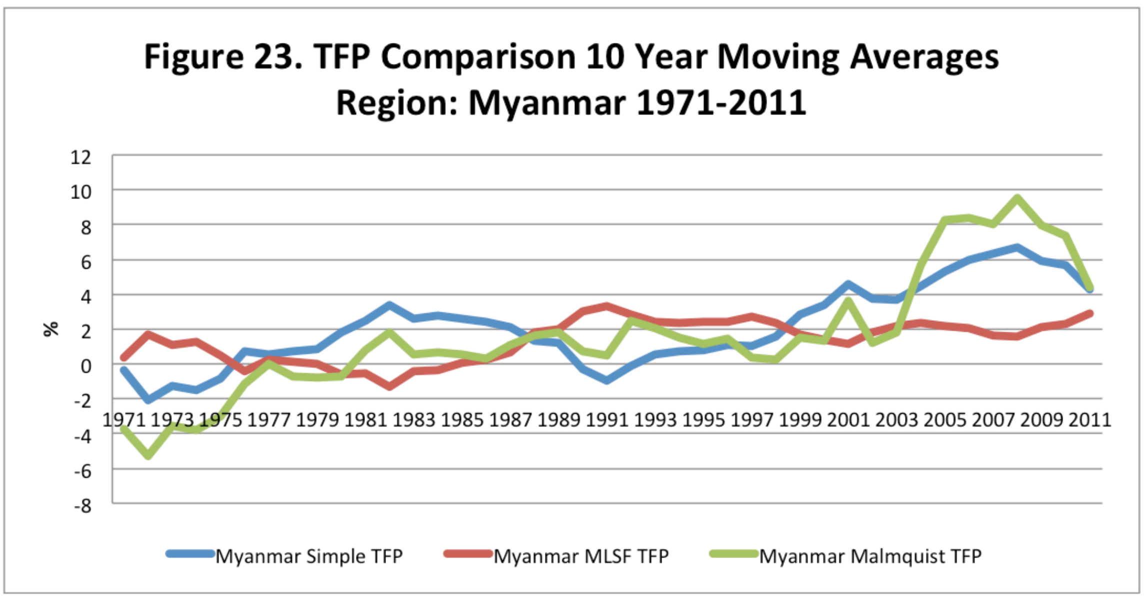


Figure 23. TFP Comparison 10 Year Moving Averages
Region: Myanmar 1971-2011
%
12
10
8
6
4
2
0
-2
-4
-6
-8
1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Myanmar Simple TFP
Myanmar MLSF TFP
Myanmar Malmquist TFP

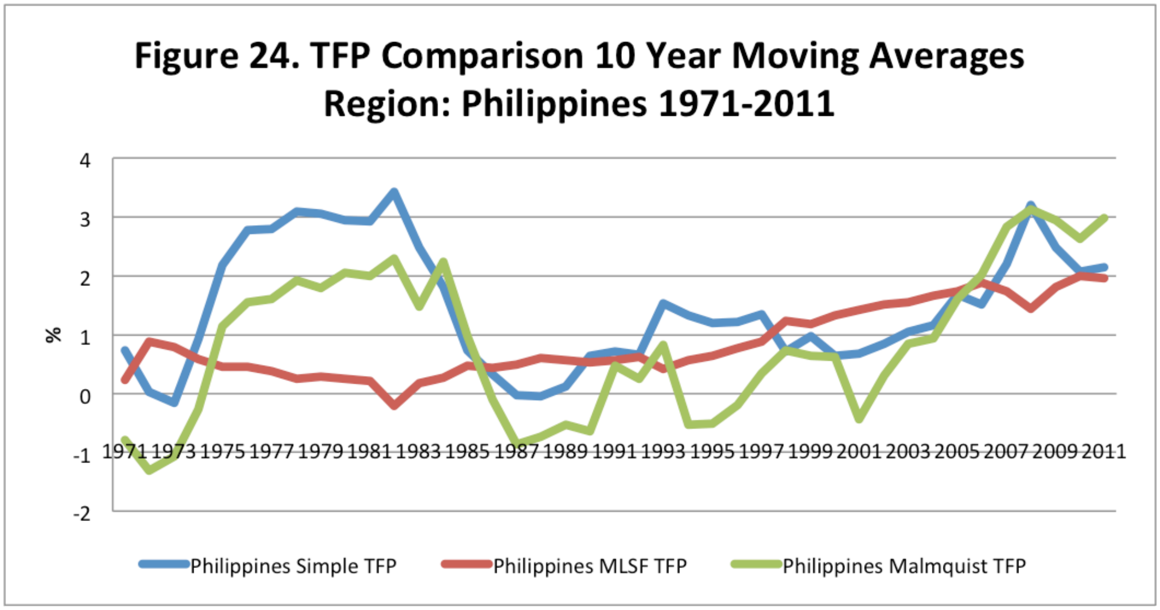


Figure 24. TFP Comparison 10 Year Moving Averages
Region: Philippines 1971-2011
%
4
3
2
1
0
-1
-2
1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Philippines Simple TFP
Philippines MLSF TFP
Philippines Malmquist TFP

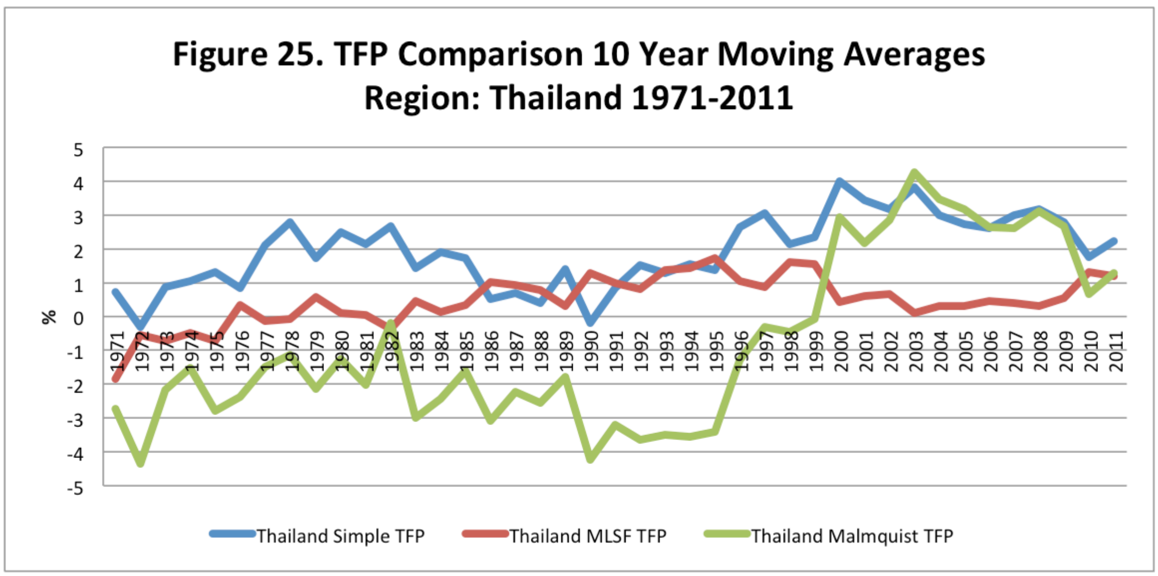


Figure 25. TFP Comparison 10 Year Moving Averages
Region: Thailand 1971-2011
%
5
4
3
2
1
0
-1
-2
-3
-4
-5
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
Thailand Simple TFP
Thailand MLSF TFP
Thailand Malmquist TFP

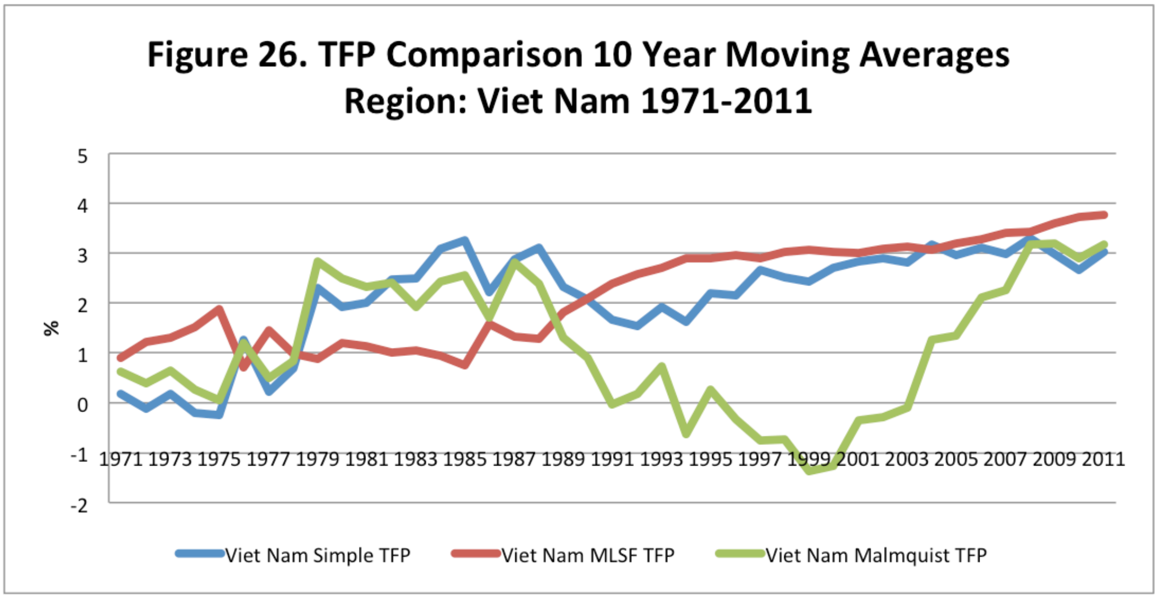


Figure 26. TFP Comparison 10 Year Moving Averages
Region: Viet Nam 1971-2011
5
4
3
2
1
0
-1
-2
%
1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Viet Nam Simple TFP
Viet Nam MLSF TFP
Viet Nam Malmquist TFP