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VIETNAM'S AGRICULTURAL PRODUCTIVITY: A MALMQUIST INDEX APPROACH

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Abstract

This paper applies Malmquist productivity index method to measure total factor productivity (TFP) growth in Vietnamese agriculture using a panel data from 60 provinces in Vietnam during the period 1985-2000. This study indicates that most of the early growth in Vietnamese agriculture (1985-1990) was due to TFP growth, in response to incentive reforms. During the period 1990-1995, the growth rate of TFP fell and Vietnam's agricultural growth was mainly caused by drastic investment in capital. In the last period 1995-2000, TFP growth increased again, though still much lower than the period 1985-1990. Overall, TFP growth rate in the whole period is estimated 1.96 percent, contributing to 38% of Vietnam's agricultural growth.

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I. Introduction

Since Vietnam started its economic reforms in 1986, her economy has grown rapidly. From being an importer of food during the early 1980's, Vietnam has now become one of the biggest rice exporters in the world. Agricultural output increased by 5.9 percent annually during the period from 1988 to 2000, while its annual growth is 4.4 percent during the period 1975-1987. The growth in agricultural output has contributed greatly to improved household income in Vietnam as about 70 percent of Vietnamese population is engaged in agricultural activities. In this context, a study on the productivity of agriculture in Vietnam as well as the impacts of market reforms on agricultural productivity is very important.

There have been several attempts that estimate the productivity and efficiency for rice farming in Vietnam. Based on rice production function, Tuong et al. (2006) estimated that TFP growth rate was 0.77 percent during 1976-1980, 3.52 percent during 1981-1987 and 3.24 percent during 1988-1994. Using region-level data, Nghiem and Coelli (2002) applied Malmquist index method to investigate total factor productivity (TFP) growth in the period 1975-1997. They found that the average TFP growth is between 3.3 and 3.5 percent per annum, with the fastest growth occurred during 1981-1987. For the period 1987-1999, their estimate of TFP growth of rice production was about 2.4 percent per annum. Kompas (2004) estimated TFP growth of rice production in Vietnam by stochastic frontier method. He found that TFP growth rate was 0.60 percent during 1976-1980, 2.74 percent during 1981-1987, 4.43 percent during 1988-1994 and 4.46 percent during 1995-99.

To my knowledge, there are few studies on Vietnam's agricultural productivity as a whole. Using agricultural Cobb-Douglass production function, a report for an ADB project by Nguyen and Goletti (2001) estimated that annual TFP growth was 2.16 percent during 1985-1989 and 0.32 percent during 1990-1999. The apparent lack of interest in agricultural productivity and efficiency in Vietnam is clearly a gap in the research on Vietnam's economy. In comparison, there have been many papers on agricultural productivity in China, whose agricultural market reforms have borne much similarity with Vietnam. Some studies on China's agricultural productivity include Brümmer et al (2006), Caster and Estrin (2001), Fan (1991, 1997), Fleisher and Liu (1992), Huang (1998), Kalirajan et al. (1996), Lin (1992), Mao and Koo (1997), McMillan et al. (1989), Stavis (1991), Wang et al. (1996), Wen (1993), Wu et al. (2001).

This study uses Malmquist index method to estimate Vietnam's agricultural productivity. Malmquist index method has been used in Nghiem and Coelli (2002) to investigate Vietnam rice farming productivity and efficiency with region-level data. It is a powerful method to estimate total factor productivity (TFP) and its components, based on panel data. The remainder of this paper is organized in sections. In section 2, I provide a brief description of Vietnam's agriculture and market reforms. Section 3 discusses the method and the data. Section 4 presents the results and discussion, which are followed by the concluding comments in section 5.

II. Vietnam's agriculture and market reforms.

Agriculture is very important to Vietnamese economy. About 62 percent of Vietnamese labor population is engaged in agricultural activities. Agriculture contributes 23 percent of GDP (Dang et al 2006) and 16% of exports (FAO 2004). After the reunification of the country in 1975, there was a crisis in Vietnam's agriculture sector, especially in the production of rice, the most important food crop in Vietnam. Although total agricultural output increased by an average growth rate of 4.5 percent during 1976-1980, there was actually a reduction in both rice output and rice yield in the same period. Pingali and Vo (1992) estimated that rice output per capita in 1980 was less than that in 1976 by 8 percent. In the mean time, rice yield reduced by 7 percent (according to data in Nguyen 1995). There was food shortage and low agricultural productivity in Vietnam in late 1970s and early 1980s, indicating the failure of the collectivization in agriculture.

In order to overcome this crisis, the government introduced some agricultural reforms in 1981. Beginning from 1981, Vietnam started departing from a collectivized agricultural system to a household-oriented contract system. This system was similar to the household responsibility system launched in China in 1979. It allowed households to have short-term (three-year) use right with their allocated plot and required them to meet output contracts with the state. The switch from the collectivized system to the contract system provided the first stimulus to Vietnamese agriculture. For example, rice yield increased by 34 percent from 1980 to 1985. However, the output and input markets were still under state control and farmers were required to sell outputs and buy inputs from the state.

Despite certain successes in the wake of this reform, the picture of Vietnamese agriculture was still very depressing before *Doi Moi* (Renovation) time in 1986. Compared to the amount in 1942, rice output capita in 1986 was only 93 percent for the whole country, 105 percent for the North and 79 percent for the South (Pingali and Vo 1992).

In December, 1986, the *Doi Moi* reform strategy at the 6th Vietnamese Communist Party Congress was publicly announced. The Doi Moi strategy called for complete renovation of the whole economy. The first priorities of Doi Moi policy were given to the industrial sector, by giving more autonomy to state-owned enterprises. Not until 1988 were major policy changes in agriculture introduced. In April, 1988, the Politburo promulgated Resolution 10 on reforming the agricultural economy. This Resolution was a radical extension of the earlier policy (Resolution 100) in 1981. It allowed farming households to have long-term (15 years) contracts on land and permitted them to make all decisions with regard to their farming activities. This policy resulted in the decollectivization process, in which the state cooperatives shrink in size and number, while farming households became the dominant force in agriculture. In November, 1988, the Government announced that except tax obligation on agricultural output, farming household were free to sell their products in the market to private traders as well as to the state companies. Private traders were guaranteed equal treatment as state trading companies. The Government also dropped its subsidy of food grain to government employees, thus dropping the two-tier price system and enabling liberalization in the agricultural output market. In addition, the agricultural input market was finally liberalized by December, 1988, when private traders were allowed to sell machinery, fertilizers and other input supplies to farmers. In 1989, further policy reforms were introduced to liberalize Vietnam's economy. Almost all prices controls were abolished, including interest rates and partly exchange rates. Government direct subsidies to state-owned enterprises were also dropped by 1989.

The combination of agricultural reforms such as Resolution 10 and trade liberation had encouraged agricultural production and export. During 1985-1989, agricultural output increased by 18 percent, rice output by 22 percent, and rice yield by 18 percent. In 1989, Vietnam, which had been a net importer of rice for two decades, exported 1.5 million tons of rice (Dang et al. 2006).

During the 1990s, there was one major policy reform in agriculture: the Land Law. In Vietnam's Constitution, land is publicly owned and the right of land was never clearly defined in laws, consequently it is difficult to secure land owner's property right. In 1993, the Land Law was passed. While this law still stated that all land is publicly owned, it recognized the land-use right of people, and enable landholders to obtain legal land-use titles (colloquially called "the Red Notebook"). As a result, households established secure legal right to their land and land can be transferred, sold, or inherited.

Besides other purposes, the Land Law was supposed to boost agricultural production by giving farmers' incentives to increase their efficiency and productivity. However, the impacts of the Land Law on agricultural production are not clear. Dang et al (2006) remarked that "land markets have failed to develop strongly" and high land rental rates, as allowed by the Land Law, might prohibit new investment by farmers and reintroduce social stratification. Do and Ieyr (2008) examined the 1993 Land Law and found that additional land rights led to increases in nonfarm activities and long-term farming but the increases are not large in magnitudes. They found no significant impact on household consumption or agricultural income. Hare (2008) assessed the impacts of land right certificates to agricultural production and found that the direct impact was rather small in the absence of supporting institutions. He pointed out that controlling for community characteristics, the impacts of land right were insignificant.

In short, Vietnam's major agricultural market reforms were implemented during 1980s and early 1990s. As a whole, Vietnam's market reform in the economy in general and in agriculture, in particular, has induced remarkable changes in Vietnam agriculture. Table 1 reports the annual changes in various indicators of Vietnamese agriculture during the period 1985-2000. Output increased at the slowest rate in the period 1985-1990 and at the highest rate during the period 1995-2000. The latter period also witnessed sharp increases in the use of machinery and fertilizer as in the period 1990-1995, but the increase in labor was considerably smaller than the period 1990-1995. Land productivity increased at the rate of 2.7 percent in the early 90s and 2.5 percent in the late 90s, slightly higher than the late 80s period (2.4 percent). Labor productivity improvement was low in the late 80s period, at 1.25 percent, and negative at -0.42 percent in the period 1990-1995. The reason for negative labor productivity during this period is possibly due to the absorption of redundant labor from the restructured state-owned enterprises (SOEs) into the agricultural sector. As a result, agricultural labor increased remarkably during the period, at the annual rate of 6.2 percent. Most of the increase occurred in 1991/92, when agricultural labor increased by 18% due to the fundamental SOE restructuring in 1991. In the period 1995-2000, the role of agriculture in absorbing redundant labor diminished. In this period, labor productivity increased by 5.1 percent, while total agricultural labor increased by 1.1 percent, just about half of the growth rate in the labor force. Technology and machine use, as reflected by the indices of tractor per labor and fertilizer per land, are highest during the 1990-94 period, and lowest during the late 80s period. The index of tractor per labor even decreased during the first reform period 1985-89, perhaps as a result of collectives being broken up and land being divided to households. However, in the 1990s, the number of machines used in agriculture increased remarkably, while the increase in the number of draft animals slowed down. Evidently, this reflects a change in the production technology in agriculture.

Insert Table 1 here

III. Method and Data

Malmquist DEA method

This paper applies the nonparametric output-oriented Malmquist DEA method based on a panel data of 60 provinces in the period 1985-2000. The total factor productivity (TFP) estimated by Malmquist DEA method is chosen in preference to the Tornqvist TFP index method, because the latter index involves the use of observed prices, which are not available in recent Vietnamese agricultural data. The Malmquist TFP index method also has a major advantage, by allowing the decomposition of TFP growth into efficiency change and technical change.

Färe et al. (1994) showed that the Malmquist productivity index could be calculated without price data. In their approach, the output distance function is defined on the output set P(x) as:

$$d(x, y) = \min\{\delta : (y/\delta) \in P(x)\}$$

The output distance function $d(x, y)$ will take a value larger than zero and less than or equal to 1 if the output vector *y* is an element of the feasible production set. If y is located on the boundary of the feasible production set, the output distance function will take a value of unity.

The output-oriented Malmquist TFP index measures the TFP change between two periods by calculating the distance functions of each data point to the relevant technology. Following Färe et al (1994), the Malmquist (output-oriented) TFP change index between period s (the base period) and period t under constant return to scale (VRS) is defined as:

$$m_o(y_s, x_s, y_t, x_t) = \left[\frac{d_t^s(y_t, x_t)}{d_s^s(y_s, x_s)} \times \frac{d_t^t(y_t, x_t)}{d_s^t(y_s, x_s)}\right]^{1/2} \tag{1}$$

in which $d_t^s, d_s^s, d_t^t, d_s^t$ are distance functions under CRS and *y, x* are the output and input vector.

The TFP change index in (1) is actually the geometric mean of two TFP change measure: the first is relative to period *s*, and the second is relative to period *t*. In all, a Malmquist index greater than unity indicates a TFP increase from *s* to *t*, while a Malmquist index less than unity indicates a TFP decrease.

Equation (1) can be arranged to show that the TFP change index is equivalent to the product of a technical efficiency change index and an index of technical change:

$$M_s^t(y_s, x_s, y_t, x_t) = \frac{d_t^t(y_t, x_t)}{d_s^s(y_s, x_s)}\left[\frac{d_t^s(y_t, x_t)}{d_t^t(y_t, x_t)} \times \frac{d_s^s(y_s, x_s)}{d_s^t(y_s, x_s)}\right]^{1/2} \tag{2}$$

Efficiency change (EC): $EC_s^t = \dfrac{d_t^t(y_t, x_t)}{d_s^s(y_s, x_s)}$ (3)

and *Technical change (TC)*: $TC_s^t = \left[\dfrac{d_t^s(y_t, x_t)}{d_t^t(y_t, x_t)} \times \dfrac{d_s^s(y_s, x_s)}{d_s^t(y_s, x_s)}\right]^{1/2}$ (4)

Furthermore, the efficiency change in (3) can be further decomposed into pure efficiency change (or efficiency change under VRS) and scale efficiency change.

$$\textit{Pure efficiency change (PEC)}: \; PEC_s^t = \frac{d_{t-VRS}^t(y_t, x_t)}{d_{s-VRS}^s(y_s, x_s)} \tag{5}$$

and a *scale efficiency change (SEC)* component

$$SEC_s^t = \frac{d_t^t(y_t, x_t)/d_{t-VRS}^t(y_t, x_t)}{d_s^t(y_s, x_s)/d_{s-VRS}^t(y_s, x_s)} \tag{6}$$

where d_{VRS} denotes a distance function under variable return to scale (VRS) assumption.

The distance function $\widehat{d}_s^t(y_s, x_s)$ is estimated by the following linear programming problems under constant return to scale (CRS).

$$[\widehat{d}_s^t(y_s, x_s)]^{-1} = \max_{\theta,\lambda} \hat{\theta} \text{ such that} \tag{7}$$

$$-\theta y_{is} + Y_t\lambda \geq 0, x_{is} - X_t\lambda \geq 0, \lambda \geq 0$$

Replacing (7) with appropriate time period notations, one could calculate $d_s^s(y_s, x_s), \widehat{d}_t^s(y_t, x_t), \widehat{d}_t^t(y_t, x_t)$.

The corresponding distance functions under VRS are obtained by adding the convex constraint $I1'\lambda = 1$ into (7).

Bootstrapping Malmquist indices

Simar and Wilson (2000) propose a bootstrap method to estimate confidence intervals for DEA efficiency scores. Simar and Wilson (1999) method to estimate confidence intervals for Malmquist indices, based on efficiency scores. The authors argue that the deterministic DEA scores as well as the Malmquist index are only estimates of the underlying, true frontiers. Therefore, the estimates obtained involved uncertainty due to sampling variation. The aim of the bootstrap is to estimate the population distribution, thus enabling the researchers to test hypotheses regarding the true parameter value.

Bootstrapping is based on the idea that by resampling the data with replacement, one can mimic the data-generating process characterizing the true data generation. The algorithm describes the procedure for bootstrapping Malmquist indices is provided in the Appendix.

Data

This paper uses annual data for 60 provinces in Vietnam, which covers the whole country, except the newly formed province of Ba Ria -Vung Tau, during the period 1985-2000. The data are collected by General Statistics Office of Vietnam and published in its several agricultural statistics books (GSO 2000, Nguyen 1995, Nguyen 2003). The 60 provinces belong to eight regions. The biggest agricultural producers are Mekong River Delta and Red River Delta, while the smallest producer is North West region, whose mountainous areas and scarce water are unfavorable to agriculture. The variables used in our TFP analysis include one output in monetary units and five inputs in quantity: land, labor, tractors, threshing machines and draft animals. Output is measured by total agricultural output value at 1994 constant price. Land is measured as the total cultivated areas in each province. Labor is the number of agricultural labor in each province. Draft animal variable is calculated as the total number of cattle and buffaloes in each province. Tractors and threshing machines are the number of tractors and threshing machines, respectively, in each province. Sample means of the variables used in the model are presented in Table 1, where the period is divided into three sub-periods: the first reform period (1985-1989), the second reform period (1990-1994), and the post-reform period (1995-2000). Clearly, in the period 1995-2000, the amounts of machinery and draft animal inputs are much higher than in the previous periods.

Insert Table 2 here

III. Results

Malmquist TFP growth, technical change and efficiency change

The empirical results of Malmquist DEA method, grouped by geographical regions, are presented in Table 3. Table 3 shows that the average TFP growth rate in Vietnam during the period 1985-2000 is 1.96%. The growth rate was highest during the initial reform period 1985-1990, when it was 3.44 percent. In the early 90s period, the TFP growth rate slowed down at 0.65% a year, but rose again at 1.81 percent annually during the late 1990s. Our estimate of TFP is a little higher than Nguyen and Goletti (2001), who estimated Vietnam's agricultural TFP was 2.16 percent in 1985-89 and 0.32 percent in 1990-99. In a paper on TFP growth in agriculture based on 93 countries from 1980 to 2000, Coelli (2005) estimated that Vietnam's TFP growth in agriculture is 2 percent, close to our estimate for the period 1985-2000.

Estimates of TFP for rice farming by Tuong et al. (2006), Kompas (2004) and Nghiem and Coelli (2002) are higher than our estimates for Vietnamese agriculture as a whole, which possibly indicate that Vietnam's TFP growth are higher in rice sector more than in other agricultural sectors. That account fits with our finding that both Mekong River Delta and the Red River Delta, which together produces two-third of Vietnamese rice supply and almost all of her rice export, have relatively high TFP growth: 4.2 percent in Mekong River Delta and 2.0 percent in Red River Delta.

Central Highlands, which mostly produce industrial crops such as coffee and rubber, rather than food, is the second best region in productivity improvement, after the rice-bowl Mekong River Delta. Four regions have negative annual TFP growth: North East (-2.1 percent), North West (-6.6 percent), North Central Coast (-1.3 percent) and South Central Coast (-3.5 percent). These four regions are noted to have unfavorable weather and terrain for agriculture. In the North East, and particularly in the North West, the terrain is hilly and mountainous, and floods are often. In the North and South Central Coast, arable areas are narrow and limited, while storms and hurricanes occur every year.

Insert Table 3 here

Table 4 provides details on the TFP index and its decomposition for 60 provinces in Vietnam in the period 1985-2000. It indicates that the Southern provinces were much better than the Northern provinces in improving their agricultural productivity and efficiency. Among 20 best-performing provinces, only four are in the North: Hai Phong, Ha Tay, Hai Duong, and Thua

Thien-Hue, the rest are in the South. Most of the provinces of Mekong River Delta are noted for improving their productivity. Except Ben Tre, 11/12 provinces in this region has positive TFP growth. Only two provinces in Mekong River Delta (Ben Tre and Ca Mau) are not in the top 20 best-performing provinces. South East region and the Central Highlands, where major industrial crops and fruit crops are planted, are the second-best and third-best regions in terms of productivity growth. In the North, only Red River Delta, the second most important agricultural region in the country, performed well in terms of TFP. Ten among eleven provinces in this region has average annual positive TFP growth during the period. All the other three regions in the North (North East, North West and North Central Coast) have low TFP growth. North East and North West provinces have lowest rankings in the country. Only one among 11 provinces in the North East and none of the three provinces in the North West has positive TFP growth.

Insert Table 4 here

Figure 1 shows the trends in partial productivity indices and TFP. Two partial productivity indices are employed: the land productivity as a fraction of output over land, and the labor productivity. During the initial period 1985-1990, all these productivity indices rose, but TFP grew faster than both land productivity and labor productivity. In 1991, all these indices experienced negative growth, perhaps due to the major economic restructuring in the economy, in which many people were fired from the state sector. While both TFP and land productivity improved in 1992, labor productivity continued to decrease in 1992 but increased again from 1993. In 1994, there was a decrease in TFP, perhaps as a result of agricultural land transferring and sale in the wake of the 1993 Land Law. After 1994, all the productivity indices appeared to follow a rising trend. By 2000, labor productivity and TFP growth rates were almost identical during the period 1985-2000, while the growth rate of land productivity was higher.

Insert Figure 1 here

Insert Figure 2 here

Figure 2 describes trends in productivity indices for different regions. It shows that TFP and labor productivity generally follow similar trends. Both TFP and labor productivity increased in 4 regions (Red River Delta, Central Highlands, South East and Mekong River Delta) and decreased in the other 4 regions (North East, North West, North and South Central Coast). Yet, land productivity increased in all regions.

Table 5 summarizes the contribution of TFP and inputs to Vietnam's agricultural growth. It shows that during the period 1985-2000, about 38 % of output growth can be attributed to TFP growth, of which 24% can be attributed to technical change and 14% to efficiency change.

Insert Table 5 here

However, the trend is not smooth over the period. In the period of initial reforms 1985-1990, the output and input markets were not fully liberalized while only reforms aimed at farmers' incentives were introduced. Output growth in this period was fully due to TFP growth. In fact, the contribution of inputs in this period was even negative at -2.1 percent, perhaps due to the decrease in machine use at the initial stage of the decollectivization process. As the collectives were broken up and household-farming became dominant, many collectively-owned tractors and other machines were not used, as reflected by the decreases in the number of tractors used in this period. Output growth was caused by both technical change (60%) and efficiency change (42%) in this period. It implies that farmers responded positively to the incentive reforms by improving their efficiency and technology progress in this period, rather than increasing their inputs.

In the second period 1990-95, the output and input markets were fully liberalized. The government considered agriculture as the sector to boost production and exports and to absorb labor redundancy from the industrial sector. As the input market was liberalized, farmers invested heavily on their inputs, as revealed by the drastic increase in machinery use during this period. At the same time, SOE restructuring in the industrial sector led to sharp rise in agricultural labor. As a result, most of the output growth in this period (89%) was attributed to input increase. Only 11 percent of the output growth was due to TFP change. Moreover, TFP change in this period was wholly caused by technical change, while efficiency change reduced by 0.6%.

In the third period, 1995-2000, there was a slowdown in the growth rate of agricultural labor (at 1.1 percent annually, compared to 6.5% in the previous period). The annual increase in agricultural labor was much smaller than the annual increase in both population and total labor force (over 2 percent annually), signifying a gradual shift in the structure of the economy toward labor-intensive manufacturing sector. In 1995, agriculture (excluding forestry and fishery) contributed 23 percent of Vietnam's GDP, but in 2000, it only contributed less than 20 percent, while the manufacturing share of GDP increased from 15 percent to 19 percent in the same period (Nguyen 2003). Yet, while labor increase slowed down, machine use continued to increase at high rate (10 percent for tractors, 22 percent for threshing machines). Consequently, input contributed 71% of output growth, while TFP contributed 29% in this period. Among TFP components, technical change contributed 18 percent of output growth, and efficiency change contributed 11 percent of output increase.

Technical efficiency of Vietnamese agriculture

Table 6 summarizes average technical efficiency of Vietnamese agriculture. The average technical efficiency estimate for Vietnamese agriculture in 1985-2000 is 0.62. Two major food-producing regions have the highest technical efficiency: Red River Delta (0.75) and Mekong River Delta (0.73). Red River Delta has slightly higher efficiency estimate than Mekong River Delta. Perhaps, the reason lies in the fact the Red River Delta has limited available land and more numerous population than Mekong River Delta, requiring the farmers in the former region to farm more intensively. In fact, the land productivity in the Red River Delta is 18% higher than that in the Mekong River Delta. In contrast, labor productivity in the Mekong River Delta is 50% higher than that in the Red River Delta.

North West region has the lowest technical efficiency estimate (0.40), while the technical efficiency estimates of North East and North Central Coast are 0.54. Thus, our results determine that the North East, North West and the North Central Coast have some serious issues with their agricultural production. They have lowest technical efficiency and lowest productivity growth over the period 1986-2000. Since these two regions already have high poverty rates compared to the national level, especially in the North West, it may be a particular concern for improving household welfare in these regions. On the other hand, our study points out that there are much ground to improve technical efficiency levels in these regions. For example, if the available inputs are used optimally, agricultural output in the North West can expand by 150% (=1/0.4-1) with given inputs and technology in the region. Therefore, improving technical efficiency in these regions may help to increase agricultural productivity and assist farming households to expand their income.

Both the Central Highlands and the South East have rather low technical efficiency estimates (0.55 and 0.59 respectively). Table 4 shows that these two regions have rather high productivity growth (3.8% and 2.6% respectively), and over 70% of the change in TFP is due to improvement of efficiency. But clearly, there is still enough room for improvement of these two regions' efficiency in the coming years. Therefore, the potentials for these regions' productivity growth are promising.

Insert Table 6 here

Bootstrapping the Malmquist indices

The above analysis is concerned with point estimates of Malmquist indices. However, the point estimates of Malmquist indices cannot answer the question if a province's TFP growth is significantly different from zero or not. In other words, we cannot say a province's TFP growth in a given year is positive or negative in statistical meaning. By bootstrapping, we can establish the confidence intervals for Malmquist index and test the results statistically. Therefore, it is possible to determine if a province's Malmquist index in a given year is significantly different from zero.

Table 7 presents the percentages of observation (province/year) with positive, negative and zero TFP growth rates. Without bootstrapping, there are 504 observation with positive TFP growth and 396 with negative TFP growth in Vietnam. By bootstrapping the Malmquist TFP index at 95% confidence interval, there remain 368 observations with positive TFP growth; 286 with negative TFP growth and 246 observations with zero TFP growth. In percentage terms, the bootstrap correct the initial estimates by changing the percentage of observations with positive TFP growth from 56% to 41%, negative TFP growth from 44% to 32% and zero TFP growth from 0% to 27%.

For instance, in the South East, without bootstrapping, one may draw a conclusion that 65% of the provinces in the region exhibits positive TFP growth, which is the second-highest percentage, after Mekong River Delta. However, after bootstrapping, only 37 percent of provinces in the region have statistically significant positive TFP growth, and this region would only rank 6th in terms of the percentages of provinces with positive TFP growth.

Insert Table 7 here

IV.Concluding Remarks

This study has examined total factor productivity of Vietnamese agriculture during the period 1985-2000 in Vietnam. During this period, Vietnam has achieved substantial success in agriculture, with an admirable annual growth rate of 5.2 percent. The reform policies carried out in the agriculture as well as in the economy as a whole have fundamentally changed the technology in agriculture, by substituting machines to human and animal labor. In this context, the approach based on agricultural production function is inappropriate since it assumes constant shares of inputs and known production function. Malmquist index approach is an attractive approach, especially in the situations like in Vietnam, where certain data such as prices of labor and capital are missing, contradictory or unreliable. By using Malmquist index approach, we can also decompose TFP growth into technical progress and efficiency improvement to determine the importance sources leading to agricultural growth.

This study indicates that most of the early growth in Vietnamese agriculture (1985-1990) was due to TFP growth, in response to incentive reforms. During the period 1990-1995, the growth rate of TFP fell and Vietnam's agricultural growth was mainly caused by drastic investment in capital. In the last period 1995-2000, however, TFP growth increased again, though still much smaller than the period 1985-1990. Overall, TFP growth rate in the whole period is estimated 1.96 percent, contributing to 38% of Vietnam's agricultural growth. Although this growth rate is significant compared to other developing countries[1], it is unstable. In 1990s, TFP only grew by 1.2 percent and most of Vietnam's agriculture growth is caused by inputs. Therefore, sustaining TFP growth would be a key factor in maintaining Vietnam's agricultural growth in the future.

My study also points out different patterns in TFP growth across provinces and regions. While the Mekong River Delta and the Central Highland achieved much success in increasing their outputs and TFP, there are some regions which experienced decreases in TFP growth. The situation was particularly severe for the North West, where TFP growth declined by 6.7 percent annually during the period. It is clear that the success of Vietnamese agricultural growth was not spread evenly. Thus, government target programs should particularly be given to the regions with declining TFP growth to assist these regions regain their competitiveness. As agriculture is still the major source of employment and income for a large population in Vietnam, investing in improving productivity and efficiency in farming should be a priority to achieve long-term economic growth and success in rural poverty alleviation.

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[1]For example, in Fulginiti and Perrin (1998), the mean agricultural TFP growth of 18 developing countries during 1961-1985 is negative, at -1.6%. Coelli and Rao (2005)'s mean agricultural TFP growth of 93 countries during 1980-2000 is 0.5%

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Appendix: Bootstrapping Malmquist productivity index

i. First, I calculate the Malmquist index by applying the DEA method for each decision-making unit (DMU) among N units, obtaining a set of $\{\hat{d}_o^t(y_t, x_t), \hat{d}_o^s(y_s, x_s), \hat{d}_o^t(y_s, x_s), \hat{d}_o^s(y_t, x_t)\}$ with *s, t* are time periods, and the DEA estimates $\hat{\theta}_1, ...\hat{\theta}_n$. From these estimates of distance function, Malmquist indices including the Malmquist TFP change and its components are calculated: $\hat{M}_s^t, \hat{E}_s^t, \hat{T}_s^t, \hat{P}E_s^t, \hat{S}E_s^t$.

ii. Let $\beta_1^*, ...\beta_n^*$ be a simple bootstrap sample from $\hat{\theta}_1, ...\hat{\theta}_n$. Draw bootstrap estimates from the original sample of scores { $\hat{\theta}_1, ...\hat{\theta}_n$ } using a bivariate smoothed representation of the probability density F

iii. For i=1, .., n, create a pseudo data set of (x_i^* , y_i^*) where x_i^* = x_i and y_i^* = ($\hat{\theta}_i / \theta_i^*$) y_i with x_i , y_i the original input and output vectors of the i^{th} unit, respectively.

iv. Solve the linear programming in (6) with the pseudo-data (x_i^* , y_i^*), one obtains the distance function estimates: $\tilde{d}_o^t(y_t, x_t), \tilde{d}_o^s(y_s, x_s), \tilde{d}_o^t(y_s, x_s), \tilde{d}_o^s(y_t, x_t)$. Use these distance functions to construct Malmquist indices $\tilde{M}_s^t, \tilde{E}_s^t, \tilde{T}_s^t, \tilde{P}E_s^t, \tilde{S}E_s^t$

v. Repeat step (ii) to (v) for B times to yield B set of bootstrap estimates: $\{\tilde{M}_s^t(b), \tilde{E}_s^t(b), \tilde{T}_s^t(b), \tilde{P}E_s^t(b), \tilde{S}E_s^t(b)\}_{b=1}^B$. In our empirical work, I set B=2000 to ensure the low variability of the bootstrap confidence intervals. The number of bootstrap iterations should be more than 1000 if the researchers are interested in confidence interval estimation. A smaller number of iterations would be enough if one only needs estimates for bias and standard deviation (see Efron and Tibshirani 1993).

vi. Construct the confidence intervals for the Malmquist indices. Since the distribution of $(\tilde{M}_s^t - M_s^t)$ is unknown, we use the bootstrap values to finds a_α, b_α such that $\Pr ob(-b_\alpha \le \tilde{M}_s^t - \hat{M}_s^t \le -a_\alpha) = 1 - \alpha$. It involves sorting the value of $(\hat{\theta}_i^* - \hat{\theta}_i)$ for b =1,…, B in increasing order and deleting ($(\alpha / 2) \times 100$ percent of the elements at either end of this sorted array and setting $-\hat{a}_\alpha$ and $-\hat{b}_\alpha$ at the two endpoints, with $\hat{a}_\alpha \le \hat{b}_\alpha$.

Thus, the bootstrap estimate of the (1-α) confidence interval for the Malmquist index is given by $\hat{M}_s^t - \hat{a}_\alpha \le M_s^t \le \hat{M}_s^t - \hat{b}_\alpha$

Table 1: Annual growth rates in Vietnamese agriculture 1985-2000 (percent)

	1985-1990	1990-1995	1995-2000	1985-2000
Output	3.37	5.73	6.18	5.18
Input				
Cultivated land	0.97	2.99	3.72	2.60
Agricultural labor	2.09	6.15	1.10	3.22
Tractor	-6.87	27.16	10.18	10.91
Threshing machines	2.61	17.47	21.54	13.90
Draft Animal	3.27	2.01	1.24	2.04
Fertilizer	3.71	15.62	12.33	10.50
Partial productivity				
Yield	2.38	2.74	2.46	2.58
Labor productivity	1.25	-0.42	5.08	1.96
Technology				
Tractor/Labor	-8.78	21.01	9.08	7.69
Fertilizer/Land	2.72	12.64	8.61	7.90

Source: Author's calculation from GSO (2000), Nguyen (2003), FAOSTAT

Table 2: Mean output and inputs in Vietnam's agriculture in one province

	1985-89	1990-94	1995-2000	1985-2000
Agricultural output (billion VND at 1994 price)	919	1140	1586	1238
Cultivated area (thousand hectares)	146	161	191	167
Labor (thousands)	276	346	410	348
Tractors (pieces)	434	767	2065	1151
Threshing Machines (pieces)	707	1078	3609	1911
Draft Animal (units)	3303	4943	11103	6740

Table 3: Regional annual TFP growth rates (%)

	All	Red River Delta	North East	North West	North Central Coast	South Central Coast	Central Highland	South East	Mekong River Delta
TFP Growth									
1985-90	3.44	2.49	2.40	0.64	0.43	-1.07	4.59	2.87	6.08
1990-95	0.65	0.92	-3.02	-20.5	-5.37	-5.61	-0.50	1.96	4.03
1995-00	1.81	2.62	-5.76	-0.05	1.06	-3.70	7.27	2.90	2.51
1985-00	1.96	2.01	-2.13	-6.64	-1.29	-3.46	3.79	2.58	4.21
Technical Change									
1985-90	2.13	2.94	0.66	0.62	-2.37	-0.93	-0.80	-0.03	4.98
1990-95	0.61	2.08	-3.61	-16.5	-4.29	-4.90	-2.34	0.13	3.89
1995-00	1.15	0.19	-3.77	-1.53	0.08	-1.47	5.10	2.35	2.24
1985-00	1.30	1.73	-2.24	-5.81	-2.20	-2.43	0.65	0.82	3.70
Efficiency Change									
1985-90	1.48	-0.10	1.78	-0.01	2.98	-0.22	5.92	2.91	1.19
1990-95	-0.03	-1.04	0.23	-3.35	-1.24	-1.12	1.93	1.99	0.16
1995-00	0.70	2.42	-1.65	1.30	1.07	-2.12	2.13	0.62	0.29
1985-00	0.72	0.43	0.12	-0.69	0.94	-1.15	3.33	1.84	0.55
Pure Efficiency Change									
1985-90	1.17	-1.41	0.98	0.05	0.93	-0.90	3.38	2.18	0.26
1990-95	0.54	-1.19	0.41	-2.13	-0.20	-1.59	0.50	-0.21	0.11
1995-00	0.12	2.36	-1.35	-0.23	-0.35	-2.18	2.18	0.75	0.13
1985-00	0.61	-0.08	0.02	-0.77	0.13	-1.55	2.02	0.91	0.17
Scale Efficiency Change									
1985-1990	1.17	1.45	0.62	-0.04	2.06	0.77	2.65	0.74	0.96
1990-1995	0.54	0.15	-0.32	-1.48	-1.25	0.48	1.58	2.12	0.08
1995-2000	0.12	0.09	-0.41	1.46	1.45	0.11	-0.05	-0.13	0.16
1985-2000	0.61	0.56	-0.04	-0.02	0.75	0.45	1.40	0.91	0.40

*Based on weighted average, weights being provincial agriculture output.

Table 4: Provincial productivity indices and their decomposition

Province	TFP	EC	TC	PEC	SEC	TFP Rank
Red River Delta						***4***
Ha Noi	1.015	0.993	1.022	0.994	0.999	27
Hai Phong	1.039	1.006	1.033	1.005	1.000	6
Vinh Phuc	0.998	1.022	0.977	1.013	1.009	37
Ha Tay	1.028	1.007	1.021	0.994	1.013	15
Bac Ninh	1.020	0.993	1.028	0.992	1.001	24
Hai Duong	1.027	1.011	1.016	1.002	1.009	18
Hung Yen	1.026	1.000	1.026	1.000	1.000	21
Ha Nam	1.012	0.989	1.022	0.990	1.000	31
Nam Dinh	1.022	0.994	1.028	0.994	1.000	22
Thai Binh	1.005	1.000	1.005	1.000	1.000	34
Ninh Binh	1.004	1.010	0.994	0.983	1.028	35
North East						***7***
Ha Giang	0.967	1.003	0.965	1.001	1.002	45
Cao Bang	0.966	1.013	0.954	1.014	0.999	46
Lao Cai	0.941	0.996	0.945	1.000	0.996	53
Bac Kan	0.900	0.977	0.922	1.000	0.977	59
Lang Son	0.965	0.962	1.004	0.960	1.001	48
Tuyen Quang	1.004	1.025	0.979	1.020	1.005	36
Yen Bai	0.987	1.010	0.977	1.009	1.000	41
Thai Nguyen	0.931	0.985	0.945	0.991	0.994	54
Phu Tho	0.951	1.000	0.951	1.000	1.000	51
Bac Giang	0.989	0.982	1.008	0.987	0.994	39
Quang Ninh	0.966	1.004	0.962	0.995	1.009	47
North West						***8***
Lai Chau	0.926	0.977	0.949	0.976	1.000	55
Son La	0.955	1.000	0.955	1.000	1.000	50
Hoa Binh	0.893	0.978	0.913	0.983	0.995	60
North Central Coast						***5***
Thanh Hoa	0.975	0.999	0.976	1.000	0.999	44
Nghe An	0.978	1.014	0.965	1.000	1.014	43
Ha Tinh	0.950	0.982	0.968	0.990	0.992	52
Quang Binh	1.021	1.022	1.000	1.009	1.013	23
Quang Tri	1.014	1.028	0.986	1.013	1.014	28
Thua Thien	1.027	1.011	1.016	1.005	1.006	20
South Central Coast						***6***
Da Nang	0.924	1.000	0.924	1.000	1.000	56
Quang Nam	0.918	0.972	0.944	0.978	0.994	58

Table 4 (continued)

Quang Ngai	0.923	1.000	0.923	1.000	1.000	57
Binh Dinh	0.982	0.981	1.001	0.972	1.009	42
Phu Yen	0.995	0.985	1.011	0.972	1.013	38
Khanh Hoa	1.012	0.997	1.015	0.988	1.009	30

Central Highlands						***3***
Kontum	0.959	0.996	0.963	0.993	1.003	49
Gia Lai	1.014	1.016	0.998	1.018	0.999	29
Dac Lac	1.032	1.034	0.999	1.010	1.023	11
Lam Dong	1.063	1.040	1.022	1.026	1.014	2
South East						***2***
HCM City	1.028	1.008	1.020	1.000	1.008	17
Ninh Thuan	1.011	1.007	1.003	1.003	1.004	33
Binh Phuoc	1.031	1.036	0.995	1.024	1.012	13
Tay Ninh	1.031	1.035	0.995	1.016	1.019	14
Binh Duong	1.031	1.053	0.980	1.030	1.022	12
Dong Nai	1.011	1.000	1.011	1.000	1.000	32
Binh Thuan	1.016	1.027	0.989	1.008	1.019	25
Mekong River Delta						***1***
Long An	1.027	1.002	1.025	0.991	1.011	19
Dong Thap	1.051	1.004	1.046	1.004	1.000	3
An Giang	1.034	1.011	1.023	1.002	1.009	10
Tien Giang	1.036	1.000	1.036	1.000	1.000	8
Vinh Long	1.038	1.000	1.038	1.000	1.000	7
Ben Tre	0.988	1.000	0.988	1.000	1.000	40
Kien Giang	1.036	1.000	1.036	1.000	1.000	9
Can Tho	1.098	1.000	1.098	1.000	1.000	1
Tra Vinh	1.042	1.019	1.022	1.004	1.015	5
Soc Trang	1.028	1.011	1.017	1.002	1.009	16
Bac Lieu	1.049	1.024	1.025	1.025	0.999	4
Ca Mau	1.015	1.000	1.015	1.000	1.000	26

Note: The results are geometric averages of annual estimates. Rank of a region is determined based on average rank of the provinces in that region.

Table 5: Contribution of TFP and inputs to Vietnam's agricultural growth (%)

	1985-1990	1990-1995	1995-2000	1985-2000
Output growth rates (%)	3.37	5.73	6.18	5.18
Contribution of TFP (%)	102.1	11.3	29.3	37.8
of which				
Technical change (%)	60.2	11.9	18.2	24.4
Efficiency change (%)	41.8	-0.6	11.1	13.5
Contribution of inputs (%)	-2.1	88.7	70.7	62.2

Table 6: Technical efficiency of Vietnamese agriculture

Province	**Technical efficiency**	***Rank***	**Province**	**Technical efficiency**	***Rank***
Country	**0.62**				
Red River Delta	**0.75**	**1**	**South Central Coast**	**0.63**	**3**
Thai Binh	0.98	1	Da Nang	0.70	20
Hung Yen	0.86	5	Phu Yen	0.69	21
Ha Tay	0.81	9	Quang Nam	0.64	26
Nam Dinh	0.81	10	Khanh Hoa	0.60	31
Hai Phong	0.80	11	Binh Dinh	0.58	35
Ha Noi	0.78	12	Quang Ngai	0.58	36
Hai Duong	0.78	13	**Central Highlands**	**0.55**	**5**
Ha Nam	0.70	19	Dac Lac	0.66	22
Ninh Binh	0.64	25	Lam Dong	0.66	23
Vinh Phuc	0.59	34	Kontum	0.45	53
Bac Ninh	0.53	43	Gia Lai	0.44	54
North East	**0.54**	**7**	**South East**	**0.59**	**4**
Bac Giang	0.89	4	HCM City	0.86	6
Phu Tho	0.61	29	Dong Nai	0.75	14
Quang Ninh	0.57	37	Ninh Thuan	0.72	18
Thai Nguyen	0.56	39	Tay Ninh	0.54	42
Lang Son	0.56	40	Binh Thuan	0.46	52
Yen Bai	0.51	45	Binh Duong	0.43	55
Tuyen Quang	0.50	46	Binh Phuoc	0.36	59
Cao Bang	0.48	48	**Mekong River Delta**	**0.73**	**2**
Bac Kan	0.47	50	Tien Giang	0.92	2
Lao Cai	0.38	57	Vinh Long	0.92	3
Ha Giang	0.36	58	An Giang	0.83	7
North West	**0.40**	**8**	Ben Tre	0.83	8
Hoa Binh	0.49	47	Can Tho	0.73	15
Son La	0.41	56	Tra Vinh	0.73	16
Lai Chau	0.30	60	Dong Thap	0.72	17
North Central Coast	**0.54**	**6**	Kien Giang	0.66	24
Nghe An	0.61	28	Soc Trang	0.62	27
Thanh Hoa	0.60	33	Bac Lieu	0.60	30

Ha Tinh	0.56	41	Long An	0.60	32
Thua Thien	0.52	44	Ca Mau	0.57	38
Quang Tri	0.48	49			
Quang Binh	0.46	51			

Table 7: Percentages of observations with positive, negative and zero TFP growth

	Positive TFP growth		***Negative TFP growth***		***Zero TFP growth***	
	No bs.	Bs.	No bs.	Bs.	No bs.	Bs.
All country	*56.0*	*40.9*	*44.0*	*31.8*	*0*	*27.3*
Red River Delta	61.8	49.7	38.2	21.8	0	28.5
North East	44.8	32.1	55.2	42.4	0	25.5
North West	44.4	28.9	55.6	51.1	0	20.0
North Central Coast	51.1	42.2	48.9	38.9	0	18.9
South Central Coast	34.4	27.8	65.6	48.9	0	23.3
Central Highlands	61.7	53.3	38.3	33.3	0	13.3
South East	64.8	37.1	35.2	19.0	0	43.8
Mekong River Delta	70.0	47.8	30.0	21.1	0	31.1
Total observations	504	368	396	286	0	246

Note: bs.: bootstrap

Figure 1: Partial and Total Productivity Growth (cumulative)

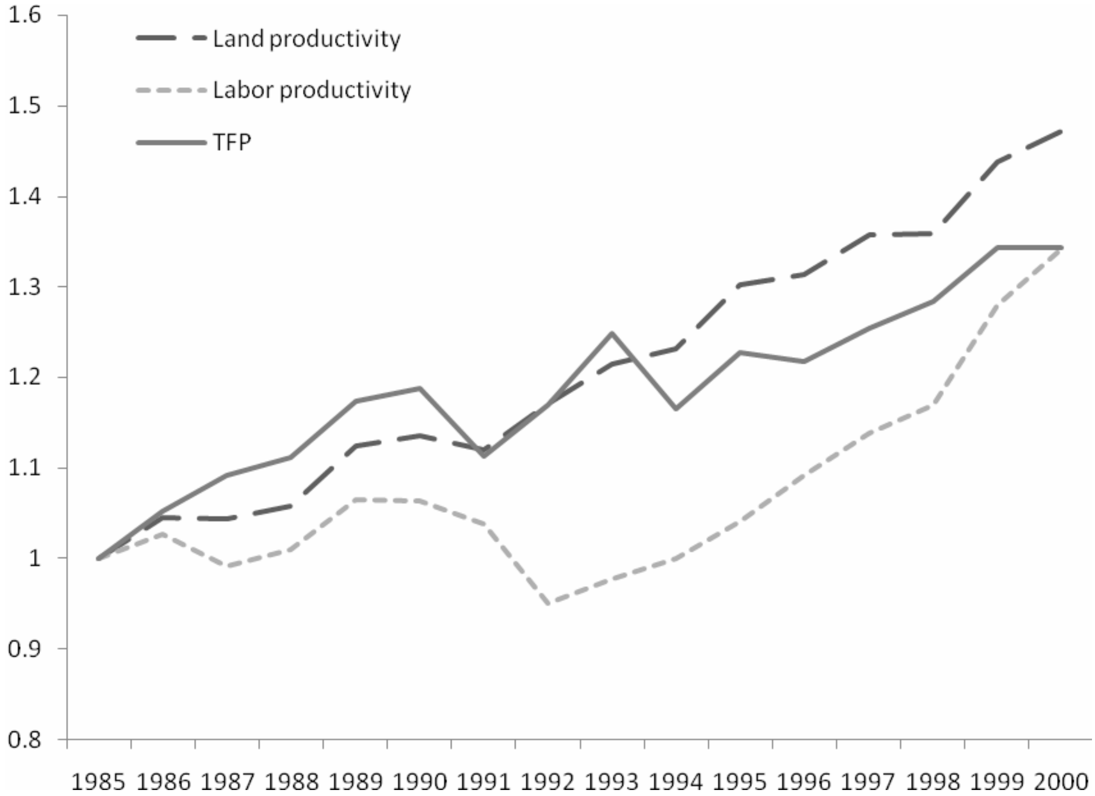

Figure 2: Partial and Total Productivity Growth in Eight Regions (cumulative)

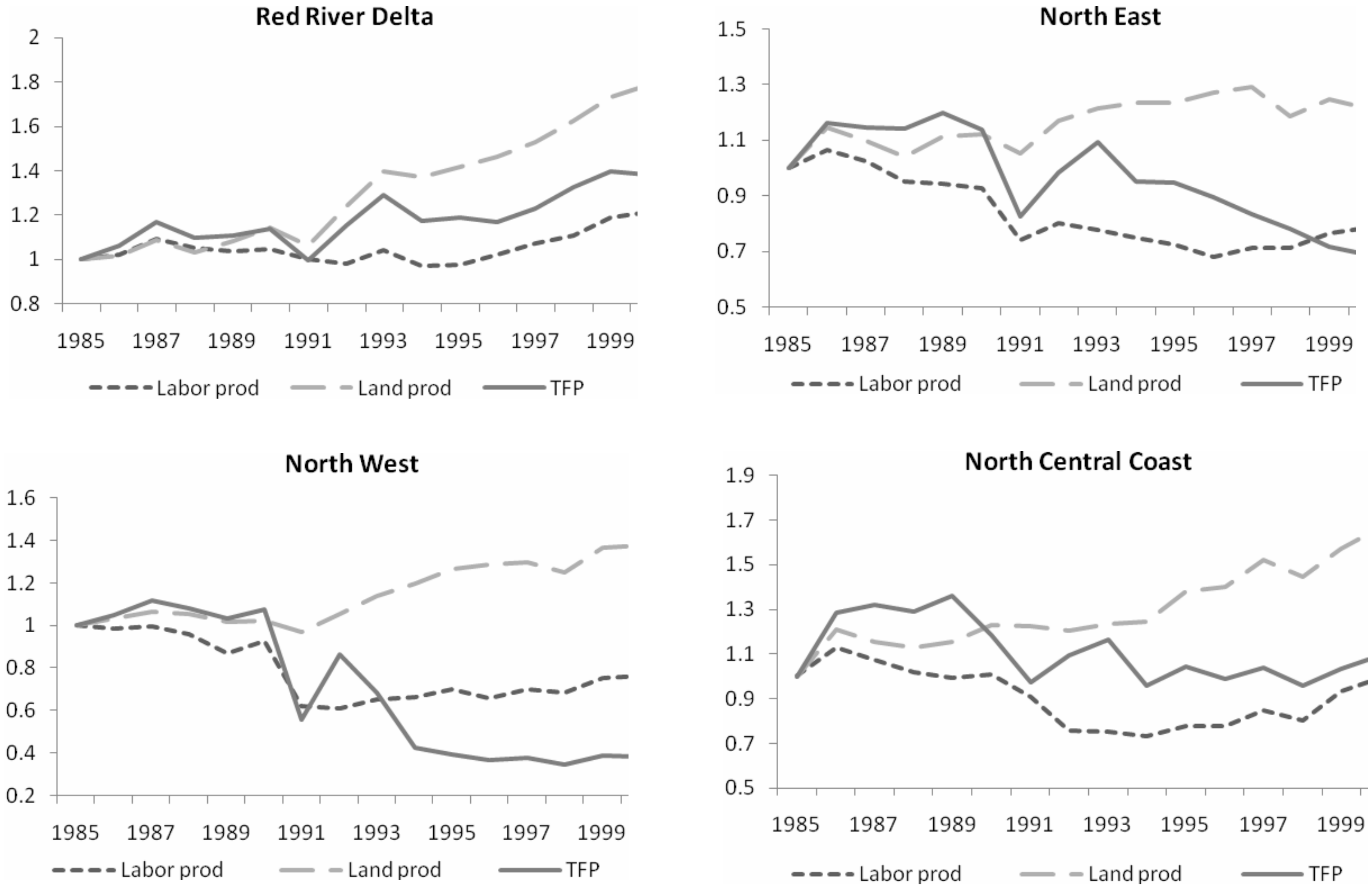

Figure 2 (continued)