Vu & Nguyen, *Cogent Economics & Finance* (2021), 9: 1972524
https://doi.org/10.1080/23322039.2021.1972524

cogent economics & finance

GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

Agricultural productivity growth in vietnam in reform and post-reform period

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Received: 9 September 2020
Accepted: 22 August 2021

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Reviewing editor:
Robert Read, University of Lancaster, UK

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 average agricultural TFP growth of 93 countries during 1980-2000 is 0.5%

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Abstract: This paper applies the Malmquist productivity index method to measure total factor productivity (TFP) growth in Vietnamese agriculture using panel data from 60 provinces in Vietnam during 1985–2000 when Vietnam implemented widespread de-collectivization, trade liberalization, and reformed her agriculture sector. This study indicates that most of the early growth in Vietnamese agriculture during the first reform period 1985–1990 was due to TFP growth in response to incentive reforms. During the second reform period 1990–1995, the growth rate of TFP fell, and Vietnam's agricultural growth was mainly caused by drastic investment in capital. In the post-reform period (1995–2000), TFP growth increased again, though still much lower than 1985–1990. Overall, the TFP growth rate in the whole period is estimated at 1.96 percent, contributing to 38% of Vietnam's agricultural growth.

Subjects: Agriculture; Agricultural Development; Asian Development

Keywords: Vietnam; productivity; agriculture; efficiency; DEA; Malmquist; bootstrap
JEL: Q10; O13; R30

1. Introduction

Since Vietnam started its economic reforms in 1986, its economy has grown rapidly. From being an importer of food during the early 1980s, Vietnam has become one of the biggest rice exporters in the world in less than two decades., the growth in agricultural output has contributed greatly to improved

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PUBLIC INTEREST STATEMENT

The article's main purpose is to measure the historical growth of total factor productivity (TFP)- a measure of how much output can be produced from a certain amount of inputs - in Vietnamese agriculture during the reform period from 1985 to 2000. This study indicates that most of the early growth in Vietnamese agriculture during the first reform period 1985-1990 was due to TFP growth in response to incentive reforms. During the second reform period 1990-1995, the growth rate of TFP fell, and Vietnam's agricultural growth was mainly caused by drastic investment in capital. In the post-reform period 1995-2000, TFP growth increased again, though still much lower than 1985-1990. This study highlights the importance of policy incentives in encouraging productivity.

household income in Vietnam as about 70 percent of the Vietnamese population is engaged in agricultural activities. In this context, a study on the productivity of agriculture in Vietnam and the impacts of market reforms on agricultural productivity during this historical period is very important.

There have been several attempts that estimate the productivity and efficiency of rice farming in Vietnam. Based on the rice production function, Tuong et al. (2006) estimated that the 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 the Malmquist index method to investigate total factor productivity (TFP) growth in 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 the TFP growth of rice production in Vietnam by the stochastic frontier method. He found that the 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 our 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. Another notable research is Ho (2012), who used both Data Envelopment Analysis and Stochastic Frontier Analysis to measure the sources of agricultural total factor productivity growth in Vietnam, based on provincial-level data in the period 1990–2006. The author concludes that (a) total factor productivity had grown during the period; (b) technical change was the major source of total factor productivity growth, while actual production moved further away from the frontier (technical efficiency reduction); (c) pure technical efficiency change was the most important reason for explaining technical efficiency reduction, and (d) there was a trend of technical efficiency diversification among province. The apparent lack of interest in agricultural productivity and efficiency in Vietnam is 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 from central planning to market have borne many similarities with Vietnam. Notable studies on the impacts of agricultural reforms on China's agricultural productivity include Brümmer et al. (2006), Carter and Estrin (2001), Chen et al. (2008), Fan (1991), Fleisher and Liu (1992), Gong (2018), Huang (1998), Cao and Birchenall (2013), Kalirajan et al. (1996), Lin (1992), Mao and Koo (1997), McMillan et al. (1989), Fan (1991), Wang et al. (2019), Wen (1993), and Wu et al. (2001). Most of those studies indicated that market reforms have led to an increase in China's agricultural productivity.

This study uses the Malmquist index method to estimate Vietnam's agricultural productivity during 1985–2000. The 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. We focussed on the 1985–2000 period for several reasons. First, this is when Vietnamese annual agricultural growth is the most impressive, averaging over 5 percent (Table 1) while it averages at 3.7 percent during the 2000–2012 period (World Bank, 2016). Finding out the reasons behind this dynamic growth is crucial for understanding the evolution of the country's agriculture. Secondly, this period witnessed a transition from a central planning economy to a market economy, together with the institutional reform in the agriculture sector, such as abolishing collective farming, liberalizing the market, and removing price controls for both inputs and outputs.

2. Vietnam's agriculture and market reforms

Agriculture is very important to the Vietnamese economy. About 62 percent of the Vietnamese labor population is engaged in agricultural activities. Agriculture contributes 23 percent of GDP (Dang et al., 2006). After the country's reunification in 1975, there was a crisis in Vietnam's agriculture sector, especially in rice production, the most important food crop in Vietnam. Although total agricultural output increased by an average growth rate of 4.5 percent during

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	7.9

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

1976–1980, there was a reduction in both rice output and rice yield in the same period. Pingali and Xuan (1992) estimated that rice output per capita in 1980 was less than that in 1976 by 8 percent. In the meantime, rice yield reduced by 7 percent (according to data in Nguyen, 1995). There was a food shortage and low agricultural productivity in Vietnam in the late 1970s and early 1980s, indicating the failure of the collectivization in agriculture.

To overcome this crisis, the Government introduced some agricultural reforms in 1981. Beginning in 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 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 & Xuan, 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 a complete renovation of the whole economy. The first priorities of the *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, 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 decide their farming activities. This policy resulted in the de-collectivization 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 for tax obligation on agricultural output, farming households were free to sell their products in the market to private traders and state

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companies. Private traders were guaranteed equal treatment as state trading companies. The Government also dropped its food grain subsidy 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, a net importer of rice for two previous 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, the land is publicly owned, and the right of land was never clearly defined in-laws; consequently, it isn't easy to secure the landowner's property right. In 1993, the Land Law was passed. While this law still stated that all land is publicly owned, it recognized people's land-use rights and enabled landholders to obtain legal land-use titles (colloquially called "the Red Notebook"). As a result, households established secure legal rights to their land, and land can be transferred, sold, or inherited.

Besides other purposes, the Land Law was supposed to boost agricultural production by incentivizing farmers 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 magnitude. They found no significant impact on household consumption or agricultural income. Hare (2008) assessed the impacts of land right certificates on 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 rights were insignificant.

In short, Vietnam's major agricultural market reforms were implemented during the 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 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 1990–1995. The 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 and 1992 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. The index of tractors per labor even decreased during the first reform period 1985–89, perhaps due to collectives being broken up and land being assigned into households. However, in the 1990s, the number of machines used in agriculture increased remarkably, while the number of draft animals slowed down. This reflects a change in the production technology in agriculture.

3. Method and data

3.1. Malmquist DEA method

This paper applies the nonparametric output-oriented Malmquist DEA method based on panel data of 60 provinces in the period 1985–2000. The total factor productivity (TFP) estimated by the Malmquist DEA method is chosen in preference to the Tornqvist TFP index method. The latter index involves using observed prices, which are not available in recent years 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

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

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

The TFP change index in (1) is the geometric mean of two TFP change measures: 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:

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

Efficiency change (EC):

$$EC_s^t = \frac{d_t^t(y_t, x_t)}{d_s^s(y_s, x_s)} \quad (3)$$

and *Technical change (TC)*:

$$TC_s^t = \left[\frac{d_t^s(y_t, x_t)}{d_t^t(y_t, x_t)} \times \frac{d_s^s(y_s, x_s)}{d_s^t(y_s, x_s)}\right]^{1/2} \quad (4)$$

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

Pure efficiency change (PEC):

$$PEC_s^t = \frac{d_{t-VRS}^t(y_t, x_t)}{d_{s-VRS}^s(y_s, x_s)} \quad (5)$$

and a *scale efficiency change (SEC)* component

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

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).

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

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

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

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

3.2. 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 and the Malmquist index are the estimates of the underlying, true frontiers. Therefore, the estimates obtained involved uncertainty due to sampling variation. The bootstrap aims 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.

3.3. Data

This paper uses annual data for 60 provinces in Vietnam, covering the whole country, except the newly formed province of Ba Ria—Vung Tau, during 1985–2000. Although the data are not recent, it is suitable for the focus of our study to see the dynamics of productivity and technology change during the reform period (1985–1994) and the after-reform period (1995–2000).

The data are collected by the General Statistics Office of Vietnam and published in several agricultural statistics books (General Statistics Office, 2000; Nguyen, 1995, 2003). The 60 provinces belong to eight regions. The biggest agricultural producers are the Mekong River Delta and Red River Delta. In contrast, the smallest producer region is the Northwest, 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. The land is measured as the total cultivated areas in each province. Labor is the number of agricultural laborers in each province. The draft animal variable is calculated as the total number of cattle and

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	11,103	6740

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 2, 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 1995–2000, the amounts of machinery and draft animal inputs are much higher than in the previous periods.

4. Findings and discussion

4.1. Malmquist TFP growth, technical change, and efficiency change

Geographically, the country includes eight regions as in Figure 1: Northeast (11 provinces), Northwest (3 provinces), Red River Delta (11 provinces), North Central Coast (6 provinces), South Central Coast (8 provinces), Central Highlands (4 provinces), Southeast (7 provinces), and Mekong River Delta (12 provinces).

The empirical results of the Malmquist DEA method, grouped by geographical regions, are presented in Table 3. Table 3 shows that the average TFP growth rate in Vietnam from 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, 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 and Rao (2005) estimated that Vietnam's TFP growth in agriculture is 2 percent, close to our estimate for 1985–2000.

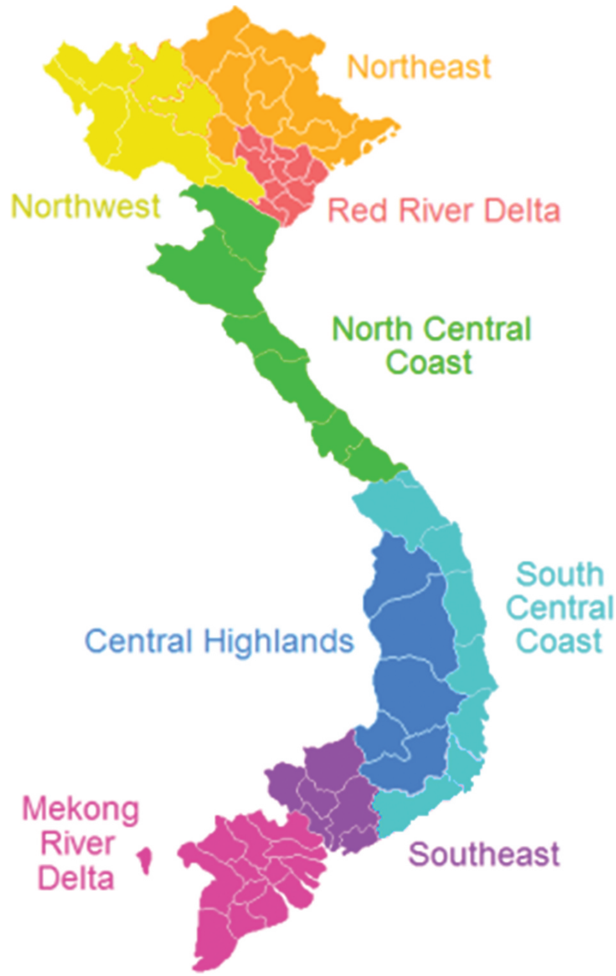
Estimates of TFP for rice farming by Tuong et al. (2006), Kompas (2004), and Nghiem and Coelli (2002) are higher than our estimates for Vietnamese agriculture as a whole, which possibly indicate that Vietnam's TFP growth is higher in rice sector more than in other agricultural sectors. That account fits our finding that both the Mekong River Delta and the Red River Delta—which produce two-thirds of Vietnamese rice supply and almost all of the country's 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: Northeast (−2.1 percent), Northwest (−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 Northeast, particularly in the Northwest, the terrain is hilly and mountainous, and floods are often. Arable areas are narrow and limited in the North and South Central Coast, while storms and hurricanes occur every year.

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

Figure 1. Vietnam's regions.

Source: Atlas of Vietnam (2021)



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 the Mekong River Delta are noted for improving their productivity. Except for Ben Tre, 11/12 provinces in this region has positive TFP growth. Only two provinces in the Mekong River Delta (Ben Tre and Ca Mau) do not belong to the top 20 best-performing provinces. The Southeast Region and the Central Highlands, where major industrial crops and fruit crops are planted, are the second-best and third-best regions in productivity growth. In the North, only the 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 have average annual positive TFP growth during the period. The other three regions in the North (Northeast, Northwest, and North Central Coast) have low TFP growth. Northeast and Northwest provinces have the lowest rankings in the country. Only one among 11 provinces in the Northeast and none of the three provinces in the Northwest has positive TFP growth.

Figure 2 shows the trends in partial productivity indices and TFP. Two partial productivity indices are employed: land productivity as a fraction of output over land and labor productivity. During the initial period 1985–1990, all these productivity indices rose, but TFP grew faster than both land 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.

Table 3. Regional annual TFP growth rates (%)

	All	Red River Delta	Northeast	Northwest	North Central Coast	South Central Coast	Central Highland	Southeast	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 a weighted average, weights being provincial agriculture output.

While both TFP and land productivity improved in 1992, labor productivity decreased in 1992 but increased again from 1993. In 1994, there was a decrease in TFP, perhaps due to 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 1985–2000, while the growth rate of land productivity was higher.

Table 5 summarizes the contribution of TFP and inputs to Vietnam's agricultural growth. It shows that during 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.

However, the trend is not smooth over the period. In the 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. 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 de-collectivization process. As the collectives were broken up and household farming became dominant, many collectively owned tractors and other machines were not used, as reflected cogent • economics & finance

Table 4. Provincial productivity indices and their decomposition

Province	TFP	EC	TC	PEC	SEC	TFP Rank
Mekong River Delta					***1***	
Can Tho	1.098	1	1.098	1	1	1
Dong Thap	1.051	1.004	1.046	1.004	1	3
Bac Lieu	1.049	1.024	1.025	1.025	0.999	4
Tra Vinh	1.042	1.019	1.022	1.004	1.015	5
Vinh Long	1.038	1	1.038	1	1	7
Tien Giang	1.036	1	1.036	1	1	8
Kien Giang	1.036	1	1.036	1	1	9
An Giang	1.034	1.011	1.023	1.002	1.009	10
Soc Trang	1.028	1.011	1.017	1.002	1.009	16
Long An	1.027	1.002	1.025	0.991	1.011	19
Ca Mau	1.015	1	1.015	1	1	26
Ben Tre	0.988	1	0.988	1	1	40
Southeast					***2***	
Binh Duong	1.031	1.053	0.98	1.03	1.022	12
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
HCM City	1.028	1.008	1.02	1	1.008	17
Binh Thuan	1.016	1.027	0.989	1.008	1.019	25
Dong Nai	1.011	1	1.011	1	1	32
Ninh Thuan	1.011	1.007	1.003	1.003	1.004	33
Central Highlands					***3***	
Lam Dong	1.063	1.04	1.022	1.026	1.014	2
Dac Lac	1.032	1.034	0.999	1.01	1.023	11
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
Red River Delta					***4***	
Hai Phong	1.039	1.006	1.033	1.005	1	6
Ha Tay	1.028	1.007	1.021	0.994	1.013	15
Hai Duong	1.027	1.011	1.016	1.002	1.009	18
Hung Yen	1.026	1	1.026	1	1	21
Nam Dinh	1.022	0.994	1.028	0.994	1	22
Bac Ninh	1.02	0.993	1.028	0.992	1.001	24
Ha Noi	1.015	0.993	1.022	0.994	0.999	27
Ha Nam	1.012	0.989	1.022	0.99	1	31
Thai Binh	1.005	1	1.005	1	1	34
Ninh Binh	1.004	1.01	0.994	0.983	1.028	35
Vinh Phuc	0.998	1.022	0.977	1.013	1.009	37
North Central Coast					***5***	
Thua Thien	1.027	1.011	1.016	1.005	1.006	20
Quang Binh	1.021	1.022	1	1.009	1.013	23
Quang Tri	1.014	1.028	0.986	1.013	1.014	28
Nghe An	0.978	1.014	0.965	1	1.014	43

(*Continued*)

Province	TFP	EC	TC	PEC	SEC	TFP Rank
Thanh Hoa	0.975	0.999	0.976	1	0.999	44
Ha Tinh	0.95	0.982	0.968	0.99	0.992	52
South Central Coast					***6***	
Khanh Hoa	1.012	0.997	1.015	0.988	1.009	30
Phu Yen	0.995	0.985	1.011	0.972	1.013	38
Binh Dinh	0.982	0.981	1.001	0.972	1.009	42
Da Nang	0.924	1	0.924	1	1	56
Quang Ngai	0.923	1	0.923	1	1	57
Quang Nam	0.918	0.972	0.944	0.978	0.994	58
Northeast					***7***	
Tuyen Quang	1.004	1.025	0.979	1.02	1.005	36
Bac Giang	0.989	0.982	1.008	0.987	0.994	39
Yen Bai	0.987	1.01	0.977	1.009	1	41
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
Quang Ninh	0.966	1.004	0.962	0.995	1.009	47
Lang Son	0.965	0.962	1.004	0.96	1.001	48
Phu Tho	0.951	1	0.951	1	1	51
Lao Cai	0.941	0.996	0.945	1	0.996	53
Thai Nguyen	0.931	0.985	0.945	0.991	0.994	54
Bac Kan	0.9	0.977	0.922	1	0.977	59
Northwest					***8***	
Son La	0.955	1	0.955	1	1	50
Lai Chau	0.926	0.977	0.949	0.976	1	55
Hoa Binh	0.893	0.978	0.913	0.983	0.995	60

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

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.

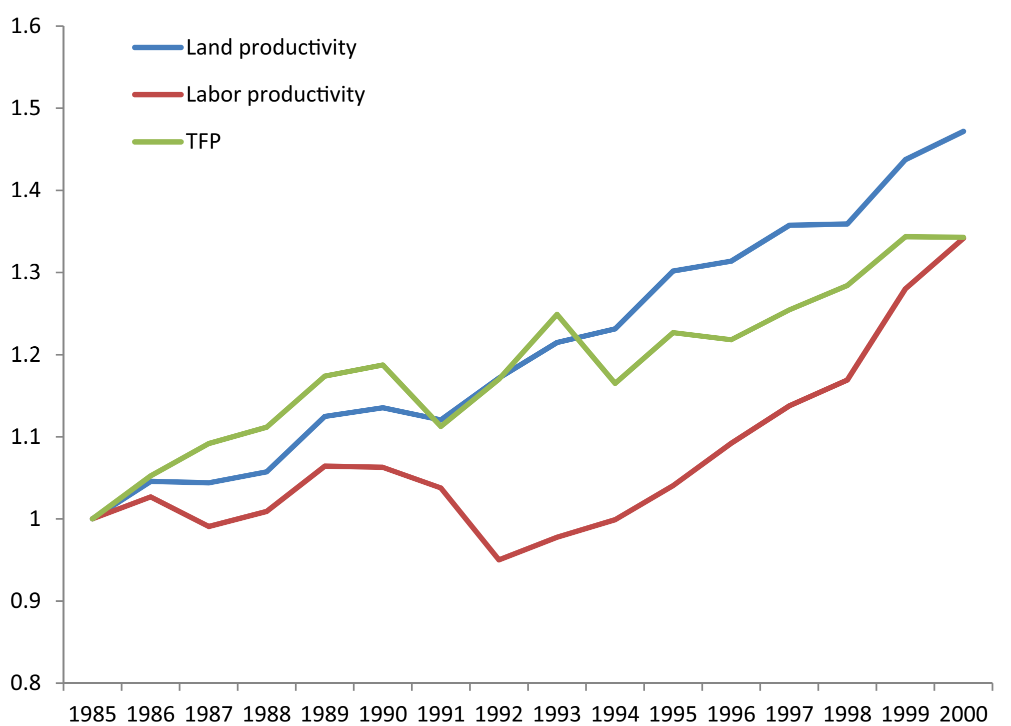
In the second period 1990–95, the output and input markets were fully liberalized. The Government considered agriculture to boost production and exports and absorb labor redundancy from the industrial sector. As the input market was liberalized, farmers invested heavily in their inputs, as revealed by the drastic increase in machinery use during this period. At the same time, SOE restructuring in the industrial sector led to a 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 was 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 economy's structure toward the labor-intensive manufacturing sector. In 1995, agriculture (excluding forestry and fishery) contributed

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

Figure 2. Partial and Total Productivity Growth (cumulative).



23 percent of Vietnam's GDP. Still, in 2000, it 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 a 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.

4.2. Technical efficiency of Vietnamese agriculture

Table 6 summarizes the 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

Table 6. Technical efficiency of Vietnamese agriculture by province

Province	Technical efficiency	*Rank*	Province	Technical efficiency	*Rank*
Country	**0.62**				
Red River Delta	**0.75**	**1**	**Southeast**	**0.59**	**4**
Thai Binh	0.98	1	HCM City	0.86	6
Hung Yen	0.86	5	Dong Nai	0.75	14
Ha Tay	0.81	9	Ninh Thuan	0.72	18
Nam Dinh	0.81	10	Tay Ninh	0.54	42
Hai Phong	0.8	11	Binh Thuan	0.46	52
Ha Noi	0.78	12	Binh Duong	0.43	55
Hai Duong	0.78	13	Binh Phuoc	0.36	59
Ha Nam	0.7	19	**Central Highlands**	**0.55**	**5**
Ninh Binh	0.64	25	Dac Lac	0.66	22
Vinh Phuc	0.59	34	Lam Dong	0.66	23
Bac Ninh	0.53	43	Kontum	0.45	53
Mekong River Delta	**0.73**	**2**	Gia Lai	0.44	54
Tien Giang	0.92	2	**North Central Coast**	**0.54**	**6**
Vinh Long	0.92	3	Nghe An	0.61	28
An Giang	0.83	7	Thanh Hoa	0.6	33
Ben Tre	0.83	8	Ha Tinh	0.56	41
Can Tho	0.73	15	Thua Thien	0.52	44
Tra Vinh	0.73	16	Quang Tri	0.48	49
Dong Thap	0.72	17	Quang Binh	0.46	51
Kien Giang	0.66	24	**Northeast**	**0.54**	**7**
Soc Trang	0.62	27	Bac Giang	0.89	4
Bac Lieu	0.6	30	Phu Tho	0.61	29
Long An	0.6	32	Quang Ninh	0.57	37
Ca Mau	0.57	38	Thai Nguyen	0.56	39
South Central Coast	**0.63**	**3**	Lang Son	0.56	40
Da Nang	0.7	20	Yen Bai	0.51	45
Phu Yen	0.69	21	Tuyen Quang	0.5	46
Quang Nam	0.64	26	Cao Bang	0.48	48
Khanh Hoa	0.6	31	Bac Kan	0.47	50
Binh Dinh	0.58	35	Lao Cai	0.38	57
Quang Ngai	0.58	36	Ha Giang	0.36	58
			Northwest	**0.4**	**8**
			Hoa Binh	0.49	47
			Son La	0.41	56
			Lai Chau	0.3	60

Delta (0.73). Red River Delta has a slightly higher efficiency estimate than the Mekong River Delta. Perhaps, the reason lies in the Red River Delta has limited available land and more numerous populations than the Mekong River Delta, requiring the farmers in the former region to farm more intensively. 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.

The Northwest region has the lowest technical efficiency estimate (0.40), while the Northeast and North Central Coast technical efficiency estimates are 0.54. Thus, our results determine that the Northeast, Northwest, and the North Central Coast have some serious issues with their agricultural production. They have the lowest technical efficiency and lowest productivity growth over the period 1986–2000. Since these two regions already have higher poverty rates than the national level, especially in the Northwest, it may be a concern for improving household welfare in these regions. On the other hand, our study points out that there is much ground to improve technical efficiency levels in these regions. For example, if the available inputs are used optimally, agricultural output in the Northwest 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 increase agricultural productivity and assist farming households in expanding their income.

The Central Highlands and the Southeast have 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 to improve these two regions' efficiency in the coming years. Therefore, the potentials for these regions' productivity growth are promising.

4.3. 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 the Malmquist index and test the results statistically. Therefore, it is possible to determine if a province's Malmquist index is significantly different from zero in a given year.

Table 7 presents the percentages of observation (province/year) with positive, negative, and zero TFP growth rates. Without bootstrapping, there are 504 observations with positive TFP growth and 396 with negative TFP growth in Vietnam. By bootstrapping the Malmquist TFP index at a 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 corrects 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 Southeast, without bootstrapping, one may conclude that 65% of the provinces in the region exhibit positive TFP growth, which is the second-highest percentage, after the Mekong River Delta. However, after bootstrapping, only 37 percent of provinces in the region have statistically significant positive TFP growth. This region would only rank 6th in terms of the percentages of provinces with positive TFP growth.

5. Concluding remarks

This study has examined the total factor productivity of Vietnamese agriculture during the post-*Doi Moi* period from 1985 to 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 have fundamentally changed agriculture technology by substituting machines for human and animal labor. In this context, the Malmquist index method is suitable since it estimates productivity without assuming constant shares of inputs and production functions. Malmquist index approach is also 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. Using the Malmquist index approach, we can decompose TFP growth into technical progress and efficiency improvement to determine the important sources of 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

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

	Positive TFP growth		Negative TFP growth		Zero TFP growth	
	No. obs.	**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
Northeast	44.8	32.1	55.2	42.4	0	25.5
Northwest	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
Southeast	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: No. obs: number of observations; bs.: bootstrap

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 1985–1990. Overall, the TFP growth rate in the whole period is estimated at 1.96 percent, contributing to 38% of Vietnam's agricultural growth. Although this growth rate is significant compared to other developing countries, it is unstable. In the 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 21st century.

Our 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, some regions experienced decreases in TFP growth. The situation was particularly difficult for the Northwest, where TFP growth declined by 6.7 percent annually during the period. 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 in regaining 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.

A supposed limitation of our research is that the data are not updated into the 21st century, focussing instead on only the reform and post-reform period. Recent studies such as World Bank (2016) indicated that after 2000, the agricultural sector had faced crucial challenges such as rising labor costs, over-using inputs, and reduced land and natural resources. Further research with more updated agricultural data could shed light on the sources of Vietnam's agricultural growth and productivity in the recent period when Vietnam is fully integrated into a global trade system with new challenges ahead.

Funding
The authors received no direct funding for this research.

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Conflicts of Interest
The authors declare no conflict of interest.
Acknowledgement.
The authors would like to thank the Japan International Cooperation Agency and Vietnam Japan University for funding the article processing charge.

Citation information
Cite this article as: Agricultural productivity growth in vietnam in reform and post-reform period, Linh Hoang Vu & Le Quy Dinh Nguyen, *Cogent Economics & Finance* (2021), 9: 1972524.

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Appendix: Bootstrapping Malmquist productivity index

(i)

First, we 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$\hat{\theta}_1, \ldots \hat{\theta}_n$. 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 $\beta_1^*, \ldots .\beta_n^*$ be a simple bootstrap sample from $\hat{\theta}_1, \ldots \hat{\theta}_n$. Draw bootstrap estimates from the original sample of scores $\{\hat{\theta}_1, \ldots \hat{\theta}_n\}$ 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, we 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 & Tibshirani, 1993).

(vi)

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

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