THE EFFECT OF INCENTIVE REFORMS UPON PRODUCTIVITY: EVIDENCE FROM THE VIETNAMESE RICE INDUSTRY

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ABSTRACT

In this study we use region-level panel data on rice production in Vietnam to investigate total factor productivity (TFP) growth in the period since reunification in 1975. Two significant reforms were introduced during this period, one in 1981 allowing farmers to keep part of their produce, and another in 1987 providing improved land tenure. We measure TFP growth using two modified forms of the standard Malmquist data envelopment analysis (DEA) method, which we have named the *Three-year-window* (TYW) and the *Full Cumulative* (FC) methods. We have developed these methods to deal with degrees of freedom limitations. Our empirical results indicate strong average TFP growth of between 3.3 and 3.5% per annum, with the fastest growth observed in the period following the first reform. Our results support the assertion that incentive related issues have played a large role in the decline and subsequent resurgence of Vietnamese agriculture.

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1. INTRODUCTION

The reasons for the decline of many centrally planned economic systems has been widely debated in recent years (eg. see Easterley and Fisher, 1995). The explanations put forward are many and varied, but almost all authors make at least some mention of the influence of low incentive structures upon economic performance. In Vietnam, there is some anecdotal evidence to support the assertion that the incentives faced by the managers and workers in farms and factories have had a large effect on economic performance. For example, in the rice industry, growth in average yield per hectare tended to stagnate or become negative when collectivism was introduced, while after the reintroduction of incentives for individual farmers, the average yields began to grow at a significant pace (Pingali and Xuan, 1992).

However, as is widely recognised in the economics literature (eg. see Coelli, 1995), partial productivity measures, such as yield per hectare, can provide misleading information on economic performance. The problem being that yield per hectare only accounts for one input, land, and takes no account of possible increases or decreases in other inputs, such as labour, fertiliser, etc. Hence, it is much better to use a productivity measure that accounts for all factors of production. Namely, a total factor productivity (TFP) measure.

In this study we set out to measure TFP growth in the Vietnamese rice industry using region-level panel data over the 22-year period since reunification in 1975. During this period two significant incentive reforms were implemented, with the intent of arresting the substantial decline in rice production levels. The first reform permitted farmers to keep their excess production (above predetermined targets), while the second reform extended the length of land leases and made them transferable among family members. The historical information on average yields suggests that these reforms were a success. However, the measurement and comparison of TFP growth rates before and after these reforms will provide us with more concrete evidence of the effects of these reforms upon economic performance.

The question of TFP growth in the Vietnamese rice industry was recently investigated by Dinh (1997) in an unpublished Masters dissertation. In that study the method used was the traditional Tornqvist index number approach, which has been widely used in many past analyses of TFP in agricultural and industrial applications. However, as is noted in Dinh (1997), a price-based index number method, such as the Tornqvist index, may not be the best approach to use in centrally planned economies. These methods require the use of price information and also assume that the economic agents involved exhibit cost minimising behaviour.[1] These assumptions are unlikely to be valid in the case of the Vietnamese rice industry, where cost minimising incentives were often limited, and prices were controlled by the central government. For example, the official farm-gate, wholesale and retail prices of rice were almost identical during the 1976-1990 period (CGPRT, 1993, pp.161-70).[2]

Hence, in this study we use an alternative TFP measurement method, the Malmquist data envelopment analysis (DEA) approach, proposed by Fare, Grosskopf, Norris and Zhang (1994). This approach uses panel data to construct a series of non-parametric production frontiers using linear programming methods. These frontiers are then used to measure the TFP growth of the various regions in our data over time. This method has the advantage that it does not require the explicit use of price information, nor does it require the assumption of cost minimising behaviour. It also has the advantage that it permits the decomposition of the TFP growth from each region into two components: technical change (shifts in the frontier) and technical efficiency change (catching up to the frontier).[3]

However, one problem that we face in this study is the fact that our panel data involves only eight cross-sectional units – the eight agricultural regions in Vietnam for which we have data. This small sample size is a problem because, as noted in Coelli and Rao (1999), the piece-wise linear nature of the Malmquist DEA frontiers can provide rather unstable implicit price information (which is implicitly used in the Malmquist DEA TFP index calculations), and hence provide unsatisfactory TFP measures. Furthermore, this problem is exacerbated by small sample sizes. Hence, in this study we develop and utilise two modified Malmquist data envelopment analysis methods, namely, a *Three-year-window* (TYW) and a *Full Cumulative* (FC) method, to attempt to circumvent this problem. These two methods seek to include extra observations from previous years to construct a more robust reference frontier in each year. The TYW method uses data from the current year plus the two preceding years, while the FC method uses data from the current year and all previous years (that are in the panel data set). These new methods, along with the standard Malmquist DEA methods, are discussed in some detail in the methodology section later in this paper.

[1] See Chapters 4 and 5 in Coelli, Rao and Battese (1998) for further discussion of price-based index number approaches to TFP measurement.

[2] CGPRT stands for Centre for Coarse, Grain, Pulse, Root and Tuber Crops of Asia and the Pacific Region.

[3] See Chapters 10 in Coelli, Rao and Battese (1998) for further discussion of the Malmquist DEA approach.

The remainder of this paper is organised into sections. In section 2 we describe the Vietnamese rice industry, and in section 3 we provide details on the data used in this study. In section 4 we describe the Malmquist DEA method, along with the two new TYW and FC variants of this method introduced in this paper. In section 5 we present and discuss our empirical results, while in the final section we make some concluding comments.

2. THE VIETNAMESE RICE INDUSTRY

Rice is the most important crop in Vietnamese agriculture and it plays a central role in the economy. It is planted on about 84 per cent of the total farm area and it accounts for more than 85 per cent of food grain output. Rice not only provides about 85 per cent of the total daily calorie intake for Vietnamese people but it is also the second-largest foreign exchange earner of the country (GSO, 1998).[4]

A proper understanding of the current situation in the Vietnamese rice industry requires a brief recap of some recent history. During the separation of North and South Vietnam between 1954 and 1975, each half of the country was under different economic policies. The North developed a command socialist system whilst the South retained its former capitalist approach. In the North, it proved very difficult to achieve food self-sufficiency, given the smaller area of arable land per capita and the poorer soil quality compared to the South. In contrast, the South always achieved food surplus status because of its abundance of arable land and its market-oriented economy (Nguyen, 1994). Furthermore, Pingali and Xuan (1992) state that North Vietnam's per capita rice output declined consistently following collectivisation policies implemented by the government. As a result, North Vietnam, became a traditional net rice importer during the period from the 1960s to the middle of the 1980s, and had to depend on food aid from other countries in the former socialist bloc.

After the reunification of the country in 1975, agricultural collectivisation was also applied to the South and resulted in widespread failure (Pingali and Xuan, 1992). By the end of 1979, there was a massive collapse of cooperatives and production groups, since collective farmers had little incentive to maintain or increase production (Tran et al., 1991). Recognising the failure of the agricultural cooperatives, the Vietnamese government introduced a series of agricultural reforms. In 1981 an annual contract system replaced the cooperative system. The cooperative lands were given to peasant households with an obligation to sell a contracted level of output to the state at a fixed price. The surplus amount could then be used for home consumption or sold to traders (David, 1994). However, the lack of land tenure security, low output prices and inadequate input supplies limited further growth of productivity. After a shortfall of production in 1987, the second reform was introduced, which allowed long-term leases of 10-20 years, with leased land transferable among family members. Due to these reforms, rice production increased significantly in the last decade. During the 1988-1997 period, rice production increased at the rate of 6.28 per cent per annum (GSO, 1988). In 1989, Vietnam re-emerged in the world's rice market as a significant exporter, after decades of being a net importer. Over the last decade it has been the world's third-largest exporter of rice, after Thailand and the United States, exporting approximately three million metric tons (MT) of rice annually.

However, as noted in the introduction section of this paper, growth in production levels and average yields can be achieved by input growth, as well as by productivity growth induced by better incentives. The purpose of this paper is to provide a comprehensive analysis of recent TFP growth in this industry, so as to net out the effect of input growth, and hence to provide a better indication of the true performance of this industry over recent years.

3. DATA

The empirical analysis in this study uses data on the eight agricultural regions of Vietnam, depicted in Figure 1. The biggest rice producers are the Mekong River and Red River Deltas, while the smallest producer is the South-West Vietnam Region, where water is scarce and cash crops such as coffee and cashew dominate rice. The data used in this study are annual data for the period 1976 to 1997, for each of these eight regions. The data is an updated version of the Dinh (1997) data set, derived from CGPRT (1993) and GSO (1998). The quantity variables used in our TFP analysis are output (of rice) and five input variables: seed, chemical fertilisers, human labour, pesticide and animal service. Sample means of these variables are presented in Table 1, where the study period is divided into three sub-periods: pre-reform (1976-1981), the first reform (1981-1987) and the second reform (1987-1997). As can be seen from Table 1, the output, measured in mega tonnes (MT) of rice, and certain inputs, do vary significantly over the study period.

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[4] GSO stands for the General Statistical Office of Vietnam.

Figure 1: Geographical Map of Vietnam

Table 1: Sample Means

Variables	1976-1981	1981-1987	1987-1997
Production (MT)	1,375,848	1,857,819	2,776,122
Area Planted (ha)	678,973	707,642	802,818
Yield (kg/ha)	1,907	2,425	3,061
Seed (kg/ha)	138	152	144
Fertiliser N (kg/ha)	76	80	80
Fertiliser P (kg/ha)	67	70	73
Fertiliser K (kg/ha)	31	33	34
Human Labour (hr/ha)	318	320	312
Pesticide (kg/ha)	0.40	0.56	3.24
Animal Service (hr/ha)	226	243	286

Seed, chemical fertilisers (N, P, K) and pesticide are measured in kilograms per hectare (kg/ha) planted. The three chemical fertilisers were aggregated into one group by using the Fisher index for use in the TFP analysis. It should be noted that the P and K fertiliser data for Region 7 (Southeast Vietnam) were missing. Given that the land characteristics of this region are similar to those of the Mekong River Delta, it was hence assumed that the quantities of P and K used per hectare of rice in Region 7 were the same as those used in the Mekong River Delta.[5]

Human labour and animal service were measured in hour/ha. These included the total hours worked by humans and animals in all operations of the production process from land preparation to harvesting, transportation and storage. Human labour and animal services included those provided by the household and those hired.[6]

Data quality was a particular concern in this study. No official agricultural census has been conducted since the reunification of the country in 1975 (David, C. C. 1994). All statistical data were collected by the district level officers of the General Statistics Office (GSO). Input data are mostly based on sales records of the state commercial companies, whilst considerable

[5] The other adjustment made to the raw data related to a border conflict in 1978 with the Khmer Rouge, which resulted in unusually low output in Region 7 and Region 8 in 1978 (Lan, 1998). To prevent this factor affecting our results, the 1978 output data for these two regions were replaced by the averages of their production levels in 1977 and 1979.

[6] Note that all input variables used for the TFP calculations were the total quantities of each input used in production. However, the per hectare values have been reported in Table 1 for ease of interpretation.

amounts of inputs were purchased from private traders, especially after the reforms. Therefore, fertiliser and pesticide data could be understated in the later years of the data. However, given that we do not have data on organic fertiliser, and the use of organic fertiliser most likely reduced as chemical fertilisers increased, we suspect that any bias caused by a poor chemical fertiliser data will be minimal.

In addition to this, we were also particularly concerned that we did not have information on the area of irrigation, which has expanded during this period. We have partly addressed this problem via our choice of a land variable, which we now discuss.

Rice land can utilised in various ways. Particularly, the typical crop patterns of rice land in Vietnam can follow a range of structures:

1. One crop of rainfed rice and then fallow for the rest of the year (typical in Region 1 and Region 6).
2. One crop of rainfed rice and one other crop, such as sweet potato, maize or winter vegetable (typical in Region 2 and Region 4).
3. One crop of rainfed rice and one crop of irrigated rice (Typical in Region 3, Region 5 and part of Region 2).
4. Two crops of rainfed rice and one crop of irrigated rice (typical in Region 7 and Region 8).
5. One crop of rainfed rice and one crop of fish (typical in lowland areas of Region 8).

Thus, by focusing only on rice production in this study, the overall productivity of the land is not made fully evident. However, data limitations prevent us from investigating these matters in any detail.

Therefore, we have two possible options for measuring the area planted variable in this study:

1. Area planted equals total area of arable land that can be used to plant rice (ie. double-crop areas are counted only once).
2. Area planted equals total area planted of rice in all seasons of the year (ie. double-crop areas are counted twice).

The first option is the preferred option when all required data are available. However, data on irrigation water, rainfall, soil quality and quantities of non-rice output produced on rice land were not available. Thus, the second option is used in this study. It can be justified by noting that, to some degree, it will take account of differences in irrigation, rainfall and soil quality across regions and/or across time. It will also partly take into account the non-rice crops grown on some of the rice land. It is clear that our data is not ideal, but we believe it is of sufficient quality to provide a good indication of productivity growth in Vietnamese rice production over recent decades.

4. METHODOLOGY

4.1 The Malmquist Productivity Index

The Malmquist productivity index (MPI), as proposed by Caves, Christensen and Diewert (1982), is defined using distance functions, which allow one to describe multi-input, multi-output production without involving explicit price data and behavioural assumptions. Distance functions can be classified into input distance functions and output distance functions. Input distance functions look for a minimal proportional contraction of an input vector, given an output vector, while output distance functions look for maximal proportional expansion of an output vector, given an input vector. In this study, we use output distance functions.[7]

Before we define the distance function we must first define the technology. Let $x_t \in R_+^N$ and $y_t \in R_+^M$ denote, respectively, an (N×1) input vector and an (M×1) output vector for period t (t=1,2,…, T). Then the graph of the production technology in period t is the set of all feasible input-output vectors, or

$$GR_t = \{(x_t, y_t): x_t \text{ can produce } y_t\}, \quad (1)$$

where the technology is assumed to have the standard properties, such as convexity and strong disposability, described in Fare et al (1994).

The output sets are defined in terms of GR_t as:

$$P_t(x_t) = \{y_t: (x_t, y_t) \in GR_t\}. \quad (2)$$

The output distance function for period t technology, as described in Shephard (1970), is defined on the output set $P_t(x_t)$ as:

[7] This choice is arbitrary. It will have no effect upon our results because of the constant returns to scale technology, which is used in the MPI to measure TFP. See Coelli, Rao and Battese (1998) for further discussion.

$$d_o^t(x_t, y_t) = \inf\{\delta_t : (y_t/\delta_t) \in P_t(x_t)\} \tag{3}$$

where the subscript "o" stands for "output oriented". This distance function represents the smallest factor, δ_t, by which an output vector (y_t) is deflated so that it can be produced with a given input vector (x_t) under period *t* technology.

The productivity change, measured by the MPI, between periods *s* and *t*, can be defined using the period *t* technology as:

$$M_o^t(y_t, y_s, x_t, x_s) = \frac{d_o^t(x_t, y_t)}{d_o^t(x_s, y_s)}. \tag{4}$$

Similarly, the MPI using period *s* technology may be defined as:

$$M_o^s(y_t, y_s, x_t, x_s) = \frac{d_o^s(x_t, y_t)}{d_o^s(x_s, y_s)}. \tag{5}$$

In order to avoid choosing the MPI of an arbitrary period Fare et al (1994) specified the Malmquist productivity change index as the geometric mean of equations 4 and 5:

$$\begin{aligned} M_o(y_s, y_t, x_s, x_t) &= \left[M_o^t(y_s, y_t, x_s, x_t) \times M_o^s(y_s, y_t, x_s, x_t)\right]^{1/2} \\ &= \left[\frac{d_o^s(y_t, x_t)}{d_o^s(y_s, x_s)} \times \frac{d_o^t(y_t, x_t)}{d_o^t(y_s, x_s)}\right]^{1/2} \end{aligned} \tag{6}$$

The MPI formula in equation 6 can be equivalently rewritten as:

$$M_o(y_s, y_t, x_s, x_t) = \frac{d_o^t(y_t, x_t)}{d_o^s(y_s, x_s)}\left[\frac{d_o^s(y_t, x_t)}{d_o^t(y_t, x_t)} \times \frac{d_o^s(y_s, x_s)}{d_o^t(y_s, x_s)}\right]^{1/2} \tag{7}$$

The first component of equation 7 measures the output-oriented technical change between period *s* and *t* whilst the second component measures shift in technology between the two periods. For further discussion of the MPI, refer to Coelli, Rao and Battese (1998).

4.2 Calculation of the Malmquist Productivity Index

The MPI has been calculated in various ways. These may be classified in two groups: those which require both price and quantity data, and those which only require quantity (panel) data. The price-based method was proposed by Caves, Christensen and Diewert (1982), who showed that if the distance functions are of translog form with identical second order terms and there is no technical and allocative inefficiency, then the Malmquist index can be computed as the ratio of Törnqvist output index and Törnqvist input index.

Fare et al (1994) subsequently showed that the MPI could be calculated without price data, if one had access to panel data. Furthermore, in this instance, the MPI can be decomposed into technical change and catch-up components, as shown in equation (7). Fare et al (1994) used Data Envelopment Analysis (DEA) methods to estimate and decompose the MPI. We now briefly outline their approach.

The Standard Malmquist DEA Method

Given suitable panel data are available, four distance functions must be calculated (hence four linear programs (LPs) must be solved) for each firm, in order to measure Malmquist TFP changes between any two periods, as defined in equation (7). First we define some notation. Let K, N, M and T represent, respectively, the total number of firms, inputs, outputs and time periods in the sample. Let ϕ denote a scalar, which represents the proportional expansion of output vector, given the input vector. Let $\lambda=[\lambda_1, \lambda_2, \ldots, \lambda_K]'$ denote the $(K\times1)$ vector of constants, which represent peer weights of a firm. Let y_{it} and x_{it} represent the $(M\times1)$ output vector and the $(N\times1)$ input vector, respectively, of the i-th firm in the t-th period (t=1,2,…T). Let Y_t and X_t represent, respectively, the $(M\times K)$ output matrix and $(N\times K)$ input matrix in period t, containing the data for all firms in the t-th period. The notation for period s are defined similarly.

The four required LPs are:

$$[d_0^t(y_{it}, x_{it})]^{-1} = \max_{\phi,\lambda} \phi$$

Subject to (s.t.)

$$-\phi y_{it} + Y_t\lambda \geq 0$$

$$x_{it} - X_t\lambda \geq 0$$

$$\lambda \geq 0 \tag{8}$$

$$[d_0^s(y_{is}, x_{is})]^{-1} = \max_{\phi,\lambda} \phi$$

s.t.

$$-\phi y_{is} + Y_s\lambda \geq 0$$

$$x_{is} - X_s\lambda \geq 0$$

$$\lambda \geq 0 \tag{9}$$

$$[d_0^t(y_{is}, x_{is})]^{-1} = \max_{\phi,\lambda} \phi$$

s.t.

$$-\phi y_{is} + Y_t\lambda \geq 0$$

$$x_{is} - X_t\lambda \geq 0$$

$$\lambda \geq 0 \tag{10}$$

$$[d_0^s(y_{it}, x_{it})]^{-1} = \max_{\phi,\lambda} \phi$$

s.t.

$$-\phi y_{it} + Y_s\lambda \geq 0$$

$$x_{it} - X_s\lambda \geq 0$$

$$\lambda \geq 0 \tag{11}$$

The above four LPs are very similar to standard DEA LPs. In fact, equations (8) and (9) are standard DEA LPs, which measure the technical efficiency of the i-th firm in the t-th and s-th year, respectively. In equations (10) and (11) the i-th observation from the t-th period is compared to the technology constructed using the period s data, and vice versa. Thus, in these LPs the ϕ need not to be greater than or equal to one, if technical regress or progress has occurred. The above four LPs are required for each firm (or region in our study) in each pair of adjacent years. Thus, if one has data on K firms over T time periods, one must solve $K\times(3T-2)$ LPs to construct the required firm-level chained indices (Coelli et al., 1998).

Two Extended Malmquist DEA Methods

The data available for this study contains only eight observations (corresponding to eight regions) for each year. Therefore, the standard Malmquist DEA method of Fare et al (1994) may produce unstable TFP indices because the sparse data will not be able to construct approximately "smoothed-surface" frontiers in each period. To overcome this problem we use two extended DEA methods, namely the TYW and the FC methods. Each method will be discussed in turn in the following sections.

a) The Three-year-window (TYW) DEA Method

The DEA window method was introduced by Charnes, Clark, Cooper and Golany (1985); Charnes, Cooper, Dieck-Assad, Golany and Wiggins (1985); and Charnes, Copper, Divine, Lopp and Stutz (1992). However, to our knowledge, no study has applied the window DEA method to calculation of the MPI.

Our window DEA technique is as follows. Our panel of T cross-sections of data is divided into a series of shorter overlapping sub-panels, each having S (arbitrarily chosen) time periods. Thus, the first sub-panel contains periods {1, 2, …, S}; the second sub-panel contains periods {2, 3, …, S+1} and so on until the last sub-panel, which contains periods {T-S+1, T-S+2,…, T}. The procedure is to construct a series of frontiers from the sub-panels and use these frontiers to calculate the distance functions needed for the Malmquist TFP calculations. The advantage of this method is to relieve degrees of freedom pressure when the number of inputs plus outputs is large relative to the number of firms.

In this study, the width of the window was arbitrarily chosen at three. Thus, the first sub-panel contains periods {1976, 1977, 1978}, the second sub-panel contains periods {1977, 1978, 1979} and the last sub- panel contains periods {1995, 1996, 1997}. Thus, in each year the frontier is constructed from 24 observations. We then use the frontier constructed using 1976-1978 data as our 1978 frontier; the frontier constructed using the 1977-1979 data as our 1979 frontier; and so on until the frontier constructed using 1995-1997 data is used as our 1997 frontier. Otherwise, the LPs are identical to those in equations (8) to (11).

b) The Full Cumulative (FC) DEA Method

This method, like the window method, is designed to alleviate the degrees of freedom problem, but it also has the additional advantage that it prevents the calculation of "technical regress", which one often calculates using the standard Malmquist DEA method, when random fluctuations in climate, etc. influence the empirical results. This technique of measuring efficiency using pooled data was used in Diewert and Parkan (1983) and Färe, Grabowski and Grosskopf (1985). However, those studies did not use the full cumulative DEA to calculate the MPI.

The FC method similar to that of the window DEA method. The first sub-panel contains periods {1, 2, …, S}. One more time period is then also added to the second sub- panel, but in contrast to the window DEA method, the first time period is not discarded. Therefore, the second sub- panel contains periods {1, 2,…., S+1}; the third sub- panel contains periods {1, 2,

…, S+2} and so on until the last sub- panel, which is actually the entire panel, contains periods {1, 2, …, T}.

In this study, the value of S was arbitrarily chosen at three. Thus, the first sub-panel contains periods {1976, 1977, 1978}, the second sub-panel contains periods {1976, 1977, 1978, 1979} and so on until the last sub-panel contains periods {1976, 1977,….1997}. Thus, we use the frontier constructed using 1976-1978 data as our 1978 frontier; the frontier constructed using the 1976-1979 data as our 1979 frontier; and so on until the frontier constructed using 1976-1997 data is used as our 1997 frontier. Otherwise, the LPs are identical to those in equations (8) to (11).

These methods are clearly quite computattionally intensive. There are two publicly available computer programs that can be used to readily calculate the standard Malmquist DEA TFP index. These are DEAP, written by Coelli (1996) and OnFront written by EMQ (1997). However, we know of no publicly available computer program that can readily calculate the two new MPI methods proposed in this study. Thus, we have written two new computer programs to estimate the two extended Malmquist DEA methods. The computer programs have been written in Visual Basic for Applications and are available from Mr Hong Son Nghiem on request.[8]

5. EMPIRICAL RESULTS

The Three-year-window (TYW) Method

The TYW results are presented in Table 1. From this table we observe that the average TFP growth rate of the country over the study period was 3.5 per cent per annum. The rate of TFP growth during the first reform period from 1981-1987 was the highest, at 6.5 per cent per annum. This is most likely due to the fact that productivity levels were coming from such a low base in this period. The introduction of the first incentive reform, where the farmers were allowed to keep any amount of production over a particular pre-defined target, has clearly had an impressive effect on productivity.

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[8] For a detailed description of computer programs, see Nghiem (1999, pp. 52-57, 127-30).

Table 2: TYW Estimates of Annual Average Malmquist TFP Change, Catch-up and Technical Change*

	R1	R2	R3	R4	R5	R6	R7	R8	Vietnam
TFP change									
1976-1981	1.061	1.015	1.027	0.999	0.988	0.991	1.018	1.036	1.027
1981-1987	1.014	1.034	1.045	1.090	1.086	1.045	1.028	1.078	1.065
1987-1997	1.023	1.023	1.052	1.001	1.013	1.017	1.005	1.018	1.024
1976-1997	1.016	1.024	1.044	1.020	1.031	1.031	1.019	1.043	1.035
Catch-up									
1976-1981	1.083	1.054	1.056	1.039	1.000	0.996	1.006	1.018	1.033
1981-1987	0.985	0.995	1.000	1.044	1.000	1.012	0.996	1.000	1.004
1987-1997	0.993	0.997	1.004	0.997	0.995	0.993	0.985	1.000	1.000
1976-1997	0.997	1.002	1.009	1.008	0.998	1.009	0.993	1.003	1.004
Technical change									
1976-1981	0.980	0.963	0.973	0.961	0.988	0.994	1.012	1.018	0.994
1981-1987	1.029	1.040	1.045	1.044	1.087	1.032	1.032	1.078	1.061
1987-1997	1.030	1.026	1.048	1.004	1.018	1.025	1.021	1.019	1.024
1976-1997	1.020	1.022	1.035	1.012	1.038	1.022	1.026	1.040	1.031

*Results in this table are the geometric means of the annual results. The national results were calculated as the weighted geometric means of regional results. The weights used are the quantity shares of each region in total production of the country. Note also that R1 refers to region 1, and so on.

We also note that, on average, the southern regions (R5-R8) achieved slightly higher TFP growth than the northern regions. This is most likely because southern farmers have more experience in commercial farming operations, than their northern counterparts. Hence, they were more able to take advantage of the new opportunities presented to them.

From the middle section of Table 2, we observe that the national average rate of catch-up growth was only 0.4 per cent per annum. This indicates that the relative productivities of the different regions remained fairly constant through this period. We also observe that the rate of catch-up does not differ significantly between North and South. It was our expectation that there would be more catch-up in the Northern regions, as they caught up to the more advanced South. However, the fast growth which occurred in the South, combined with the limited knowledge of commercial farming practices among Northern growers, have most likely contributed to the results we have obtained here.

The final section of Table 2 contains technical change information. On average, technical progress increased 3.1 per cent per annum over the study period. This is, by far, the main contributor to TFP growth in this study. Hence, the technical change indices are quite similar to the TFP indices, discussed above.

It is interesting to note, however, that during the first reform, the average growth rates of technological progress of southern regions were higher than the northern counterparts. While, during the second reform period, the average technological progress of the northern regions was higher than that of the southern regions. This may indicate that the northern farmers have become more accustomed to the new technologies, and we may now see a convergence in the productivities of the North and South, in the years to come.

<u>The Full Cumulative (FC) Method</u>

The FC results are presented in Table 3. The results are quite similar to the TYW results, as one would hope. The average TFP growth rate of the country over the study period was estimated to be 3.3 per cent per annum, which differs from the TYW estimate by only 0.2 per cent.

The general pattern of the FC results is quite similar to the TYW results. We observe that technical change is again the main contributor to TFP growth. In fact, on average, the catch-up effect is equal to zero based on the FC method. We also observe that TFP growth is fastest in the first reform period (1981-1987); it is fastest in the northern regions; and in the final period (1987-1997) the northern regions achieve faster growth than the southern regions (on average).

<u>Comparison of the Malmquist DEA TFP and the Törnqvist TFP Indices</u>

One of the main reasons that we have used the Malmquist DEA approach to measure TFP growth in this study, as opposed to the more commonly used Tornqvist index, was a concern that the available price information, which was fixed by the State, may not reflect market prices, and hence may introduce biases into our measures of TFP growth. Hence, in this section we calculate the Tornqvist index, and compare it with our Malmquist DEA results.[9]

The Tornqvist results are listed in Table 4. The annual average Törnqvist TFP change index is 3.1 per cent, which is quite similar to our Malmquist DEA TFP results, of 3.3 per cent and 3.5 percent, for FC and TYW, respectively. The similarity in results indicate that the implicit shadow prices used in the Malmquist DEA TFP calculations are quite similar to the observed prices used in the Tornqvist calculations. This need not be the case in all situations. See Coelli and Rao (1999) for further discussion.

Table 3: FC Estimates of Annual Average Malmquist TFP Change, Catch-up and Technical Change*

	R1	R2	R3	R4	R5	R6	R7	R8	Vietnam
TFP change									
1976-1981	1.074	1.002	1.055	0.970	0.946	0.985	1.017	1.017	1.018
1981-1987	1.018	1.034	1.035	1.075	1.078	1.041	1.025	1.073	1.059
1987-1997	1.008	1.004	1.067	0.989	1.020	1.017	1.005	1.016	1.024
1976-1997	1.010	1.012	1.052	1.007	1.027	1.030	1.017	1.036	1.033
Catch-up									
1976-1981	1.073	1.001	1.055	0.969	0.946	0.982	1.006	1.000	1.009
1981-1987	1.002	1.015	1.012	1.059	1.026	1.022	0.996	1.000	1.013
1987-1997	0.988	0.992	1.007	0.987	0.987	0.994	0.985	0.999	0.998
1976-1997	0.993	0.997	1.009	1.000	0.989	1.009	0.993	1.000	1.000
Technical change									
1976-1981	1.001	1.001	1.000	1.001	1.000	1.004	1.012	1.017	1.008
1981-1987	1.015	1.019	1.022	1.016	1.051	1.018	1.029	1.073	1.046
1987-1997	1.031	1.029	1.045	1.022	1.021	1.027	1.021	1.020	1.026
1976-1997	1.024	1.024	1.034	1.019	1.031	1.023	1.025	1.039	1.033

*Results in this table are the geometric means of the annual results. The national results were calculated as the weighted geometric means of regional results. The weights used are the quantity shares of each region in total production of the country. Note also that R1 refers to region 1, and so on.

[9] See Caves, Christensen and Diewert (1982), Dinh (1997) or Coelli, Rao and Battese (1998) for information on the Tornqvist TFP index.

Table 4: Annual Average Törnqvist TFP Change Indices*

	R1	R2	R3	R4	R5	R6	R7	R8	Vietnam
1976-1981	1.070	0.971	1.032	1.080	1.018	0.989	0.991	1.012	1.024
1981-1987	1.024	1.027	1.028	1.071	1.059	1.045	1.037	1.054	1.048
1987-1997	1.022	1.021	1.047	1.029	1.015	1.012	1.003	1.018	1.026
1976-1997	1.017	1.019	1.032	1.046	1.026	1.025	1.013	1.034	1.031

*Results in this table are the geometric means of the annual results. The national results were calculated as the weighted geometric means of regional results. The weights used are the quantity shares of each region in total production of the country. Note also that R1 refers to region 1, and so on.

6. CONCLUSIONS

This study has made two significant contributions. The first is the development of two extended Malmquist DEA methods for use in the calculation of productivity change when one has a limited number of cross-sectional observations. The three year window (TYW) and full cumulative (FC) methods were developed and applied in this study. These approaches deal with the degrees of freedom problem by pooling observations from previous years to obtain improved estimates of the frontier in each year of the analysis. This avoids the danger of obtaining unstable results derived from frontiers constructed using only a few observations. The FC method has the additional advantage that it prevents the calculation of "technical regress", which is usually due to climatic variation from year to year, rather than any sudden loss of technological knowledge.

The second significant contribution of this study is the provision of valuable information on productivity growth in Vietnamese rice production. We apply our two new extended Malmquist DEA TFP methods to panel data on the eight rice-growing regions in Vietnam, over the 22-year period from 1976 to 1997. We calculate TFP growth, catch-up and technical change for each of these regions and Vietnam as a whole. We find that TFP growth averaged between 3.3 and 3.5 per cent per year over this period, which is well above average compared to agricultural productivity growth in other developing countries (see Fulginiti and Perrin, 1998). We observe that the vast majority of this TFP growth is due to technological change, with our average measures of catch-up only contributing between 0.0 and 0.4 per year.

We also observe that productivity growth was higher following the two incentive reforms, introduced in 1981 and 1987, with the faster growth occurring following the first incentive reform, in which farmers were allowed to keep any production which exceeded the targets set by the State. We also look at how productivity growth differs between regions, with particular interest in differences between northern and southern regions. We expected to find greater catch-up in the northern regions, as they became closer to the more advanced southern regions, but our results did not reflect this. One possible explanation for this is the rapid growth that was occurring in the South during this period, meaning that the North was chasing a target which was moving away from them at a rapid rate. Furthermore, it is likely that the southern farmers had had greater experience with commercial farming practices, and hence were more able to take advantage of the new opportunities offered by the incentive reforms. This hypothesis is supported by an observation that TFP growth in the northern regions began to outstrip that of the southern regions in the later half of our study period. This suggests that the northern farmers may be well on the way to matching the impressive performance of their southern cousins.

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