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Market Reform, Productivity and Efficiency in Vietnamese Rice Production.

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1. Introduction

Since the beginning of its 'doi moi' market reform process in 1981, Vietnam has achieved remarkable success in increasing the output of rice. From being a large importer of rice throughout the early 1980's, Vietnam has now become the third largest exporter of rice in the world, with the total output of all agricultural products more than doubling during the main period of reforms from 1981 to 1994.[1] Even more notable is the fact that these gains have been achieved with a relatively modest growth of most inputs and with little or no technological change. The market reform process in Vietnamese agriculture over this period has been pervasive, including a significant liberalization of internal and external trade, greater autonomy for farmers in decision making and fundamental institutional change including the reform of the property rights regime. This paper argues that this considerable market reform has greatly enhanced the incentives for farmers to work hard and to use land more efficiently, and thus largely explains the dramatic increases in rice output and productivity. The reform process itself is captured through changes in effort variables and a decomposition of total factor productivity (TFP) due to enhanced incentives for two main reform periods: output contracts (1981-87) and trade liberalization (1988-94). The results show that the more extensive is market reform the larger the increase in TFP and the share of TFP growth due to incentive effects, suggesting that more competitive markets and secure property rights matter greatly.

However, in the post-reform period (1995-99), the incentive component of TFP dissipates as a result of falls in the price of rice and slow increases in input prices, especially for hired labour, fertilizer and capital. A stochastic production frontier is estimated to determine what farm-specific factors limit efficiency gains. Results show that farms in the main rice growing regions, those with larger farm size and farms with a higher proportion of rice land ploughed by tractor are more efficient, suggesting the need for additional reforms to augment productivity. In particular, the requirement that rice be grown in every province in Vietnam, restrictions on farm size (especially in the north) and the slow development of rural credit markets for capital and land are seen to restrict the level and growth of efficiency substantially.

Section 2 of the paper provides some background, briefly describing rice production in Vietnam and the characteristics of the main market reform periods. Data sources and variable construction are detailed in section 3 and in an appendix to the paper. Following McMillan, Whalley and Zhu (1989) and Che, Kompas and Vousden (2001), sections 4.1 to 4.3 present the basic model be used to explain the effects of market reform on rice output and productivity. The model captures market reform measures through policy induced changes in TFP and a decomposition of TFP into productivity changes due to enhanced incentive effects from

[1] The output of rice itself increased from 12,415 in 1981 to 23,528 thousand tons in 1994 (GSO, 1995), increasing further to 31,315 thousand tons in 1999.

those due to other 'unexplained' factors.[2] In Section 4.4, estimates of a production function from provincial level panel data for the years 1991 to 1999 are used to obtain measures of TFP with market reform over an aggregate data set. Section 4.5 estimates the contribution of incentive effects to productivity growth over the two main and post reform periods. The process of market reform is captured through the effects of changes in policy and market parameters on average per unit profits. There are two things to consider here. First, in transitional economies the share of output that accrues to the state authority varies under different institutional settings, from communal systems to share-contracting schemes and finally to private competitive markets with taxes on retained earnings. Prices received by farmers for their product also vary considerably across these regimes. To capture such changes, this paper estimates an effective output price (the farmer's share of output multiplied by the actual output price) over time. With market reform it is asserted that both actual and effective prices increase, and this is certainly true in the case of Vietnam. With the reform process, in other words, output is directed over time toward markets where prices are higher and the share of output apportioned to the state government for centrally-directed distribution falls.

Second, in transitional economies, factor and product prices generally increase at different rates with market reform. In the paper this process is characterized through a weighted-cost share parameter which measures the ratio of average factor to product prices under various institutional arrangements. As is true for most transitional economies, and again this is the case for Vietnam, the value of this share-cost parameter falls with reform. Changes in factor prices lag behind the increases in product prices and the result implies that average per unit profits rise over time. This, combined with a rising effective price of output, generates the emerging profits function developed in the paper. It is not until the post-reform (1995-96) period that input prices finally begin to rise. This, combined with the fall in the world price of rice, decreases per unit average profits and so dissipates the incentive effect.

Section 5.1 reviews the basics of stochastic frontiers and technical inefficiency models. Section 5.2 provides the econometric specification and 5.3 summarizes the results. A well-known concern with standard stochastic production frontiers is that they generally assume that all firms share a similar technology. However, for rice production in Vietnam this is not a serious problem. Although input proportions vary, rice is grown basically in the same way, using the same inputs, in each of the sixty provinces. Differences in natural conditions and the level of usage of common inputs, such as tractors, can be accounted for by the appropriate variables in the efficiency model. This aside, the key advantage of stochastic production frontiers is that of being able to model the firm-specific factors which determine efficiency differences directly, which is essential for forming an assess-

[2] Che, Kompas and Vousden (2001) extend the static model to the case of an intertemporal economy where incentive effects result in induced capital formation and both larger transitional growth rates and steady state values for rice output.

ment of the effects of government policy on rice production in Vietnam.[3] Section 6 concludes.

2. Background

2.1. Rice production in Vietnam

Rice is the most significant industry in Vietnamese agriculture. With market reform, the proportion of rice in foodstuff production, in terms of output (unhusked rice equivalent), has increased from 80.8 per cent in 1980 to 97.6 per cent in 1996 (SDAFF, 2001). Rice production also absorbs the greatest percentage of the labour force in rural areas, where about 70 per cent of workers in the Vietnamese economy live, and on average contributes 67 per cent of household income (WB, 1995). In addition, rice production is a crucial source of nutrition for the population. In Vietnam, starch-products make up 90 per cent of daily nourishment and of that rice supplies 83.1 per cent of the calorie intake in the rural regions and 77.6 per cent in urban areas (MAFI, 1987, SDP,1995a). Moreover, rice accounts for roughly 24 per cent of total export revenue (SDAFF, 2001).

Vietnam is naturally suited for rice production, especially for so-called wet rice production. Located in a tropical area with high humidity, the weather is especially amenable and the land is fertile. With this, Vietnam is also blessed with an advantageous water system, with an extensive network of rivers, favorable topography and rain fall patterns (WB, 1996a). Rice is planted in every province in Vietnam (with the exception of Ba Ria-Vung Tau, the so–called, Special Petroleum Processing Zone, which is excluded in this study). However, the most important rice areas are the Red River Delta (RRD) in the north and the Mekong River Delta (MRD) in the south. Together the two deltas account for 70 per cent of total rice output in Vietnam.

The MRD with an area of 3.9 million hectares has 2.1 million hectares used for rice production, with an agricultural population of 11.7 million (SDAFF, 2001). This rice area was formed by the alluvial soil raised by the Mekong and Bassac rivers. Flooding often threatens around 25 per cent of the sown area and induces poor crops (SDP, 1995a), but generally favorable conditions in the allow for a triple rice crop during the year; the Winter-Spring crop between March and May, the Summer-Autumn crop between August and September and the Winter crop from December to the following January.

The area of the RRD is 1.7 million hectares, providing 0.6 million hectares for rice production, with an agriculture population of 10.6 million (SDAFF, 2001). Flooding is also a problem, but as a whole the irrigation system is much better than that in the MRD and consequently maintains a stable water supply for at

[3] For a useful discussion of stochastic production frontiers and alternative techniques, see Kalirajan and Shand (1999). Useful alternatives to the standard approach include Huang and Liu's (1994) construction of 'non-neutral' stochastic frontiers and Tsionas's (2002) use of stochastic frontiers with random coefficients.

least 85 per cent of the total area. Overall, the conditions of the alluvial soil and the weather are less favorable than that in the MRD, with roughly 88 per cent of the total rice area cultivated providing double or triple harvests per year: mainly the Winter-Spring crop between May and June, and the Winter crop between November and December (SDP, 1995a).

In general, both rice output (figure 1) and net exports (figure 2) have increased dramatically in the 1990s, with annual growth rates in output alone of over 5.5 per cent throughout the period. Although there has been relatively little technological change in the way in rice is produced in Vietnam, and certainly nothing like the 'green revolution' that characterizes other transitional and developing countries, rice output and total factor productivity appears to have increased due to enhanced crop rotation and new and higher quality seeds. In addition, total irrigated area has increased from 1.2 million hectares in 1976 to 1.88 million hectares in 1994 (MRW, 1994), and the amount of fertilizer use in terms of nitrogen, phosphates and potassium (NPK) in 1994 was 3.5 times that of 1976 (GSO, 1995).

2.2. Market reform periods

The relevant transitional periods for rice production in Vietnam can be divided into the communal system (1975–80), used as a base comparison throughout, and two principal market reform periods designated by (a) output contracts (1981–87) and (b) trade liberalization (1988–94), followed by a post-reform period (1995-99). The overall process is characterized by a move from public ownership and central planning to a form of private property and more competitive markets, with enhanced incentives to produce more and more efficiently.

In broad terms, under the communal system, virtually all of rice production was located in compulsory agricultural collectives, with all farm activities, including the choice of inputs, designated by state-planning authorities. After harvest, a portion of output was extracted by the central government. The remainder was required by law to be sold entirely to the state at low state prices (roughly 20–30% of the estimated market price). Small private plots were allowed but only for the household consumption of subsidiary agricultural goods, and since individual effort was hard to accurately determine the distribution of rice within the commune was based on egalitarian criteria. As a apparent result of these controls the output of rice fell markedly and especially so over the period 1977–80, forcing Vietnam to import large amounts of rice, roughly 1.5 million tons or 13 percent of total food requirements per year (GSO, 1995 and SDP, 1995), to meet domestic demand.

The period of output contracts corresponds to a move to de-collectivize agriculture. Plots of land were allocated to prior members of the commune and farmers were allowed to organize production activities privately, in what effectively was a tentative first move towards private property rights. Although, for the most part, rice was still required to be sold in state markets at low state prices, private domestic markets (for some portion of output sold, roughly 20%) inevitably emerged and were condoned by state authorities. In fact, the period is generally characterized by a 'dual price' system (a low state price and a competitive market price), albeit with strict controls to prevent arbitrage opportunities between markets.

The period of trade liberalization established effective private property rights over both land (initially 10–15 year leases) and capital equipment, albeit with restrictions on farm size (along with initial allocations to prior commune members in non-contiguous blocks) and prohibitions against the removal of land from rice production. Production decisions were de-centralized, all farm income (after tax) was retained by the farmer and in 1990 the central government abolished the dual price system. Rice could now be sold on competitive domestic markets with an incentive structure that rewarded individual effort. In 1993 tenure arrangements over land were extended (to 20 year leases), although blocks were further redivided into smaller areas among family members, provisions for the exchanging of leases and the sale of land were introduced and farmers (through voluntary cooperatives) could now sell rice freely in international markets. In the post reform period (1995-99), all prior reforms in the period of trade liberalization where retained, if not further guaranteed, and a number of more minor restrictions on input markets (especially those for labour) where removed. Nevertheless, rural capital and land markets remain far less developed, with considerable difficulty in obtaining a loan and if granted a loan with a term longer than one year.

As a whole, the effects of market reform on rice production are striking, with the more pervasive the degree of liberalization the higher the rate of growth of rice output. Table 2 shows this clearly. Although rice output has increased steadily over the periods of market reform, the growth rate of rice output is significantly higher in the second stage of reform, or the period of trade liberalization. Labour inputs have increased slowly over time and sown areas of land have actually decreased. Material inputs (such as fertilizer), although clearly important have grown more slowly than output in each period, while investment has increased dramatically from 1988–94, continuing in the post reform period (1995-99), apparently accounting for much of the high rates of growth in output throughout the period. The last column of Table 1 shows the annual growth rates for total factor productivity (TFP), calculated in the usual way as Solow residuals. In all stages TFP exhibits positive growth, with little apparent technological change. It is the argument of this paper that TFP will partly depend on the extent of market reform and part of the exercise to follow involves a decomposition of TFP to capture this effect.

3. Data sources and variables

Two data sets are used in this paper. The first, used for estimating productivity change and the contribution of incentive effects to productivity growth, is aggregate time series data for the period 1976-99. The key variables are rice output, labour, land, material inputs (fertilizer, seeds, insecticide), capital (tractors and buffalo), rice output and input prices. The second data set used in the estimates of the stochastic production frontier (section 5) is a balanced panel data set, cross-sectional for 60 provinces in Vietnam, from 1991 to 1999, or 540 observations in total. Estimates of the share coefficients in the stochastic production function are also used to calibrate the 'institutional production function' and derive measures of total factor productivity with market reform in sections 4.4 and 4.5. Data sources and various adjustments are described in detail the appendix. A brief description of the main variables of interest is contained in table 3 with summary statistics listed in table 5.

A few additional remarks are in order. As mentioned, although rice is produced in every one of the 60 provinces in Vietnam, the Red River Delta (RRD) and the Mekong River Delta (MRD) are the main rice growing regions. The smallest producers of rice (less than 100,000 tons per year) are Binh Phuoc province, which is relatively small in area, and the principal coffee (Gialai Kontum) and mining (Cao Bang, Bac Kan). The largest rice output provinces (more than a million tones per year) are located in the MRD (Tien Giang, Soc Trang, Long An, Kien Giang, An Giang) which as a whole accounts for roughly half of Vietnam's output of rice, although only 27 per cent of the country's population. In terms of natural conditions, the MRD and the RRD are the most favorable for growing rice, with up to three rice crops per year. The average farm size in the RRD (0.5 hectare/farm) is smaller than the average farm size for the country (1.8 hectare/farm) and much smaller than in the MRD (3.8 hectare/farm). However, the number of threshing machines in the RRD is almost double that of the MRD. In the MRD, with a large volume of high-quality rice exports, rice processing takes place in mills rather than on the farm to maintain international standards.

4. Market reform and total factor productivity

4.1. The technical production function

The model of the effects of market reform on agricultural output is based on the approach used by McMillan, Whalley and Zhu (1989) to analyze Chinese agriculture, extended by Che, Kompas and Vousden (1999, 2001) to account for the nature of rice production and the various market reform measures introduced in Vietnam. Let ε_n represent the level of effort of a typical farmer so that for N workers $\varepsilon_n N$ is the effective contribution of labour to output measured in 'efficiency units'. As mentioned, the value of ε_n can be broadly interpreted to include everything that determines the quality of the farmer's labour as well as the willingness to literally exert more effort due to the enhanced incentives that accompany market reform and the removal of externally imposed restrictions on the kinds of tasks a farmer may undertake.

With security over land tenure and the freedom to manage farm production, the typical farmer may be expected to manage land-use in a way which increases the productivity of a given area. To capture this effect let L represent total sown area and let ε_l capture the effort associated with exploiting and managing the land. Optimal land use may involve effort directed towards increasing the number of crops sown in a given area or simply the planning involved in increasing the yield on a given amount of land. With reform, for example, it was common in Vietnam to initiate multiple cropping of rice and certainly so relative to production plans in the communal period. The total input of land measured in efficiency units is given by $\varepsilon_l L$.

Assume a 'technical' constant returns to scale production function[4]

$$Q = \alpha_0(\varepsilon_n N)^{\alpha_1}(\varepsilon_l L)^{\alpha_2} M^{\alpha_3} K^{\alpha_4} \tag{4.1}$$

where Q, L, M, and K represent output, land, material inputs (e.g., fertilizer and seeds) and physical capital or, in per capita terms,

$$q = \frac{Q}{N} = \alpha_0 \varepsilon_n^{\alpha_1} \varepsilon_l^{\alpha_2} l^{\alpha_2} m^{\alpha_3} k^{\alpha_4} \tag{4.2}$$

where q, l, m, k are output, land, material inputs, and capital per farmer.

4.2. The farmer's profit function

In principle, farmers may work in different institutional settings that vary from a communal system to various forms of share-contracting and private competitive markets. Let farm income received be given by

$$y = \beta p(q - d) \tag{4.3}$$

where p is the price of the agricultural good at which output is sold and d is a constant term that can be considered as the fixed rent or lump-sum tax the farmer has to deliver to the state for the right to use the property. Outside of pure communal arrangements, the value β is the fraction of the additional revenue generated that the farmer is allowed to keep, so that β can be considered as a share-cropping contract between the landlord (the State) and the farmer. For our purposes, the value βp also represents an average goods price including three components defined as

$$\beta p = (\beta_s p_s + \beta_m p_m + \beta_w p_w) \tag{4.4}$$

[4]This is consistent with the empirical literature on agricultural production functions for twenty-two developing countries (Hayami and Ruttan, 1985) and China (Tang, 1980). The specification is confirmed for panel data for Vietnam, 1990 to 1999, in section 5.2

where p_s, p_m and p_w are the state price, the market-clearing price and the export price respectively and β_s, β_m and β_w are the fractions or shares of agricultural output, that sum to one, allocated or delivered to the state, the domestic market or sold internationally. Different regimes imply different values for βp. Under the communal system, the farmer was required to sell the entire agricultural output to the State at a low state controlled price, implying that $\beta_s = 1$. In the output-contracts stage of reform, domestic markets existed but were still tightly controlled, with the farmer still required to sell the major share of output to the State at the low compulsory price, with the remainder to be sold on the domestic market at a higher domestic market price. No trade in international markets was allowed and arbitrage between state and domestic markets was rigorously enforced. With the period of trade liberalization, the state market was effectively abolished, controls were largely removed from the domestic market and international trade was permitted. Rice output was allocated between domestic and world markets at higher prices, with the differential between domestic market prices and the world export price p_w becoming increasingly smaller.[5]

Assume the farmer chooses inputs in order to minimize costs. With constant returns to scale, minimizing costs subject to equation (4.1) gives a total cost (TC) function

$$TC = c_0 \prod_i w_i^{\alpha_i} Q \tag{4.5}$$

where α_i are the share parameters in the technical production function, c_0 is a constant defined by

$$c_0 = \alpha_0^{-1} \alpha_1^{-\alpha_1} \alpha_2^{-\alpha_2} \alpha_3^{-\alpha_3} \alpha_4^{-\alpha_4} \tag{4.6}$$

and w_i are input prices indexed across effective labour, effective land, material inputs and capital. Define $W(\mathbf{w}) \equiv \prod_i w_i^{\alpha_i}$ as the average (real) factor price, so that the cost function per farmer (C) can be given as

$$C = c_0 W(\mathbf{w}) q. \tag{4.7}$$

During the process of market reform, factor markets in Vietnamese agriculture changed considerably in terms of both their structure and their speed of development. In the earlier stages, some types of inputs were 'free' (such as the labour of the farmer), or unpaid, receiving only implicit or in-kind payments. With market reform such payments became explicit and it is necessary to take into account any resulting increases in input costs. In addition, more importantly, in Vietnam, as is the case in many transitional economies, factor and product prices generally increase at different rates with market reform, with changes in factor prices lagging behind the increase in product prices. To capture these effects,

[5]Since Vietnam is a natural exporter of agricultural goods, its export price will exceed its domestic market price under autarky with free internal trade, which in turn will exceed its domestic price under tightly regulated domestic markets. All prices are higher than the state-controlled price.

define $\omega \equiv W(\mathbf{w})/\beta p$ as a weighted-cost share parameter or the ratio of observed average factor to product prices. The farmer's profit function (π) thus becomes

$$\pi = \beta p(q - d) - c_0 W(\mathbf{w})q = \beta p\left[q(1 - c_0\omega) - d\right] \tag{4.8}$$

using equations (4.3) and (4.7) and the definition of ω.

4.3. Optimal behavior and the institutional production function

Following McMillan, Whalley and Zhu (1989), assume the farmer receives utility from income but dislikes the effort of hard work and of planning for more efficient use of land, so that

$$U(\pi, \varepsilon_n, \varepsilon_l) = \pi - \frac{\varepsilon_n^z}{z\delta} - \frac{\varepsilon_l^z}{z\delta} \tag{4.9}$$

where $\delta > 0$ and $z > 1$ are constants, so that marginal disutility of effort increases with effort. The effort-disutility coefficient z is analogous to the coefficient of risk aversion and δ is chosen to guarantee that the utility function is jointly concave. It is assumed that z is that same across effort variables for labour and land, although this clearly could be generalized. Substituting from equations (4.2) and (4.8) gives

$$U(\pi, \varepsilon_n, \varepsilon_l) = \beta p\left[\alpha_0 \varepsilon_n^{\alpha_1} \varepsilon_l^{\alpha_2} l^{\alpha_2} m^{\alpha_3} k^{\alpha_4}(1 - c_0\omega) - d\right] - \frac{\varepsilon_n^z}{z\delta} - \frac{\varepsilon_l^z}{z\delta}. \tag{4.10}$$

Consider the farmer's optimal choice of effort levels. Maximizing (4.10) with respect to ε_n and ε_l implies that optimal values for labour and land effort must satisfy

$$\varepsilon_n^* = \left(\delta\beta p(1 - c_0\omega)\alpha_0 l^{\alpha_2} m^{\alpha_3} k^{\alpha_4} \alpha_1^{(z-\alpha_2)/z} \alpha_2^{\alpha_2/z}\right)^{1/\nu} \tag{4.11}$$

and

$$\varepsilon_l^* = \left(\delta\beta p(1 - c_0\omega)\alpha_0 l^{\alpha_2} m^{\alpha_3} k^{\alpha_4} \alpha_2^{(z-\alpha_1)/z} \alpha_1^{\alpha_1/z}\right)^{1/\nu} \tag{4.12}$$

for $\nu = (z - \alpha_1 - \alpha_2)$. Finally, substituting equations (4.11) and (4.12) into the per capita technical production function, or (4.2), and multiplying both sides by N, gives the following 'institutional' production function

$$Q = AN^{\gamma_1} L^{\gamma_2} M^{\gamma_3} K^{\gamma_4} \tag{4.13}$$

where the total factor productivity coefficient A is given by

$$A = \alpha_0^{z/\nu}[\delta\beta p(1 - c_0\omega)]^{(\alpha_1+\alpha_2)/\nu} \alpha_1^{\alpha_1/\nu} \alpha_2^{\alpha_2/\nu} \tag{4.14}$$

and share parameters are

$$\gamma_1 = (z\alpha_1 - \alpha_1 - \alpha_2)/\nu \qquad \gamma_2 = z\alpha_2/\nu \qquad \gamma_3 = z\alpha_3/\nu \tag{4.15}$$

and

$$\gamma_4 = z\alpha_4/\nu \tag{4.16}$$

for labour, land, material inputs and capital respectively.

The institutional production function captures the farmer's response to institutional arrangements and government policies, through changes in effective prices βp and the average ratio of input to product prices ω. It is equation (4.13) rather than (4.1) that would be estimated using observable input and output data. In this equation total factor productivity (A) and the optimal choice of effort depend both on the price level p, effective product prices βp and the ratio of average input to effective output prices ω, variables which clearly differ from one stage of market reform to the next.

4.4. Total factor productivity with market reform

This section uses the market reform augmented share parameters from the estimates of the institutional production function, the values of γ in equation (4.13), to derive estimates of total factor growth calculated as a Solow residual for each of the years 1981-99. Values for these share parameters are drawn from the estimate of the stochastic production frontier, which follows in section 5. The values for capital, labour, land and material inputs (table 7) are 0.17, 0.13, 0.24 and 0.51 respectively. The annual growth rate for total factor productivity (A) is calculated in the usual 'growth accounting' manner as the difference between the growth of output and the growth of each input weighted by share parameters. The resulting estimates of the year-by-year growth rates for A are then used to calculate an index for TFP using the average of the years 1976-80 in the communal period as the base. These figures are summarized in table 2. Average fitted annual growth rates are also given for the communal regime (1976-80) and for each of the two main reform stages, or output contracts (1981-87) and trade liberalization (1988-94), as well as the post-reform period (1995-99).

The effects of market reform are striking. In the communal period output and TFP increased by only 0.4 and 0.6 per cent per year. With the output contracts stage of reform and the period of trade liberalization, both output and TFP growth rates increased dramatically, with the more extensive the degree of market reform the larger the relevant growth rates. The growth of TFP is in the trade liberalization stage is almost double that of output contracts. These impressive continued throughout the post reform period, albeit with a slight fall in the growth of rice output to 5.72 per cent compared to 6.14 per cent under trade liberalization.

It is usual in studies of this kind to attempt to explain the sources of TFP growth. However, in the case of Vietnam this is difficult. In particular, there are no reliable figures for human capital, a potentially large factor in productivity improvement. However, we are able to directly estimate the incentive component of TFP and its relative contribution to growth since the beginning of the reform process. While this may be a poor substitute for direct observation of human capital accumulation and learning by doing, it does provide us with an estimable measure of productivity change that can be directly related to policy, or market reform, through changes in the 'institutional' parameters βp and $(1 - c_0\omega)$. Accordingly, we now consider the relative importance of these incentive effects in Vietnamese TFP growth for rice.

4.5. Contribution of Incentive Effects

In this section the institutional production function is used to decompose TFP (A), given equation (4.14), into two components; the first attributable to incentive effects as captured in the effort variables, or

$$A_1 = [\beta p(1 - c_0\omega)]^{(\alpha_1+\alpha_2)/\nu} \tag{4.17}$$

and the second

$$A_0 = \left(\delta^{\alpha_1+\alpha_2}\alpha_0^z\alpha_1^{\alpha_1}\alpha_2^{\alpha_2}\right)^{1/\nu} \tag{4.18}$$

as an 'unexplained residual' reflecting the influence of a host of other factors, where $A_1 \cdot A_0 = A$. While z, δ, α_1 and α_2 are all known (or can be calculated) and are assumed to be time invariant, α_0 will change over time. With the available data set, its time path cannot be estimated and thus we cannot directly estimate the time path of A_0. However, the time path of A has already been estimated as a Solow residual (section 4.4) and we have time series data for the 'institutional variables' βp and $c_0\omega$ so that a time path for the incentive component of TFP or A_1 can be estimated.

Given the relationship that exists between the share parameters in the technical and institutional production function, equations (4.15) and (4.16), it is straightforward to calculate the estimated values of α_i from the values of γ_i and the work-disutility coefficient z. Following McMillan, Whalley and Zhu (1989:793), the effort disutility coefficient can be derived directly from equation (4.14) with a knowledge of βp. To simplify, calculate z from the approximate growth rate of A in two contiguous years during the communal system and within a given reform period, where the average weighted-cost share parameter ω and β are roughly the same. Using values for βp and given the estimated value of the proportional growth in total factor productivity from section 4.4 , z can be shown to range from 2.8 to 3.2. A value of $z = 3$ is chosen for all calculations. The approximate values of the share parameters in the technical production function are thus $\alpha_1 = 0.38$, $\alpha_2 = 0.26$, $\alpha_3 = 0.3$ and $\alpha_4 = 0.10$ for labour, land, material inputs and capital respectively.[6] Figure 3 represents the values of βp and ω

[6] Given the relative importance of fertilizer in rice production, the share parameters for Vietnam do not differ much from the estimates for agricultural production obtained by Tang (1980) for China (0.50 for labour, 0.25 for land, 0.15 for material inputs and 0.10 for capital) and for twenty-two other developing countries (0.53, 0.10, 0.16 and 0.21, respectively) reported by Hayami and Ruttan (1985). The difference in the estimates for labour in Vietnam may be explained by the use of labour work days rather than (the unavailable) work hours.

(drawn from table 3) over the sample period, with increases in rice prices until 1996 (from initially low state prices) and a fall in the weighted ratio of input to output prices until 1992 (due principally to the fall in the price of fertilizer), afterwards rising throughout or until 1999.

Using all information, the resulting indexed series for A_1 (the communal period is set equal to 100) can be calculated, along with the proportion of TFP growth due to A_1. All measures are summarized in table 3, which also indicates the average annual growth rates for all relevant variables for the two market reform and the post-reform periods. The growth rates in output, inputs and TFP are also repeated from table 2, again showing that the more extensive is the degree of market reform the larger is the growth of both rice output and TFP. It is clear from the results that although the incentive component is quite strong in the period of trade liberalization (1988-94), this effect dissipates (and indeed shows negative growth) in the post-reform period. The reason is clear. A fall in the price of rice and increases in the ratio of input to output prices, or a fall in $(1-c_0\omega)$, results in a fall in effective per unit profits τ, which drives the incentive effect. Much of the increase in input prices is explained by an increase in the relative cost of hired, which doubled between 1980 and 1999, with much of the increase occurring in the late 1990's. Since 1994 the price of labour increased at a rate of 7.2 per cent per year. In addition, although the cost for fertilizer decreased from 1980 to 1994 at a rate of about 6 per cent per year, market pressures resulted in an increase from 1995 to 1999 at a rate of 12 per cent per year. The cost of capital per a unit of output has also increased by 3.7 per cent per year since 1995 (estimated from Rice Farm Surveys (1994), the State Department of Prices (1995, 2001) and Nguyen T. Hien (1991).

The relationship between the incentive component of TFP and total TFP is illustrated for Vietnam in figure 4 which graphs the time paths of the indices of A (TFP) and A_1,the incentive component. The diagram does not intended to show any absolute relationship between A and A_1 because both indices are set equal to 100 in the initial period (the communal regime). Rather, the graphs illustrate the cumulative growth of the incentive component relative to the cumulative growth of TFP. The bold vertical lines in the figure indicate the switch from the output-contracts to the trade liberalization regime in 1987 and from trade liberalization to the post reform period in 1995. The transition to a more extensive market reform regime is thus seen to result in a rapid increase in both TFP and the incentive component of TFP. Moreover, after 1987, cumulative growth due to the incentive effect rises steadily from just over one-third of cumulative TFP growth in 1987 to three-fifths of cumulative TFP growth in 1994. However, after 1995, the incentive component begins to diminish rapidly, although the index for TFP continues to increase throughout (perhaps due to increases in irrigation and better rice seeds). Given the decrease the incentive effect, it is natural to ask what other policy measures would be appropriate to increase productivity and efficiency. We now turn to this issue.

5. Stochastic production frontier and efficiency

5.1. Stochastic frontiers and inefficiency

Stochastic production frontiers were first developed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977). The specification allows for a non-negative random component in the error term to generate a measure of technical inefficiency, or the ratio of actual to expected maximum output, given inputs and the existing technology. The idea can be readily applied to panel data, following Battese and Coelli (1995). Indexing firms by $i = 1, 2, ..., n$, the stochastic output frontier is given by

$$Y_{it} = f(X_{it}, \beta)e^{v_{it}-u_{it}} \tag{5.1}$$

for time $t = 1, 2, ..., T$, Y_{it} output, X_{it} a $(1 \times k)$ vector of inputs and β a $(k \times 1)$ vector of parameters to be estimated. As usual, the error term v_{it} is assumed to be independently and identically distributed as $N(0, \sigma_v^2)$ and captures random variation in output due to factors beyond the control of firms. The error term u_{it} captures firm-specific technical inefficiency in production, specified by

$$u_{it} = z_{it}\delta + w_{it} \tag{5.2}$$

for z_{it} a $(1 \times m)$ vector of explanatory variables, δ a $(m \times 1)$ vector of unknown coefficients and w_{it} a random variable such that u_{it} is obtained by a non-negative truncation of $N(z_{it}\delta, \sigma_u^2)$. Input variables may be included in both equations (5.1) and (5.2) as long as technical inefficiency effects are stochastic (see Battese and Coelli, 1995).

The condition that $u_{it} \geqq 0$ in equation (5.1) guarantees that all observations lie on or beneath the stochastic production frontier. A trend can also be included in equations (5.1) and (5.2) to capture time-variant effects. Following Battese and Corra (1977) and Battese and Coelli (1993), variance terms are parameterized by replacing σ_v^2 and σ_u^2 with $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$. The technical efficiency of the i-th firm in the t-th period for the basic case can be defined as

$$TE_{it} = \frac{E(Y_{it} \mid u_{it}, X_{it})}{E(Y_{it} \mid u_{it} = 0, X_{it})} = e^{-u_{it}} = \exp(-z_{it}\delta - w_{it}) \tag{5.3}$$

and clearly must have a value between zero and one. The measure of technical efficiency is thus based on the conditional expectation given by equation (5.3), given the values of $v_{it} - u_{it}$ evaluated at the maximum likelihood estimates of the parameters in the model, where the expected maximum value of Y_{it} is conditional on $u_{it} = 0$ (see Battese and Coelli, 1988). Efficiency can be calculated for each individual firm per year by

$$E[\exp(u_i) \mid v_i + u_i] = \frac{1 - \Phi(\alpha_a + \gamma(v_i + u_i)/\sigma_a}{1 - \Phi(\gamma(v_i + u_i)/\sigma_a)} \exp\left[\gamma(v_i + u_i) + \sigma_a^2/2\right] \tag{5.4}$$

for $\sigma_a = \sqrt{\gamma(1-\gamma)\sigma^2}$ and $\Phi(\cdot)$ the density function of a standard normal random variable (Battese and Coelli, 1988). The value of $\gamma = 0$ when there are no deviations in output due to inefficiency and $\gamma = 1$ implies that no deviations in output result from stochastic random effects with variance

5.2. Econometric specification

Generalized likelihood ratio tests are used to help confirm the functional form and specification. As a pre-test, the null hypothesis of a Cobb-Douglas form of the production function was tested against a general translog specification by setting the relevant parameters for squared and interaction terms in the translog form equal to zero. The resulting test statistic was $\chi^2_{10} = 9.4$ compared to a critical value of 19.7. A Cobb-Douglas functional form was thus selected. Accordingly, equation (5.1) for unbalanced panel data set (1990–1999) is specified by a production function in log-linear Cobb-Douglas form, or

$$\ln Y_{it} = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln LAB_{it} + \beta_3 \ln LAN_{it} + \beta_4 \ln IN + \beta_6 T + v_{it} - u_{it} \quad (5.5)$$

where Y_{it} is the output of rice, K is the stock of capital (tractors and buffalo), LAB is labour in working days, IN is material inputs and T is a time trend.

The provincial 'farm-specific' factors used in the technical inefficiency model, or equation (5.2), are average farm size ($SIZE$), the percentage of paddy in which tractors are used (TL), a binary variable indicating soil conditions ($SOIL$), 1 for the main rice growing regions, or the MRD and the RRD, the number of threshing machines (MA) and the number of tractors (CA), so that

$$u_{it} = \delta_0 + \delta_1 \ln SIZE_{it} + \delta_2 \ln TL_{it} + \delta_3 SOIL_{it} + \delta_4 \ln MA_{it} + \delta_5 \ln CA_{it} + \omega_{it} \quad (5.6)$$

for $\omega_{it} \sim N(0, \sigma^2_\omega)$. As mentioned, specific input variables can be included in equation (5.6) as along as technical inefficiency effects are stochastic and input variables in the production function are exogenous to the composite error term (Battese and Coelli, 1995).[7]

Additional likelihood ratio (LR) tests are summarized in Table 6. Correct critical values from a mixed χ-squared distribution (at the 5% level of significance) are drawn from Kodde and Palm (1986). The relevant test statistic is

$$LR = -2\{\ln[L(H_0)/L(H_1)]\} = -2\{\ln[L(H_0)] - \ln[L(H_1)]\} \quad (5.7)$$

where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the null and alternative hypotheses respectively. The null hypothesis of a deterministic time trend in equation (5.6) is rejected. The null hypothesis that technical inefficiency effects are absent ($\gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$) and that farm-specific

[7] See Forsund, Lovell and Schmidt (1980) for a general discussion of the use of input variables in a technical inefficiency model.

effects do not influence technical inefficiencies ($\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$) in equation (5.6) are both rejected, as is $\delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$. Finally, the null hypothesis that $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2) = 0$, or that inefficiency effects are not stochastic, is rejected. All results indicate the stochastic effects and technical inefficiency matter and thus that traditional OLS estimates are not appropriate in this study. Additional LR tests reject non-constant returns to scale.

5.3. Results

Table 7 summarizes the results for the stochastic production frontier and inefficiency models. The coefficients on capital, labour, land and material inputs are 0.17, 0.13, 0.24 and 0.51 respectively. A time trend also tests as significant at 1.1 per cent per year.[8] Results show that farms in the main rice growing regions, those with larger farm size, those that use more threshing machines, and farms with a higher proportion of rice land ploughed by tractor are more efficient. The size of the binary variable $SOIL$ is perhaps the least surprising. Superior conditions for growing rice in the MRD and RRD, compared especially to the highlands in the north, are clearly reflected in provincial-wide measures of efficiency throughout the sample period (table 8). The MRD in particular consistently ranks best in efficiency, year-to-year. Figure 5 compares average technical efficiency between the MRD and RRD (the principal rice areas) and Vietnam as a whole. The measures for the MRD and RRD are 11 to 13 per cent higher throughout than the average for Vietnam as a whole. The policy requirement that rice be produced in every province of Vietnam thus appears inappropriate, at least in terms of the potential loss in efficiency that results from producing rice outside of the Mekong and Red River Deltas.[9]

The coefficient for the proportion of rice land ploughed by tractor (TL) is also substantial at -0.35, and remains large even when testing with MRD and RRD taken separately. An increase in number of tractors in rice fields clearly increases efficiency. The are two policy concerns here. First, and most importantly, the absence of an credit market undoubtedly limits the amount of tractors in rice production. Transactions costs on loans in rural areas are prohibitive and when granted are often for terms of only one year or less. Indeed, much of the otherwise rapid increase in capital in the reform periods and after (table 2), is due to accumulation from retained earnings, and not from borrowing (Che, Kompas and Vousden, 2001). Second, land policy itself often makes it difficult to employ tractors in rice fields. Plots are often small and butt directly to adjoining plots (separated only by a mound of dirt) and restrictions against farm size and con-

[8] By comparison, a more standard panel data set regression (with random effects) contained in Kompas and Che (2001) for the period 1991 to 1994 gives share parameters for capital, labour, land and material inputs is 0.12, 0.17, 0.27 and 0.47 respectively. The sharp increase in the number of tractors since 1995 (SDAFF, 2001) may partly explain the difference in estimates.

[9] For an analytical discussion for land policy and land policy reform in Vietnam, see Che (1997), Duncan (1998) and Marsh and MacAulay (2002).

tiguous plots (especially in the north), often make the use of tractors impractical, or at least not without a good deal of cooperation among farmers.

The coefficient of average farm size is smaller than may be expected, but still indicates that government restrictions on farm size limit efficiency. However, this value rises considerably when estimating over the RRD and MRD (regions of comparable fertility) taken separately. In a data set that includes only the RRD the coefficient on average farm size in the technical inefficiency model is -2.7, while in the MRD it is -0.1, both significant at the one percent level. This makes good sense. In the RRD, where restrictions on farm size are more severe and more broadly enforced, average farm size is small at 0.5 hectare per farm, compared to 3.8 hectares per farm in the MRD, so that efficiency gains are far from exhausted. The reason for smaller farm size in the RRD is usually attributed to a high population density in rural areas in the north combined with a policy that allocated equal (and non-contiguous) plots of land to all commune members with reform, as well as the explicit legal and moral restrictions against 'excessive land accumulation'. Moreover, although land can be leased in the north for up to 20 years there still is no well-developed market for the exchange of land or leases. To a lesser extent this also applies to the south as well. Thus, smaller farm size, the consequent smaller proportion of tractors used in rice fields, more restrictive land regulations and the slightly worse natural soil conditions in the RRD explain the lower levels of efficiency compared to the MRD.

The coefficient on threshing machines is also relatively small, but it should be noted that the MRD has about a third of the threshing machines of the RRD. In the MRD, where a large proportion of rice is destined for export, quality standards require that rice be sent directly to the mills for processing. The coefficient on the number of tractors, as opposed to the proportion of rice land ploughed by tractors, is positive for the simple reason that in most rural areas (other than the MRD and RRD) tractors are used for general transportation and for other industrial crops or small-scale industry. When testing for the MRD and RRD alone, where tractors are mostly dedicated for rice production, the coefficient tests at -0.18, as expected.

Finally, although average technical efficiency is low for Vietnam as a whole (59.2 percent) it is clear that efficiency for rice farms in Vietnam and in the principal rice growing provinces (MRD and RRD) has been rising over time, albeit slowly, from roughly 55 to 65 per cent in Vietnam as a whole and 66 to 78 per cent for the principal rice growing areas (figure 5). The gradual increase in the amount of capital (tractors and buffalo) is undoubtedly the key explanation for this trend. The only exception is the year 1994 where all areas experienced a fall in efficiency and especially so in the MRD and RRD. The reason for this fall appears to be largely due to Resolution 5 (Nguyen Sinh, 1995), outlined first in 1993, which further redivided farm size into smaller and non-contiguous plots, allocated now across prior family farm members. Previous technical efficiency measures were not recovered until three of four years later, or 1997 for Vietnam as a whole and 1998 for the principal rice growing areas.

6. Concluding remarks

This paper has focused on the effects of the reforms which have occurred in Vietnamese rice production since 1980. A simple model is used to consider optimizing behavior by farmers based on an 'institutional' production function, which reflects not only the usual technical relationship between inputs and outputs, but also effort responses to the institutional and market arrangements within which farmers work. Assuming farmers choose their effort levels optimally, it is possible to estimate these 'incentive effects' at each stage of reform and compare them with the overall change in total factor productivity. Results show that this incentive component represents a higher proportion of post-1980 total factor productivity growth for the later trade liberalization stage of reform than for the earlier, more reform-limited output contracts stage. We also observe an earlier response of productivity to reform in the south than in the north, conceivably because of the more recent experience of market institutions in the south. The overall results confirm that the more extensive is market reform the larger the increase in TFP and the share of TFP growth due to incentive effects, suggesting that more competitive markets and secure property rights matter greatly. Nevertheless, in the post reform period (1995-99), the incentive effect dissipates as the world price of rice falls and the prices of inputs finally begin to rise. Stochastic frontier estimates indicate that efficiency can be enhanced through appropriate additional reforms, especially with respect to land and capital markets. In particular, the requirement that rice be grown in every province in Vietnam, restrictions on farm size (especially in the north) and the slow development of rural credit markets for capital and land are seen to restrict the level and growth of efficiency substantially.

APPENDIX: Data Sources and Adjustments

Original data sources are drawn mainly from the General Statistics Office of Vietnam (GSO) and the SDAFF (Statistics Department of Agriculture, Forestry and Fisheries) 2001, and related project investigations, studies and reports by Vietnamese organizations, such as the State Planning Committee (SPC), the Ministry of Agriculture and Food Processing Industry (MAFI), the Ministry of Water Resources (MWR), the State Department of Price (SDP), and international organizations including the World Bank (WB) and the Food and Agriculture Organization (FAO).

The balanced panel data set used for estimation of the stochastic production frontier for rice is cross-sectional for 60 provinces over the years 1991 to 1999 and is obtained from the National Investigation of Rural Regions (SDAFF, 2001 and GSO, 1995b). A rice equivalent for output is chosen rather than rice output alone since in the same rice fields farmers usually overlap production with other short-term cereal crops, such as sweet potatoes and maize. Time series data for rice output is from SDAFF (1991) and MAFI (1991) for the period 1976-90, from SDAFF (1995a) for 1990-93, GSO (1995) for 1994 and the SDAFF (2001) for 1995 to 1999. All measures were verified by alternative data sets contained in the SDAFF (2001) for the years 1975-1999. A rice equivalent output is chosen rather than rice output alone, because in the same rice fields farmers usually overlap production with other short-term cereal crops, such as sweet potatoes and maize. Since there is clear (nutritional) substitution between rice and these grains (SDP, 1995a), the State's target usually emphasizes output in terms of a rice equivalent rather than rice only.

Labor is measured as person-days and is obtained by multiplying average person-days per hectare in agriculture (SRF, various issues) by the rice cultivated area (SDAFF (1991, 1994, 1995b), MAFI (1991), GSO (1995), SDAFF (2001). Average working day per hectare for rice production is 245.4 for the north and 161.5 for the south respectively (SDAFF, 2001, SDP, 2002, SRF, 1995).

The land input is measured as the sown area of rice, with data provided by (SDAFF, 2001). The Vietnamese government divides the soil quality of land into seven levels and levies land tax depending on quality (UNDP-FAO, 1989). An investigation by the World Bank (WB, 1994b) distinguished the quality of soil into five grades in terms of cultivated area. Sold conditions and irrigation is more advanced in the Red River Delta than in the Mekong River Delta (MWR, 1994 and WB, 1995). According to the World Bank (1995), the difference in output between zero and 100 percent irrigation on a farm amounts to 645 kg/hectare of rice, everything else equal. Capital inputs are obtained as a weighted sum of draught animals (SDAFF (1992, 1995a), MAFI (1991) and GSO (1995)) and tractors (SDAFF, 2001). The conversion from the number of draught animals to tractor capacity is based on (Blomqvist, 1986) and assumes that a bullock-day (a pair of bullock working 8 hours) is approximately the same as a tractor-hour at 15 to 25 horsepower. Total capital input for rice production is then derived as the total capital input for cultivation multiplied by the proportional share of rice cultivated area to the total cultivated area of agriculture.

Material inputs include the nutrition content of all fertilizers (organic and chemical), insecticides and seeds (Tang, 1980, Sicular, 1988). The conversion factor used to aggregate organic and chemical fertilizers is similar to that used by Tang (1980:61). Following Tang (1980, p.61) and Sicular (1985), total material input variable is constructed by a measuring the nutrition content of all fertilizer (organic and chemical), insecticide, and seeds that are used for rice production. The total nutrition content of all fertilizer is determined from the nutritional content of organic and chemical fertilizer separately. Here, the amount of organic fertilizer for the rice industry is derived from the total amount of organic fertilizer used for agriculture. Organic fertilizer for agriculture is assumed to be supplied from two main sources: night soil and large animal manure (buffaloes, cattle and pigs). The population-adjusted night-soil equals the rural population (GSO, 2000) multiplied by a rural utilization rate (0.9). The standard number of large animals equals the sum of buffaloes, cattle and pigs (GSO, 2000), for which the weighted ratios are 1, 1 and 0.33 respectively. Organic fertilizer for rice production is obtained by multiplying the amount of organic fertilizer for agriculture with the weighted ratio between food grain area sown to the total sown area for cultivation. The chemical fertilizer data used for rice production is derived directly from the multiplication of the average amounts of chemical fertilizer used (1992) in the north 165.4 kg/ha and the south 193 kg/ha (the Survey of Rice Farmers, SRF) and the rice area in every province (SDAFF, 2001). The data set for insecticides is constructed by multiplying the average use of insecticide per hectare in the year 1992, or 5.8 kg and 7.6 kg in the north and south, respectively, (SRF, 1993) and total rice area (SDAFF, 2001). The data for seeds are calculated from the average use of seeds per hectare in 1992, or 140 kg/ha and 240 kg/ha in the north and south respectively (SRF, 1995) multiplied by the total rice area (GSO, 1995). The time series for chemical fertilizers is calculated from the average amounts of chemical fertilizer used per hectare multiplied by cultivated area in each year (SDAFF, 2001). The series data for insecticides and seeds are calculated from the average use of insecticide and seeds per hectare (SDAFF, 1996) multiplied by rice area for each year.

The value of β, equation (4.4), in the output contracts stage of reform is set at a market share of 0.8, 0.2 and zero for the state, domestic and international market. This is average data computed from the GSO, 1994 years) in which the market share is 0.88, 0.12 (in 1985), 0.82, 0.18 (in 1986) and 0.82, 0.18 (in 1987) for state and domestic markets for grains. Research by the State Planning Committee in 1995 also used the rate 0.8, 0.2 to adjust the multiple prices for grain at this time. In the stage of trade liberalization, the share of output sold to the state was clearly zero, with the share between domestic and international markets was obtained from average GSO data from 1988-94.

Time series data for nominal rice prices for 1976-94 was obtained from the

State Department of Price (SDP, 1996). These prices are multiplied by the appropriate values of β as in equation (3.4) to obtain an average nominal rice price. To convert this to an average real price, it would normally be usual to deflate by the consumer price index. However, in the case of Vietnam, such price indices are highly volatile and unreliable due largely to poor and erratic construction methods. Under the circumstances, a more reliable measure of the underlying rate of inflation is the Dong/U.S. dollar exchange rate which is used here as the deflator for βp. This is in line with the high correlation between the Vietnamese inflation rate and the ratio Dong/$US noted by the World Bank (1994:67-68) and is a measure commonly used by the Vietnamese (especially so during periods of high inflation). Following the practice of the State Department of Price (SDP), the nominal rice price in Nam Dinh and Can Tho is taken to represent the rice price in the north and south respectively. The price of rice from 1995 to 1999 is from the SDAFF, 2001.

The number of tractors, average farm size the proportion of land ploughed by tractor for rice and the number of threshing machines are obtained from SDAFF, 2001. Input prices used to construct the weighted-cost share parameter ω, are measured in rice units or, for example, how many tons of rice farmers have to pay to get one ton of urea, to employ one thousand labour work-days, or to rent one hectare of land. Many official data sources for input expenditures are already measured in terms of rice units as a matter of practice. The time-series data for the relative price of urea to rice are drawn from the Central Price Committee (CPC), as reported in Nguyen Hien (1991) and Nguyen Khiem (1995).

REFERENCES

Aigner, D. J., C. A. K. Lovell and P. Schmidt, 1977, "Formation and estimation of stochastic frontier production function models," *Journal of Econometrics*, 6, 21–37.

Battese, G. E. and T. J. Coelli, 1988, "Prediction of firm-level technical efficiencies with a generalized frontier production function and panel data," *Journal of Econometrics*, 38, 387–399.

Battese, G. E. and T. J. Coelli, 1992, "Frontier production functions, technical efficiency and panel data: with applications to paddy farmers in India," *Journal of Productivity Analysis*, 3, 153–169.

Battese, G. E. and T. J. Coelli, 1993, "A stochastic frontier production function incorporating a model for technical inefficiency effects," Working Papers in Econometrics and Applied Statistics, No. 69, Department of Econometrics, University of New England, Armidale.

Battese, G. E. and T. J. Coelli, 1995, "A model of technical inefficiency effects in a stochastic frontier production function for panel data," *Empirical Economics*, 20, 325–332.

Battese, G. E. and G. S. Corra, 1977, "Estimation of a production frontier model: with application to the pastoral zone of Eastern Australia," *Australian Journal of Agricultural Economics*, 21, 169–179.

Blomqvist, Ake, 1986, "The village and beyond: market and public policy (1)," in Scarp Marden Evaluation Baseline Study, edited by J. Freedman, Ottawa: Canadian International Development Agency.

Che T. Nhu, 1997, *The Effects of Internal and External Trade Liberalization on Agricultural Growth: A Case Study of Vietnam*, unpublished Ph.D. dissertation, Australian National University. Canberra.

Che, T. Nhu, T. Kompas and N. Vousden, 1999, "Market reform and Vietnamese agriculture," in Suiwah Leung, ed., *Vietnam and the East Asian Crisis*, Edward Elgar, UK.

Che, T. Nhu, T. Kompas and N. Vousden, 2001, "Incentives and static and dynamic gains from market reform: rice production in Vietnam," *Australian Journal of Agricultural and Resource Economics*, 45, 547-572.

Che, T. Nhu, T. Kompas and N. Vousden, 2001, "Market reform and incentives in Vietnamese rice production," working paper, National Centre for Development Studies, Australian National University, Canberra.

Chu V. Lam, Nguyen T. Nguyen, Phung H. Phu, Tran Q. Toan and Dang T. Xuong., 1992, "Hop tac hoa nong nghiep Viet nam, lich su-van de-trien vong," (Agricultural cooperatives in Vietnam: history, problems, prospective), Su That Publishing House, Hanoi.

Coelli, T. and G. E. Battese, 1996, "Identification of factors that influence the technical inefficiency of Indian farmers," *Australian Journal of Agricultural Economics*, 40, 19–44.

Coelli, T., D. S. Prasada Rao and G. E. Battese, 1998, *An Introduction to*

Efficiency and Productivity Analysis, Boston: Kluwer.

Congress of Vietnam, 1988, "Luat Ve Su Dung Dat," (Land Law), pamphlet, Hanoi.

Congress of Vietnam, 1993, "Luat Ve Su Dung Dat," (Land Law), pamphlet, Hanoi.

CPP (Communist Party Politburo), April 5, 1988, order no. 10, "Reform of economic management in agriculture," Cong Bao, Hanoi.

CPS (Communist Party Secretariat), 1981, order no. 100, "Reform of contract work: expanding the use of output contracts with group and individual workers in agricultural cooperatives," Cong Bao, Hanoi.

Dang D. Trung, 2002, "Coffee and subsistence production: complementary or competition? A case study from an Ede (Rhade) village in Vietnam," Paper presented in the 46th Annual Conference of the Australian Agricultural and Resource Economics Society, Canberra.

Duncan, R., 1998, *Vietnam: Advancing Rural Developement, From Vision to Action*, A report for the Consultative Group for Vietnam, Hanoi.

FAO (Food and Agriculture Organisation), 1999, Yearbook, Fertilizer, 49, Rome.

Farrell, M. J., 1957, "The measurement of productive efficiency," *Journal of the Royal Statistical Society, series A*, CXX, 253–290.

Forsund, F. F., C. A. K. Lovell and P. Schmidt, 1980, "A survey of frontier production functions and of their relationship to efficiency measures," *Journal of Econometrics*, 13, 5–25.

Green, W. H., 1993, "The econometric approach to efficiency analysis," in H. O. Fried, C. A. K. Lovell and S. S. Schmidt, eds., *The Measurement of Productive Efficiency: Techniques and Applications*, New York: Oxford University Press, 68–119.

GSO (General Statistics Office), 1995, *Statistical Yearbook 1975-94*, Statistical Publishing House, Hanoi.

Hayami, Y. and V. W. Ruttan, 1985, *Agriculture Development: An International Perspective*, Baltimore: Johns Hopkins University Press.

Huang, C. J. and J. Liu, 1994, "Estimation of a non-neutral stochastic frontier production function," *Journal of Productivity Analysis*, 5, 171–180.

Kalirajan, K. P. and R. T. Shand, 1999, "Frontier production functions and technical efficiency measures," *Journal of Economic Surveys*, 13, 149-72.

Kodde, D. A. and F. C. Palm, 1986, "Wald criteria for jointly testing equality and inequality restrictions," *Econometrica*, 54, 1986: 1243–1248.

Kong, X., R. E. Marks and G. H. Wan, 1999, "Technical efficiency, technological change and total factor productivity growth in Chinese state-owned enterprises in the early 1990s," *Asian Economic Journal*, 13, 267–281.

MAFI (Ministry of Agriculture and Food Processing Industry), 1975-94, "Bao cao hang nam," Annual Reports, unpublished, Hanoi.

MAFI, 1991, “A report on mechanization in agriculture 1986-90, and the strategy for the next five years,” unpublished, Hanoi.”

MAFI, 1993, “Tap hop cac bao cao ve dam bao luong thuc,” (Workshop on the guarantee of foodstuff), unpublished, February, 1993.

Marsh, S. P. and T. Gordon MacAulay, 2002, “Land reform and the development of comeercial agriculture in Vietnam: ploicy and issues,” *Australian Agribusiness Review*, 10, 1-19.

McMillan, J., J. Whalley and L. Zhu, 1989, “The Impact of China’s Economic Reforms on Agricultural Productivity Growth,” *Journal of Political Economy,* 781-807.

Meeusen, W. and J. van den Broeck, 1977, “Efficiency estimation from Cobb-Douglas production functions with composed error”, *International Economic Review*, 18, 435–444.

MWR (Ministry of Water Resource), GSO, 1994, “So lieu thong ke thuy loi Vietnam,” (Statistical data, water sources sector of Vietnam 1986-90), Gioi Publishing House, Hanoi.

MWR, various years, “Bao cao hang nam,” Annual Reports, unpublished, Hanoi.

Nguyen, S. Cuc, 1995, *Agriculture of Vietnam, 1945-1995, (Nong Nghiep Viet Nam)*, Statistical Publishing House, Hanoi.

Nguyen T. Hien, 1991, “Chinh sach gia vat tu nong san nong nghiep Vietnam,” (The policy of Vietnam on the price of materials in agriculture), paper presented at the workshop, “The policies on development of agriculture of Vietnam by the State Planning Committee (SPC) and the Food and Agricultural Organisation (FAO) in Hanoi,” August, 1991, unpublished, Hanoi.

Nguyen T Khiem, 1995. “Vietnam: agricultural policy reforms and microeconomic environment,” paper presented at the “Vietnam Update”, Canberra, November, unpuplished, Canberra.

Pandey, S., Nguyen T. Khiem, Tran C. Thien, 2002, “Market access, food security and upland rice: some micro-economic evidences from the northern mountains regions of Vietnam,” paper presented at the 46th Annual Conference of the Australian Agricultural and Resource Economics Society, Canberra.

Rice Trader, 1991-94, “Bao cao hang nam,” Annual Reports, unpublished, Hanoi.

Schmidt, P. and C. A. Knox Lovell, 1979, “Estimating technical and allocative inefficiency relative to stochastic production and cost frontiers,” *Journal of Econometrics*, 9, 343–366.

SDAFF (Statistics Department of Agriculture, Forestry and Fishery, GSO), 2001, “Statistical data of Vietnam: agriculture, forestry and fishery 1975-2000,” Statistical Publishing House, Hanoi.

SDAFF, 1991, “Statistical data of agriculture, forestry and fishery in Vietnam for 35 years: 1956-90,” joint documentation by SDAFF (GSO) and the Institute of Planning and Construction for Agriculture, Hanoi.

SDAFF, 1992, "Statistical data of Vietnam: agriculture, forestry and fishery 1976-1991, the pivotal areas of commodity production," Statistical Publishing House, Hanoi.

SDAFF, 1996, "Data collection on the situation of the rice industry," unpublished, Hanoi.

SDAFF, 2001, "Statistical data of Vietnam: agriculture, forestry and fishery 1975-2000," Statistical Publishing House, Hanoi.

SDP (State Department of Price), 2001, "Competition and competitive power for the Vietnamese rice industry," project paper presented by Vu Xuan Dao, Research Institute of Market and Prices, unpublished, Hanoi.

SDP, Project 93-98-120/DT (Part One), 1995, "Research project on market and price for rice production in the market economy of Vietnam," unpublished, Hanoi.

Sicular, T., 1985, "China's grain and meat economy: recent development and implications for trade," *American Journal of Agricultural Economics*, 67.

SPC (State Planning Committee), 1995, "Principles of changing agricultural structures in Vietnam rural areas," unpublished, Hanoi.

SRF (Survey of Rice Farmers), various years, unpublished.

Tang, Anthony M., 1980, "Food and agriculture in China: trends and projections, 1952-77 and 2000," in *Food Production in the People's Republic of China*, Anthony M. Tang and Bruce Stone, research report, no.15, International Food Policy Research. Institute, Washington.

Tsionas, E. G., 2002, "Stochastic frontier models with random coefficients," *Journal of Applied Econometrics*, 17, 127-47.

WB (World Bank), 1994, *Vietnam: Toward the Market Oriented Economy*, The National Political Publishing House, Hanoi.

Table 1: Main statistics for Vietnamese rice production, 1976 to 1999

Year	Output *('000 tons)*	Sown land *('000 ha)*	Yield *(tons/ha)*	Net Exports *('000 tons)*
1976	11,827.2	4,710.0	1.8	-728.2
1977	10,597.1	4,710.0	1.6	-1,258.8
1978	9,789.9	4,664.0	1.5	-172.4
1979	11,362.9	4,618.0	1.7	-1,400.2
1980	11,647.4	4,572.0	1.8	-959.2
1981	12,415.2	4,526.0	1.9	-571.0
1982	14,390.2	4,481.0	2.3	-318.2
1983	14,743.3	4,435.0	2.3	0.2
1984	15,505.6	4,389.0	2.5	-276.0
1985	15,801.1	4,297.0	2.6	-387.8
1986	15,937.6	4,250.0	2.7	-416.3
1987	15,043.4	4,243.0	2.6	-375.2
1988	16,938.1	4,109.0	2.8	-365.8
1989	18,933.7	4,108.0	3.1	1,227.6
1990	19,167.2	4,108.0	3.0	1,453.7
1991	19,563.7	4,101.0	3.0	774.0
1992	21,536.9	4,100.0	3.2	1,664.0
1993	22,783.1	4,039.0	3.3	1,456.6
1994	23,474.2	4,039.0	3.3	1,684.0
1995	24,903.6	4,203.5	3.5	1,988.0
1996	26,332.7	4,387.6	3.6	3,003.0
1997	27,467.3	4,199.5	3.7	3,575.0
1998	29,075.3	4,213.4	3.7	3,730.0
1999	31,315.1	4,213.4	3.9	4,508.0

Sources*: The Statistics Department of Agriculture, Forestry and Fishery, General Statistics Office of Vietnam (SDAFF), 2001*

Table 2: Rice production in Vietnam, annual growth rates (%), 1976 to 1999

Period	Output	Labor	Land	Material inputs	Capital	TFP
1976-80	0.40	0.41	-0.80	-1.10	2.20	0.60
1981-87	4.56	0.33	-1.30	3.21	2.23	2.74
1988-94	6.14	1.98	-0.52	2.78	7.54	4.43
1995-99	5.72	2.32	0.50	1.08	9.88	4.46

Figure 1: Rice production in Vietnam ('000 tons), 1976 to 1999

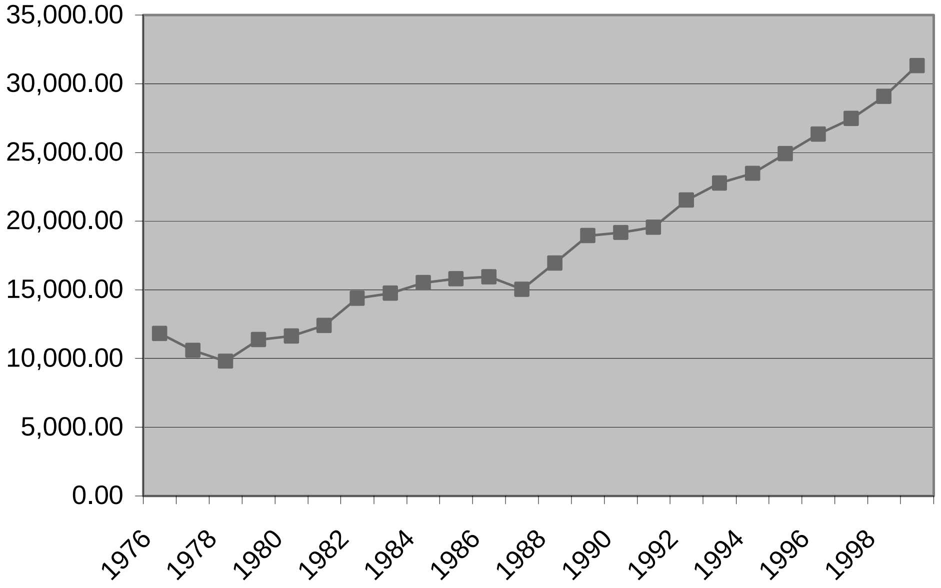


Figure 2: Net Exports of Rice in Vietnam ('000 tones), 1976 to 1999

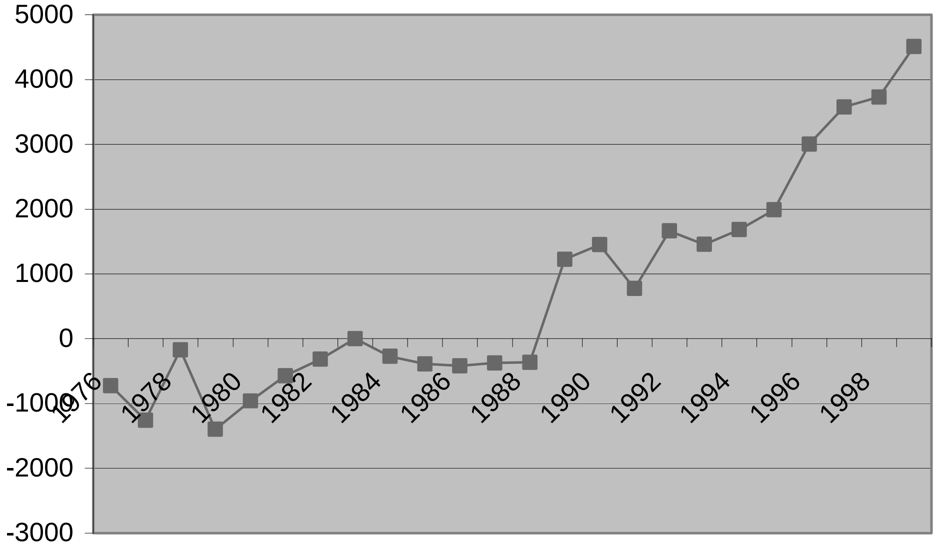


Table 3: Description of output and input variables

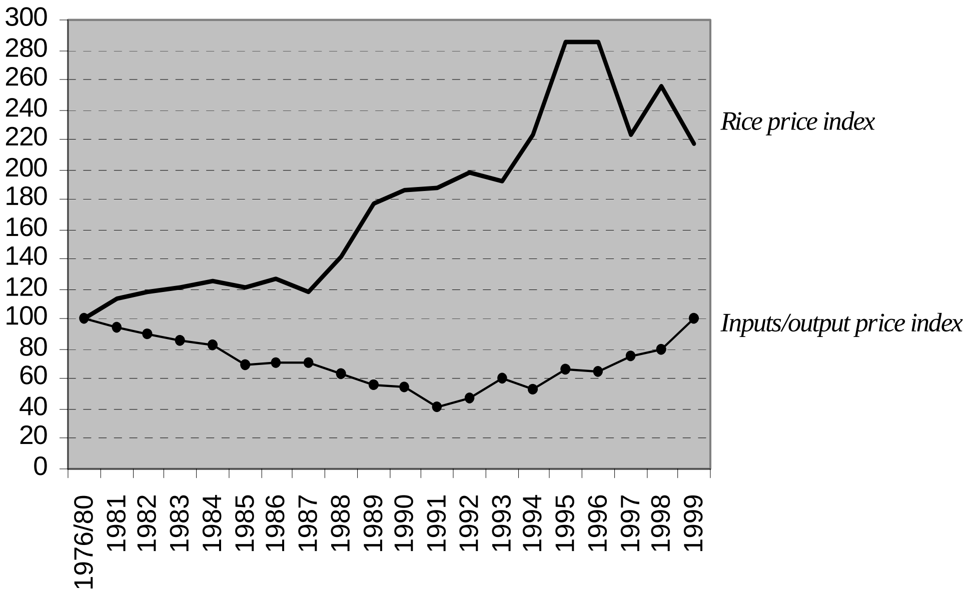
Variables	Denotation	Description	Units
Output	Y	Total paddy equivalent output	Tons
Capital	K	Total capital, including buffaloes, cattle and	‘000 horsepower:
Labour	LAB	Total days working	‘000 working days
Land	LAN	Sown land area used	ha
Material inputs	IN	Total material inputs, e.g., fertilizers, seeds	‘000 tons standard fertilizers tones
Tractor number	CA	Total number of tractors	units
Farm size	SIZE	Average farm size	ha/farm
Tractor used proportion	TL	Proportion of land ploughed by tractor over land used for rice production	per cent
Natural conditions	SOIL	Soil and weather conditions	1 for RRD & 0 for other areas
Threshing machines	TM	Total number of threshing machines used	units

Table 4: Growth indexes of output, inputs, total factor productivity (TFP), prices and component of TFP growth due to incentive effects (A_1)

Year	Index of									Proportion of TFP growth due to incentive effects (%)
	Output (*Y*)	Labour (*LAB*)	Land (*LAN*)	Material inputs (*IN*)	Capital (*K*)	Total factor productivity (*A*)	Rice price (βp)	$1 - c_0\,\omega$	A_1	
1976-80	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0
1981	112.4	104.4	97.2	100.2	114.6	116.6	114.5	100.3	103.3	20.0
1982	130.3	105.3	96.3	103.9	111.9	126.8	119.0	101.0	104.5	16.7
1983	133.5	103.8	95.3	110.1	111.3	127.3	122.8	102.0	105.4	19.9
1984	140.4	104.5	94.3	111.5	114.4	133.1	126.3	103.0	106.4	19.3
1985	143.1	105.6	92.3	130.0	123.0	131.1	122.1	105.8	106.0	19.5
1986	144.3	104.8	91.3	125.9	135.6	131.3	128.2	106.0	107.3	23.4
1987	136.2	103.5	91.2	128.0	108.5	124.4	118.6	106.1	105.2	21.5
1988	153.4	105.5	88.3	128.1	106.9	139.4	142.5	109.9	110.8	27.4
1989	171.4	108.0	88.3	133.4	107.7	154.9	178.4	112.0	119.0	34.6
1990	173.5	109.8	88.3	137.7	119.4	155.2	186.7	112.5	120.9	37.8
1991	177.1	113.5	88.1	139.4	156.9	154.6	189.2	113.8	122.0	40.3
1992	195.0	115.9	88.1	139.7	162.8	166.7	198.7	115.3	123.9	35.8
1993	206.3	117.0	86.8	144.0	168.7	171.6	193.9	114.5	122.2	30.9
1994	212.5	117.4	86.8	146.0	174.6	174.9	225.0	114.7	129.3	39.1
1995	225.5	120.0	90.3	147.1	180.6	183.8	292.0	113.3	142.2	50.3
1996	238.4	122.9	94.3	149.7	186.5	191.5	286.6	114.2	142.2	46.1
1997	248.7	124.7	90.2	151.5	218.7	195.2	224.2	113.6	128.2	29.6
1998	263.2	128.2	90.5	152.3	237.5	205.2	256.9	114.0	135.1	33.4
1999	283.5	132.1	90.5	153.8	252.9	221.3	218.9	112.3	125.9	21.3
	Average annual growth rate (*per cent per year*)									
	Output	Labour	Land	Material inputs	Capital	TFP (*A*)	Rice price (βp)	$1 - c_0\,\omega$	A_1	
1981-87	4.56	0.33	-1.30	3.21	2.23	2.74	2.18	0.91	0.72	
1988-94	6.14	1.98	-0.52	2.78	7.54	4.43	7.87	0.39	2.48	
1995-1999	5.72	2.32	0.50	1.08	9.88	4.46	-2.02	-1.53	-1.11	

Note: *Annual growth rate is measured as the fitted value of the exponential growth rate.*

Figure 3: Rice price index (*βp*) and relative price of inputs/output (*ω*= *W(w)/βp*) index for Vietnam, 1981-99 *(1976/80=100)*



Sources*: Estimated from the sources from the State Department of Price of Vietnam and the State Planning Committee.*

Figure 4: The cumulative growth of output, total factor productivity (*A*) and the part of total factor productivity due to market reform (*A1*) for Vietnam

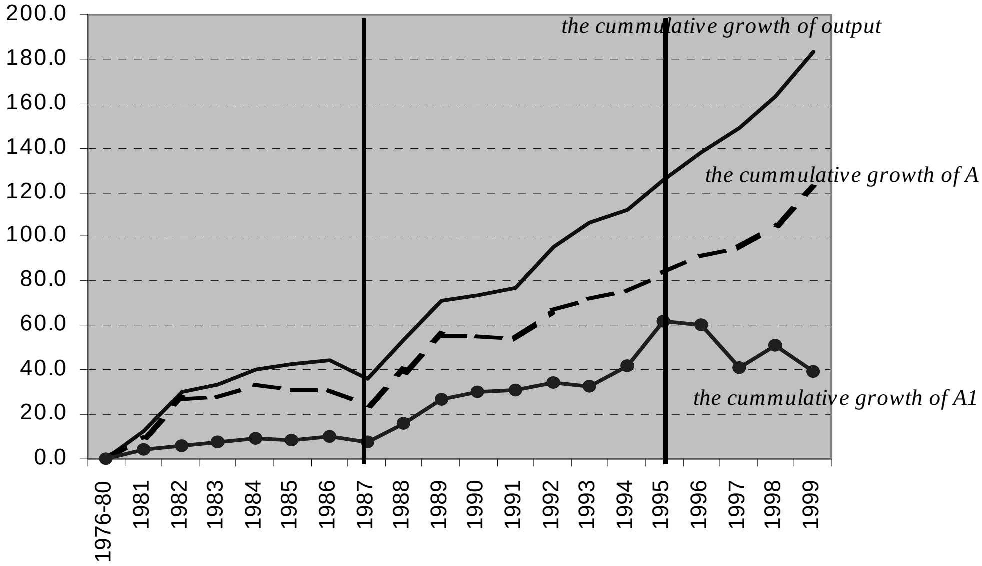


Table 5: Summary statistics for key variables for 60 provinces in Vietnam, 1991-99

Variables	Units	Average	Stdev	Min	Max
Output (Y)	*'000 tons*	419.4	445.6	31.2	2,100.0
Capital (K)	*'0000 horse power*	11,591.2	13,732.7	325.4	79,902.9
Labor (LAB)	*'000 working days*	17,205.8	15,173.2	978.4	114,847.2
Land (LAN)	*'000 hectare*	120.9	106.7	12.2	514.3
Material inputs (IN)	*'000 tons*	44.1	30.5	3.9	145.0
Tractor number (CA)	*units*	1,455.4	2,717.6	2.0	31,123.0
Farm size (SIZE)	*hectare/unit*	1.8	1.4	0.2	4.5
Tractor used proportion (TL)	*percentage*	0.4	0.3	0	1.0
Threshing machines (MA)	*units*	2,325.2	6,419.4	0.8	69,541.0

Table 6: Generalized likelihood ratio tests, parameter restrictions for the stochastic production frontier and technical inefficiency models (equations 5.5 and 5.6)

Null hypothesis	χ^2-statistic for Regression 1	$\chi^2_{0.99}$-value	Decision
$\gamma=\delta_0=\delta_1=\delta_2=\delta_3=\delta_4=\delta_5=0$	151.62	19.38	reject H_0
$\gamma=0$	23.54	8.27	reject H_0
$\delta_0=\delta_1=\delta_2=\delta_3=\delta_4=\delta_5=0$	411.4	17.75	reject H_0
$\delta_1=\delta_2=\delta_3=\delta_4=\delta_5=0$	139.7	16.07	reject H_0

Note: *The critical values for the hypotheses are obtained from Table 1 of Kodde and Palm (1986).*

Table 7: Parameter estimates of the stochastic production frontier and technical inefficiency models for Vietnam (equations 5.5 and 5.6)

	Coefficient	Asymptotic T-ratio
Stochastic production frontier model		
Constant	0.40*** *(0.17)*	2.30
Capital (K)	0.17*** *(0.02)*	8.78
Labor (LAB)	0.13*** *(0.03)*	4.07
Land (LAN)	0.24*** *(0.04)*	6.94
Material inputs (IN)	0.51** *(0.03)*	1.61
Time (T)	0.011*** *(0.002)*	4.88
Technical inefficiency model		
Constant	0.63*** *(0.1)*	6.10
Average farm size (SIZE)	-0.03*** *(0.01)*	2.60
Tractor used proportion (TL)	-0.35*** *(0.08)*	4.46
Natural conditions (SOIL)	-0.29*** *(0.04)*	7.45
Threshing machine (MA)	-0.01* *(0.01)*	1.54
Tractor number (CA)	0.04*** *(0.02)*	2.81
Sigma-squared	0.07***	11.74
Gamma	0.94***	18.84
Ln (likelihood)	9.87	
Mean Technical Efficiency (per cent)	59.2	

Notes: **, ** and *** denote statistical significance at the 0.10 level, 0.05 and 0.01 level respectively. Numbers in parentheses are asymptotic standard errors.*

Figure 5: Average technical efficiency during 1991-1999 for Vietnam and the principal rice areas (the Red River Delta and the Mekong River Delta)

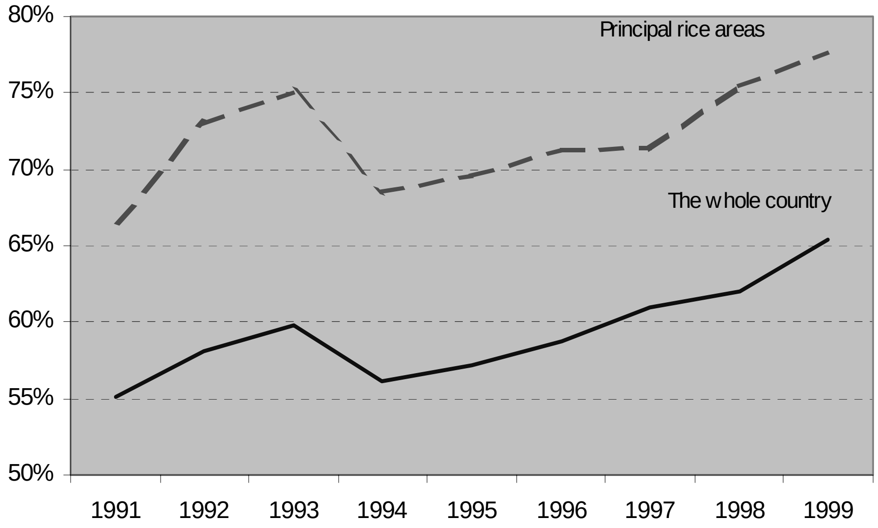


Table 8: Predicted technical efficiency for rice production in Vietnam (60 provinces), 1991-99

Zone and Province	1991	1992	1993	1994	1995	1996	1997	1998	1999
Red River Delta Zone									
1 Ha Noi	0.21	0.51	0.51	0.38	0.40	0.44	0.44	0.49	0.49
2 Hai Phong	0.44	0.55	0.60	0.54	0.51	0.58	0.58	0.60	0.61
3 Ha Tay	0.47	0.54	0.59	0.44	0.48	0.53	0.52	0.59	0.66
4 Hai Duong	0.48	0.67	0.87	0.57	0.62	0.67	0.74	0.77	0.79
5 Hung Yen	0.48	0.66	0.86	0.55	0.61	0.66	0.73	0.75	0.77
6 Ha Nam	0.48	0.62	0.67	0.50	0.59	0.59	0.62	0.66	0.68
7 Nam Dinh	0.56	0.73	0.81	0.59	0.70	0.70	0.73	0.75	0.75
8 Thai Binh	0.67	0.90	0.96	0.80	0.84	0.76	0.73	0.74	0.83
9 Ninh Binh	0.50	0.71	0.79	0.48	0.55	0.57	0.70	0.75	0.74
North East Zone									
10 Ha Giang	0.44	0.47	0.53	0.53	0.56	0.59	0.64	0.66	0.71
11 Cao Bang	0.41	0.34	0.48	0.45	0.45	0.53	0.54	0.51	0.54
12 Lao Cai	0.46	0.45	0.50	0.47	0.47	0.54	0.54	0.56	0.58
13 Bac Kan	0.35	0.39	0.48	0.49	0.44	0.42	0.48	0.47	0.44
14 Lang Son	0.29	0.35	0.39	0.37	0.38	0.39	0.43	0.51	0.49
15 Tuyen Quang	0.43	0.49	0.56	0.58	0.60	0.63	0.63	0.67	0.71
16 Yen Bai	0.42	0.54	0.61	0.57	0.59	0.59	0.60	0.61	0.72
17 Thai Nguyen	0.37	0.50	0.61	0.59	0.51	0.47	0.51	0.65	0.64
18 Phu Tho	0.34	0.46	0.48	0.44	0.45	0.47	0.49	0.51	0.58
19 Vinh Phuc	0.38	0.55	0.59	0.58	0.57	0.61	0.54	0.57	0.61
20 Bac Giang	0.27	0.35	0.35	0.32	0.29	0.33	0.36	0.50	0.55
21 Bac Ninh	0.54	0.76	0.75	0.67	0.62	0.61	0.74	0.56	0.61
22 Quang Ninh	0.50	0.64	0.71	0.49	0.44	0.50	0.55	0.59	0.56

North West Zone										
23	Lai Chau	0.44	0.45	0.47	0.44	0.43	0.37	0.49	0.49	0.55
24	Son La	0.31	0.28	0.35	0.36	0.38	0.44	0.49	0.49	0.53
25	Hoa Binh	0.57	0.49	0.59	0.52	0.57	0.52	0.57	0.57	0.66
North Central Southern Zone										
26	Thanh Hoa	0.49	0.51	0.62	0.49	0.53	0.42	0.56	0.59	0.65
27	Nghe An	0.41	0.44	0.44	0.49	0.52	0.49	0.61	0.56	0.60
28	Ha Tinh	0.35	0.48	0.48	0.53	0.53	0.49	0.55	0.48	0.60
29	Quang Binh	0.38	0.45	0.35	0.38	0.40	0.47	0.44	0.37	0.49
30	Quang Tri	0.50	0.53	0.35	0.36	0.51	0.59	0.58	0.47	0.65
31	Thua Thien Hue	0.52	0.52	0.41	0.32	0.49	0.53	0.53	0.51	0.56
South Central Southern Zone										
32	Da Nang	0.96	0.91	0.93	0.94	0.89	0.92	0.88	0.83	0.84
33	Quang Nam	0.55	0.49	0.51	0.52	0.48	0.51	0.50	0.50	0.50
34	Quang Ngai	0.59	0.43	0.40	0.46	0.45	0.52	0.49	0.53	0.58
35	Binh Dinh	0.62	0.52	0.43	0.50	0.50	0.53	0.55	0.55	0.60
36	Phu Yen	0.74	0.70	0.52	0.66	0.64	0.74	0.76	0.70	0.76
37	Khanh Hoa	0.62	0.57	0.61	0.63	0.59	0.57	0.61	0.62	0.62
Central Highland Zone										
38	Kon Tum	0.62	0.62	0.50	0.43	0.43	0.51	0.54	0.45	0.48
39	Gia Lai	0.48	0.40	0.39	0.33	0.43	0.42	0.43	0.43	0.47
40	Dak Lak	0.52	0.48	0.44	0.39	0.37	0.46	0.51	0.42	0.49
North East Southern Zone										
41	Hochiminh City	0.55	0.47	0.53	0.52	0.50	0.44	0.51	0.51	0.52
42	Lam Dong	0.33	0.32	0.27	0.25	0.29	0.30	0.35	0.36	0.35
43	Ninh Thuan	0.68	0.66	0.68	0.64	0.69	0.69	0.71	0.69	0.82
44	Binh Phuoc	0.33	0.32	0.32	0.25	0.31	0.29	0.33	0.29	0.32
45	Tay Ninh	0.61	0.46	0.58	0.57	0.56	0.62	0.66	0.65	0.66
46	Binh Duong	0.61	0.63	0.64	0.53	0.64	0.64	0.71	0.71	0.74
47	Dong Nai	0.53	0.47	0.57	0.61	0.59	0.55	0.56	0.55	0.54
48	Binh Thuan	0.58	0.58	0.66	0.59	0.58	0.59	0.62	0.66	0.62
Mekong River Delta Zone										
49	Long An	0.72	0.56	0.61	0.65	0.64	0.68	0.70	0.72	0.72
50	Dong Thap	0.77	0.87	0.85	0.83	0.81	0.82	0.84	0.87	0.91
51	An Giang	0.85	0.92	0.96	0.88	0.88	0.89	0.88	0.90	0.89
52	Tien Giang	0.91	0.95	0.91	0.86	0.86	0.87	0.90	0.87	0.86
53	Vinh Long	0.77	0.71	0.68	0.66	0.67	0.68	0.67	0.71	0.70
54	Ben Tre	0.75	0.69	0.68	0.56	0.58	0.58	0.52	0.54	0.52
55	Kien Giang	0.82	0.79	0.79	0.85	0.93	0.90	0.93	0.95	0.97
56	Can Tho	0.83	0.84	0.74	0.84	0.90	0.95	0.93	0.95	0.96
57	Tra Vinh	0.77	0.70	0.53	0.96	0.72	0.78	0.73	0.71	0.80
58	Soc Trang	0.74	0.73	0.59	0.76	0.83	0.81	0.79	0.88	0.93
59	Bac Lieu	0.83	0.80	0.85	0.80	0.70	0.71	0.65	0.81	0.86
60	Ca Mau	0.89	0.88	0.90	0.88	0.79	0.78	0.68	0.85	0.86