THE IMPACT OF AGRICULTURAL POLICY DISTORTIONS ON THE PRODUCTIVITY GAP: EVIDENCE FROM RICE PRODUCTION

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Abstract

This study determines how production and trade policy distortions affected rice productivity in thirty-three rice-producing countries. A rice-productivity index for each country is constructed, and a model linking the productivity gap with policy distortions is presented. After controlling for the differences in infrastructure, openness, and human capital, this article shows that high subsidies and protection in developed countries combined with taxation of rice farming in poor countries have widened the gap in rice productivity between rich and poor rice countries.

Key words: agricultural policy distortions, trade policies, productivity, rice

The agricultural sector in many developing countries has suffered from both a set of policy distortions and low productivity, but in all the attempts to find workable solutions the interaction between these two problems has been overlooked. For many commodities including rice, while developed countries have heavily subsidized their production and exports and limited their imports, developing countries have taxed their producers severely in favor of their consumers. Recently, many developing countries have reinforced the taxations of grain production in an attempt to halt the increases in consumer prices. Studies have concluded that these distortions have depressed prices, hurting specifically farmers in small open economies. That the depressed farm prices and revenues are likely to affect farmers' ability to adopt new technology has, however, been forgotten. Indeed, low farm prices and revenues reduce poor farmers' ability to afford investments associated with the adoption of new technology; even if technology is available, productivity will remain low as long as poor farmers do not expect much profit from adopting it. At a time when developing countries still lag far behind in productivity levels, struggle with food insecurity, and suffer from inefficient resource allocation and lack of competitiveness, exploring the link between agricultural policy distortions and productivity is long overdue.[1]

The objective of this article is to determine how policy distortions affected productivity in the rice sector for thirty three prominent rice-producing countries during

[1] Past studies (e.g. Nin et al. (2003)) often assume that changes in agricultural policies are detached from productivity growth. One of the rare studies on the impacts of government program on productivity in agriculture is Makki, Tweeten, and Thraen (1999), but it was confined only to the US case.

the period 1961-2002. The specific objectives are to (i) measure the levels and growth rates of total factor productivity (TFP) in rice production for the selected countries, (ii) provide a model linking productivity with production and trade policies, and (iii) estimate the impacts of policy distortion on productivity gaps among these producing countries.

The innovation in this article is twofold. First, I use constructed productivity indexes instead of yields. A dynamic panel data model is employed to obtain the indexes from the best of three different formulations, including that of Cermeno, Maddala, and Trueblood (2003), who modeled the residual measuring TFP in a two-way fixed effects autoregressive form. Second, I provide an empirical model testing the link between productivity and policy distortion to explain why developed countries' subsidies combined with developing countries' taxation may have contributed to the productivity gap.

The results of the analysis help assess how heavy subsidies in developed countries and taxation in developing countries affect productivity for poor rice farmers. The findings provide a timely indication of how renewed taxation, which many policy makers in the developing world still use as a tool to deal with rising consumer prices, may hurt productivity and efficiency at farm levels. The article also draws broader implications for many commodities, not just rice, on whether the efforts and usual recommendations to poor countries to improve their productivity and competitiveness are really detached from the need for policy reforms. This article therefore is intended to influence the decision on the need for multilateral reforms at a time when the negotiations to dismantle these distortions stalled and when the need to achieve higher agricultural productivity in developing countries is urgent.

Rice Policies and Productivity

The thirty-three prominent rice-producing countries, the focus of this study, are described in Appendix A. Based on the differences in their agricultural value–added and productivity levels, their position as net exporters or importers, and their rice policies, these 33 countries can be roughly divided into three groups. Group 1 includes OECD rice-producing countries: Australia, the EU (Italy), Japan, Korea, and the United States. This group has highest rice yields, heavily subsidizes its rice production and export, and sets high import protections. Group 2 includes developing countries that are net rice exporters: Argentina, China, Colombia, Egypt, Guyana, India, Myanmar, Pakistan, Suriname, Thailand, Vietnam, and Uruguay. Countries in this second group mostly have relatively high yields and apply few producer subsidies but often tax their exports. Group 3 includes mostly low-income countries that produce rice but still import from the two other groups: Bangladesh, Brazil, Cambodia, Guinea, Indonesia, Iran, Laos, Madagascar, Mali, Malaysia, Nepal, Nigeria, Peru, Philippines, Sri Lanka, and Tanzania. Many countries in this third group have the lowest rice yields, and they often tax their rice production and export.

The stark contrast between the heavy production and export supports in developed countries in Group 1 and the low support and taxation of rice production in developing countries is illustrated in figure 1. This figure particularly compares the levels of producer support estimate (PSE) between the OECD countries and developing countries such as India and Indonesia. Levels of PSE below the x-axis for India and for Indonesia indicate taxations on rice production. These rice policy distortions from both developed and developing countries have strained price and volumes of production and trade. Developed countries' producer support, an implicit export subsidy, and export programs lower world and farm prices for small open economies. Moreover, the high levels of protection in the OECD countries keep consumer prices high, a punishment on their own consumers, and limit developing countries' access to the rich countries. Additionally, production and export taxes in developing countries have depressed farm prices further.

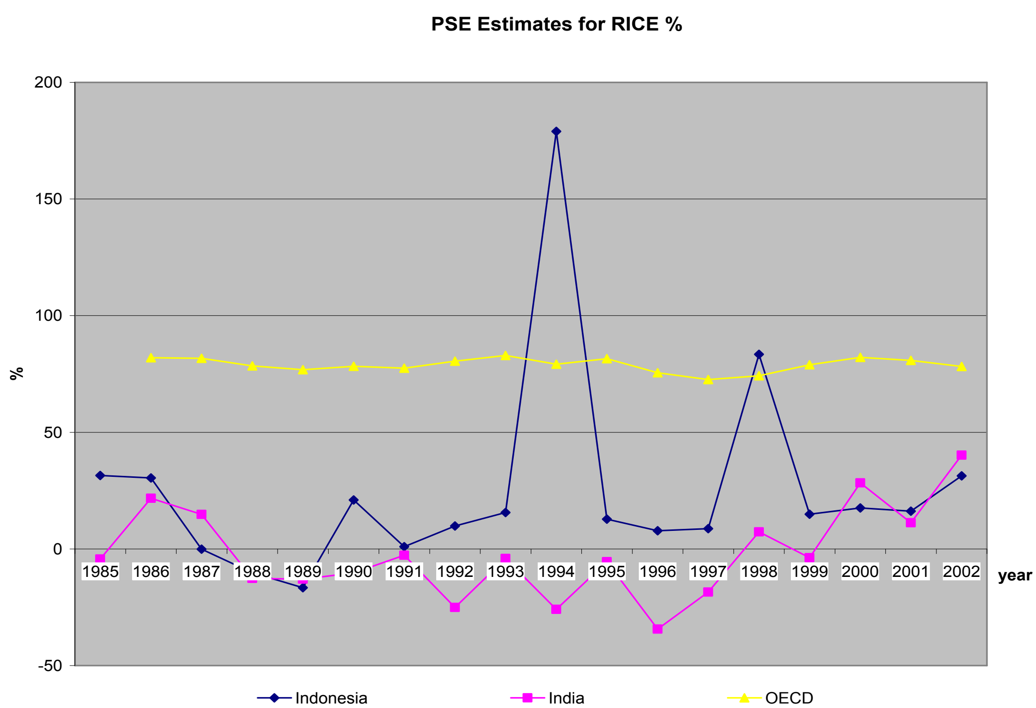

Figure 1. PSE estimates for rice (%)

Sources: OECD (2004); Mullen et al. (2004); Thomas and Orden (2004); and Mullen, Orden, and Gulati (2005).

The removal of these distortions, especially tariff and subsidies in the highly distorted rice market will improve overall welfare (see Cramer, Wailes, and Shui, 1993; Cramer, Hansen, and Wailes, 1999; Wailes, 2003). The benefit may not, however, extend to rice farmers in low-income producing countries that import rice (such as Bangladesh, Indonesia, Madagascar, Nigeria, and the Philippines). It has always been argued that unless these farmers find ways to increase their lagging productivity, they may not be able to enjoy the outcome of the reforms. In other words, the efforts to improve farm productivity in these developing countries are often perceived as a detached prerequisite for benefiting from the reforms.

A close look at how the distortions affect farm prices in developing countries challenges such a conventional thinking. As poor farmers, especially in developing countries, are price-takers, the low price resulting from domestic and foreign policy distortions may discourage any incentive to expand production; this is because they see little or no profit from an increase in production through technology adoption or acreage expansion. Moreover, with the absence of input subsidies and lack of infrastructure, their meager revenues resulting from the distortions do not allow them to invest in the adoption of available technology (e.g., using high-quality seeds, using better packaging and storage, or controlling grain quality). One hypothesis then is that the distortions have contributed to the low levels of productivity in these poor countries. Although the need to increase productivity in developing countries is clear, one may ask whether the rise in productivity is really a prerequisite for obtaining the benefit from the policy reforms aimed at removing these distortions or is a benefit from the policy reforms.

To test such a hypothesis, I turn to the mainstream literature. Besides the settled argument that slow technology transfer and differences in human capital endowment and research and development expenditures have caused the technology gap between rich and poor countries, there are two different views regarding the link of production and trade policies to technology. On the one hand is the neo-classical trade theory claiming that freer and more open trade will lead to a productivity gain because of the expanded division of labor within a larger market. This view is enhanced by the 'new' trade theory contending that openness induces the spillover effects of R&D, leading to output and productivity growth, especially for developing countries. Implications of 'new' trade theories since the early 90s (e.g., Grossman and Helpman, 1991; Barro and Sala-i-Martin, 1995) supported by empirical findings (e.g., Van Biesebroeck, 2003 and Schor, 2004) indicate that the channels through which openness in input and output markets affect productivity include (i) availability of imported resources, (ii) improved communication to exchange information for better management, (iii) copying or imitation of technology, and (iv) pressure to innovate (hence to increase productivity) because of competition.[2] These arguments have convinced formerly closed developing economies to open up and reduce their import protection and export taxes following the Uruguay Round. That this openness has led to a significant increase in agricultural productivity in small open economies is at best questionable, however, especially in the face of the productivity gap for a commodity like rice.

[2] See Coe and Helpman (1995), and Coe, Helpman, and Hoffmaister (1997).

On the other hand is the Schumpeterian idea that distortions such as heavy protection of farmers help secure large profits that can be invested in improving productivity, while de-regulation (such as market liberalization) will induce too much competition and reduce profits and investment in innovation.[3] This view appears at least to side with the hypothesis that agriculture support and protection in developed countries may have helped them raise their own productivity, whereas openness in some developing countries may have reduced their farm productivity; this hypothesis seems to provide explanations for the wide technology gap. But one may ask why high protection has not worked in favor of productivity in some developing countries like Indonesia, Madagascar, Nigeria, or Senegal. As neither one of these two views provides a straight answer, I attempt to use available data on rice to seek an explanation for the link between policy distortions and productivity gaps.

Framework

The first step is to provide a framework based on a dynamic panel model in order to construct indexes of productivity levels and growth for rice using the available data. Then I use a model that links trade policies with productivity, employing these indexes to explain the relation between rice policy distortions and rice productivity.

Productivity indexes

The rice production function for a country i ($i = 1, \dots N$) is specified in a Cobb-Douglas form and can be written in general terms as $Y_{it} = F(X_{it}^1, \dots, X_{it}^k, e^{v_{it}})$, where Y

[3] Rodrik (1992) showed that more imports for instance do not necessary lead to a rapid technology catch-up.

represents output and X's are the amount of input, t ($t = 1, \ldots, T$) represents a time period and the superscripts 1, …k represent k input types. The exponent of the residual v_{it}, represents the index of the level of technology to be estimated. Following Cermeño, Maddala, and Trueblood (2003), henceforth CMT, I write the residual in a dynamic form as $v_{it} = \mu_i + \lambda_t + \Phi v_{it-1} + \varepsilon_{it}$ for which ε_{it}~ $iid\ (0, \sigma_\varepsilon^2)$ where the μ and λ represent country and time specific-effects, respectively. The terms μ, λ, and ε are assumed to be uncorrelated to each other.

The justification for the dynamic error component models stems from the heterogeneity of the cross-sectional units (countries) involved and the idea that over time, technology follows different paths for the various countries in the study. Such an expression allows one to test that the residual is stationary (Φ =1). Taking the logarithms of the production function leads to the following

$$(1-\phi \mathrm{L})y_{it} = (1-\phi \mathrm{L})\sum_{j=1}^{k-1}\alpha_j x_{it}^j + (1-\phi \mathrm{L})\varphi X_{it}^k + \mu_i + \lambda_t + \varepsilon_{it}. \quad (1)$$

Variables y and x represent the logarithms of output and input per worker, and L is the lag operator. The expression in (1) implies that constant return to scale (CRS) technology only holds if $\phi = 0$.

The expression of residual terms (the last three terms) in (1) assumes that the level of technology has a country-specific component and a common average intercept. The difference is only perceptible at the country level. This is the most common expression of residuals used in panel data to measure growth of technology, as in the Solow model. However, it is unrealistic to assume that technology grows at the same annual rate for all countries after taking out the country-specific effect. CMT considered two other alternatives of the expression of v_{it} in replacing λ_t by θ_i*t, indicating that the growth rate of TFPs (coefficients on time trend) are different for each country over time, and by $\theta*t$, indicating that TFP growth rate is the same for all countries.

Rewriting (1) and taking into account these alternative expressions of λ_t leads to the following econometric models of production per worker:

$$y_{it} = \gamma y_{it-1} + \sum_{j=1}^{k-1} \alpha_j x_{it}^j + \sum_{j=1}^{k-1} \beta_j x_{it-1}^j + \delta_0 X_{it}^k + \delta_1 X_{it-1}^k + \theta_i * t + \mu_i + \varepsilon_{it} \qquad (1a)$$

$$y_{it} = \gamma y_{it-1} + \sum_{j=1}^{k-1} \alpha_j x_{it}^j + \sum_{j=1}^{k-1} \beta_j x_{it-1}^j + \delta_0 X_{it}^k + \delta_1 X_{it-1}^k + \theta * t + \mu_i + \varepsilon_{it} \qquad (1b)$$

$$y_{it} = \gamma y_{it-1} + \sum_{j=1}^{k-1} \alpha_j x_{it}^j + \sum_{j=1}^{k-1} \beta_j x_{it-1}^j + \delta_0 X_{it}^k + \delta_1 X_{it-1}^k + \lambda_t + \mu_i + \varepsilon_{it} . \qquad (1c)$$

Equation (1c) is exactly the same as (1) under the following restrictions: $\beta_j + \gamma.\alpha_j = 0$ for all j and $\delta_1+\gamma.\delta_0 =0$. Moreover, CRS can be tested or imposed under $\delta_0 = 0$ (i.e. $\delta_1 =0$ also). The aim here is to determine which of the three specifications best represents the data to provide estimates of the parameters θ's, μ, and λ_t ; these estimates are employed to construct TFP index level and growth for each country (or group of country). [4]

[4] This method differs from earlier work such as Ball, Butault and Nehring (2001), in which productivity index is directly calculated as the ratio between input and output indexes. See also Amadi and Thirtle (2004).

Linking policy distortions with productivity gaps

(a) Adoption of technology

Technology adoption generally increases with expected profits from the adoption, i.e., it decreases with adoption costs and increases with expected farm revenue (Weiss, 1994). The expected profits depend mainly on prices received by farmers and prices of direct inputs associated with the technology. Variables that may affect adoption of technology also include variables linked to the overall agricultural production such as infrastructure (e.g., dams for irrigation) and input delivery (Ransom, Paudyal, and Adhikari, 2003), trade openness (reflecting the degree of trade spillover effects on technology; see Coe and Helpman, 1995), and human capital (on which training and extension depend). Therefore, technology level can be expressed as:

$TFP = \mathrm{f}(P_d, \mathbf{w}, INFRA, HK, OPEN)$, or using a total difference:

$$\mathrm{d}TFP = \mathrm{d}P_d + \mathrm{d}\mathbf{w} + \mathrm{d}INFRA + \mathrm{d}HK + \mathrm{d}OPEN \qquad (2)$$

where P_d is the price received by farmers, $\mathbf{w}$ represents the vector of input and equipment prices directly linked to the technology use, $INFRA$ represents agricultural infrastructure index (e.g. irrigation and input delivery systems), HK is human capital, and $OPEN$ is degree of openness.

(b) Policies and productivity

The last step of the model derivation is to define the prices received by farmers. These differ for the three groups of rice-producing countries. If P_{ri} is the adjusted reference price (i.e., the adjusted world price at the location where competition takes place) for group i and P_{di} is the domestic farm-gate price, the quantity $MPS_i = P_{di} - P_{ri}$ is called market price support and measures the extent of the support programs. (In percentage term, $MPS_i = (P_{di}-P_{ri})/P_{ri}$.)

(i) For Group 1 (OECD countries with high yields), which would be a net rice importer in a free–trade world, the competition would be at the countries' borders so that the following holds:

$$Pr_1 + TR_1 + MM_1 \equiv CIF_1,$$

where Pr_1 is the adjusted reference price, TR_1 is the cost of transportation from Group 1's farms to its borders, and MM_1 is the marketing margin between Group 1' farms and its borders

The price received by farmers, which is relevant to revenue and profit for technological adoption is $P_{d1} = Pr_1+MPS_1$, or by using the above identity,

$$P_{d1} = CIF_1 - TR_1 - MM_1 + MPS_1 \qquad (3)$$

where CIF_1 is rice c.i.f. price, TR_1 is the cost of transportation; MM_1 is the marketing margin between Group 1'farms to its borders; and MPS_1 is the price support.

(ii) For Group 2 (developing countries with relatively high yields), a net rice exporter, the competition is at these countries borders so that the following holds:

$$PR_2 + TR_2* + MM_2 \equiv FOB + TR_2\,,$$

where PR_2 is the adjusted reference price, TR_2* is cost of transportations from Group 2's farms to its borders, MM_2 is the marketing margin between Group 2's farms and its borders, FOB is *f.o.b.* price for a competing exporter (an outsider) and TR_2 is the cost of transportation from the competitor's border to Group 2's borders.

The price received by farmers is $P_{d2} = PR_2+MPS_2$, or by using the above identity

$$P_{d2} = FOB + TR_2 - TR_2^{*}- MM_2 + MPS_2. \quad (4)$$

FOB is competitor's f.o.b. price, TR_2 is the cost of transportation from the competitor's border to Group 2's borders; TR_2* is the cost of transportation between Group 2's farms to its own borders; MM_2 is the marketing margin between Group 2's farms and its borders; and MPS_2 is the price support.

(iii) For Group 3 (developing countries, lowest yield), a net importer, the competition is at the farm-gate so that the following holds:

$$PR_3 \equiv CIF_3 + TR_3 +MM_3 ,$$

where PR_3 is the adjusted reference price, CIF_3 is the rice *c.i.f.* price at Group 3's borders, and MM_3 is the marketing margin between Group 3's borders and Group 3's farms.,

The price received by farmer is $Pd_3 = PR_3+MPS_3$; the farm-gate price is then

$$P_{d3} = CIF_3 + TR_3 + MM_3 + MPS_3 \quad (5)$$

where CIF_3 is the rice *c.i.f.* price at Group 3's border; TR_3 is the cost of transportation from Group 3's borders to Group 3's farms; MM_3 is the marketing margin between Group 3's borders and Group 3's farms; and MPS_3 is the price support.

Using 3, 4 and 5, I can now define the differences between price received by farmers in OECD and farmers in the other two groups of countries:

$dP_{d12} = P_{d1}\text{-}P_{d2} = f((CIF_1 – FOB – TR_1 – MM_1 - TR_2 + TR_2^{*}+ MM_2);$

$(MPS_1$- - $MPS_2))$; (6a)

$dP_{d13} = P_{d1}$-P_{d3} $=g((CIF_1 - CIF_3 - TR_1 - MM_1 - TR_3 - MM_3); (MPS_1 - MPS_3))$ (6b)

Equations 6a and 6b show that the difference in price received by rice farmers in OECD and in developing countries depends mostly upon both (i) the wedges between the border prices of rice along with the differences between transportation costs and marketing margins on both sides of the trading groups and (ii) the contrast between the high price support in developed countries and taxation of rice production in developing countries.

Empirical model

To derive an econometric model, I assumed that the first arguments of the function f(.) in (6a) and g(.) in (6b), namely the differences among *cif*'s and *fob* prices, and among the marketing margins and transportation costs are constant because of arbitrage in the worlds' rice market.[5] Under such assumptions, the substitution of (6a) or (6b) into (2), and the use the log form of the difference lead to the following

$$\begin{aligned}\log(\frac{TFP_1}{TFPi})_t &= \eta_0 + \eta_1 \log(S_1 - S_i)_t + \sum_k \eta_{2k} \log(\frac{w_{1k}}{w_{ik}})_t + \eta_3 \log(\frac{INFRA_1}{INFRA_i})_t \\ &+ \eta_4 \log(\frac{HK_1}{HK_i})_t + \eta_5 \log(\frac{OPEN_1}{OPEN_i})_t + \tau_{it},\end{aligned} \quad (7)$$

where subscript 1 refers to Group 1 (OECD countries) and *i* to countries in either Group 2 (rice exporters in developing world) or Group 3 (rice importers in the developing world); *S* is a measure of domestic price support (whose values can take any sign); *w* is the input

[5] An assumption is also that both the marketing margins and transportation costs are symmetric between two trading partners. But a cross-sectional unit specific dummy can always capture these differences in the estimation even if they don't vanish completely.

price (such as agricultural and farm equipment price); *INFRA, HK,* and *OPEN* are the agricultural infrastructure index, level of human capital, and degree of country openness, respectively; and the ηs are parameters and τ represents the error term.

Data and Method

Data are yearly and cover the period between the years 1960 and 2002. Appendix B explains the data and their sources. The estimation proceeded in two stages. The first stage was to estimate the three models (1a), (1b), and (1c). The variable inputs for the production function include labor, land, number of tractors, and fertilizer. The dependent variable is milled rice production per worker. I first pooled the data and considered the three groups of countries as the main cross-sectional units in order to compare the level of technology among the three groups. This helps track the levels and growth rates of TFP in each of the group has evolved over the years. The parameters of all the three alternative forms of the dynamic panel model were estimated using the maximum likelihood estimator. Then I estimated parameters within each group to obtain the technology-level indexes and scaling these levels compared to a baseline. The TFP-index levels and growth over time were then computed.

The second stage was to estimate the parameters of equation (7) using mainly the TFP estimates from the first stage and using a support measure. OECD countries served as the group of reference, and all gaps were measured in terms of the ratio between average values for OECD countries and those of individual countries.

Results

Measures of productivity level and growth

Tables 1-4 show the results of the estimation of rice-productivity indexes between and within the three groups of countries. Each of these tables shows the results of the estimation from three competing models based on the forms of the time component of the error terms to identify the level of technology; the best model, determined by the Akaike's Information Criterion (AIC), is the bold-face column. The best fit appears to be in model (1b), where there is a common time trend of TFP beside the cross-sectional effect representing the level of technology; the only exception is in table 3 on the productivity measures for country Group 2, where (1a) yields the best fit.

(a)Between-group estimation

In table 1, the three groups of countries are taken as the cross-sectional units and Group 3 was chosen as the basis for comparison. In all three models, (1a), (1b), and (1c), the coefficients μ_i for Group 1 and Group 2 are both positive and statistically significant and μ_i is larger for Group 1. As expected, the high-income rice-producing countries in Group1 have on average the highest level of TFP, compared to rice exporters in Group 2 and to low-income rice-producing countries in Group 3. Based on model (1b), the coefficient θ representing common trend for all three groups indicates that the trend in world rice productivity grew at 0.4 percent on average per year between 1961 and 2002.

Table 1. Pooled Panel Estimation

	Model					
	(1a) $\mu_i + \theta_i * t$		**(1b) $\mu_i + \theta * t$**		(1c) + $\mu_i + \lambda_t$	
Dep. var: output per worker						
Lag (prod. per worker)	0.652		**0.634**		0.647	
	(42.93)		**(42.12)**		(42.72)	
fertilizer per worker	0.088		**0.084**		0.074	
	(8.29)		**(8.04)**		(6.84)	
tractor per worker	0.068		**0.061**		0.044	
	(6.03)		**(5.51)**		(3.84)	
land per worker	0.968		**0.960**		0.938	
	(43.93)		**(44.38)**		(42.94)	
φ (Labor)	0.035		**0.026**		0.005	
	(2.25)		**(1.67)**		(0.33)	
Technology	μ_i	θ_i	**μ_i**	**θ**	μ_i	λ_t 0.013
Group 1	0.168	0.001	**0.229**	**0.004**	0.219	(average)
	(5.35)	(1.04)	**(10.04)**	**(7.46)**	(9.65)	
Group 2	0.041	0.003	**0.115**		0.112	
	(2.06)	(3.65)	**(8.70)**		(8.51)	
Group 3 (base)						
-2Res. Log likelihood	-437.0		**-488.4**		-369.6	
AIC	-435.0		**-486.4**		-367.6	
BIC	-429.8		**-481.2**		-362.4	

Note: Numbers in parenthesis and below the coefficients are t-values. Group 1 includes Australia, EU (Italy), Japan, Korea, and the United States. Group 2 includes Argentina, China, Colombia, Egypt, Guyana, India, Myanmar, Pakistan, Suriname, Thailand, Vietnam, and Uruguay. Group 3 includes Bangladesh, Brazil, Cambodia, Guinea, Indonesia, Iran, Laos, Madagascar, Mali, Malaysia, Nepal, Nigeria, Peru, Philippines, Sri Lanka, and Tanzania.

(b) Within-group estimation

Tables 2, 3, and 4 summarize the results within each group of countries. Table 2 presents the estimation on Group 1 (the OECD rice producers and exporters). Here one reason why (1b) produced the best fit is that the countries in Group 1 are relatively homogenous in terms of the level and increase in technology over the last four decades. Results show that Australia has the highest level of TFP index in this group: this is consistent with the high level of paddy yields achieved in Australia (see Appendix A).

Moreover, the coefficient on trend θ is significant and indicates that rice TFP in Group 1 grew at 1.6 percent per year on average for the last four decades. The coefficient on labor is positive and statistically significant; IRS technology characterizes rice production in Group 1. This is not surprising because the high-income rice-producing countries have invested much in R&D and technology and human capital that countered the diminishing marginal returns from the use of other inputs such as capital, labor, and fertilizer.

Table 2. Parameters of the Rice Production Function for *Group 1*

	Model					
	(1a)		**(1b)**		(1c)	
Dep. var: output per worker						
Lag (prod. per worker)	0.516		**0.156**		0.229	
	(8.73)		**(2.26)**		(3.02)	
fertilizer per worker	0.033		**0.008**		0.020	
	(1.13)		**(0.39)**		(0.98)	
tractor per worker	0.040		**0.012**		0.021	
	(1.63)		**(0.95)**		(1.60)	
land per worker	0.892		**0.795**		0.742	
	(15.58)		**(16.79)**		(11.58)	
φ (Labor)	0.033		**0.165**		0.213	
	(0.27)		**(2.61)**		(3.29)	
Technology index	μ_i	θ_i	$\boldsymbol{\mu_i}$	$\boldsymbol{\theta}$	μ_i	λ_t
Australia	-0.013	0.004	**0.535**	**0.016**	0.553	0.017
	-0.05	(1.46)	**(5.45)**	**(8.20)**	(5.05)	(average)
Japan	0.218	0.000	**0.199**		0.201	
	1.20	(0.05)	**(4.76)**		(4.76)	
Korea	0.136	0.003	**0.193**		0.223	
	0.58	(0.64)	**(3.17)**		(3.42)	
United States (base)	base 0	base 0				
-2Res. Log likelihood	-280.6		**-361.2**		-240.6	
AIC	-278.6		**-359.2**		-238.6	
BIC	-275.4		**-35.9**		-235.6	

Note: Numbers in parenthesis and below the coefficients are t-values. Group 1 includes Australia, EU (Italy), Japan, Korea, and the United States. The model (1a) has residual of the form $\mu_i + \theta_i * t$; (1b) has $\mu_i + \theta * t$ and (1c) has $\mu_i + \lambda_t$.

Table 3. Parameters of the Rice Production Function for *Group 2*

	Model					
	(1a)		(1b)		(1c)	
Dep. var: output per worker						
Lag (prod. per worker)	**0.060**		0.088		0.097	
	(4.10)		(5.36)		(5.62)	
fertilizer per worker	**0.032**		0.027		0.018	
	(1.63)		(1.23)		(0.74)	
tractor per worker	**0.059**		-0.029		-0.028	
	(2.29)		(-1.14)		(-1.05)	
land per worker	**1.073**		1.106		1.105	
	(30.14)		(32.98)		(31.28)	
φ (Labor)	**0.707**		0.560		0.556	
	(7.28)		(6.16)		(5.80)	
Technology	$\boldsymbol{\mu_i}$	$\boldsymbol{\theta_i}$	μ_i	θ	μ_i	λ_t
Argentina	**1.825**	**0.003**	1.990	0.009	1.986	0.011
	(5.61)	**(1.51)**	(6.90)	(7.72)	(6.56)	(average)
China	**-1.648**	**0.006**	-1.083		-1.074	
	(-6.11)	**(3.52)**	(-4.41)		(-4.17)	
Colombia	**1.129**	**0.012**	1.364		1.359	
	(5.04)	**(7.25)**	(7.17)		(6.83)	
Egypt	**1.236**	**0.007**	1.434		1.427	
	(8.90)	**(4.56)**	(10.79)		(10.25)	
Guyana	**1.366**	**0.009**	1.312		1.300	
	(4.99)	**(3.85)**	(0.242)		(5.08)	
India	**-1.891**	**0.002**	-1.465		-1.452	
	(-8.80)	**(1.23)**	(-7.26)		(-6.86)	
Myanmar	**0.126**	**0.006**	0.112		0.108	
	(1.62)	**(2.82)**	(2.56)		(2.32)	
Pakistan	**0.017**	**-0.007**	0.028		0.033	
	(0.25)	**(-3.75)**	(0.56)		(0.63)	
Suriname	**4.503**	**-0.002**	3.909		3.900	
	(6.55)	**(-1.08)**	(6.45)		(6.51)	
Thailand	**0.071**	**-0.011**	-0.148		-0.145	
	(1.33)	**(-6.08)**	(-4.89)		(-4.67)	
Uruguay	**2.994**	**0.014**	3.157		3.146	
	(5.87)	**(5.94)**	(7.30)		(6.95)	
Vietnam (base)						
-2 Res. Log likelihood	**-638.2**		-595.6		-439.8	
AIC	**-636.2**		-593.6		-437.8	
BIC	**-632.0**		-589.4		-437.8	
					-433.7	

Note: Numbers in parenthesis and below the coefficients are t-values.
The model (1a) has residual of the form $\mu_i + \theta_i * t$; (1b) has $\mu_i + \theta * t$ and (1c) has $\mu_i + \lambda_t$.

Table 4. Parameters of the Rice Production Function for *Group 3*

	Model					
	(1a) $\mu_i + \theta_i * t$		**(1b) $\mu_i + \theta * t$**		(1c) + $\mu_i + \lambda_t$	
Dep. var: output per worker						
Lag (prod. per worker)	0.354		**0.478**		0.545	
	(12.31)		**(17.42)**		18.11	
fertilizer per worker	0.025		**0.035**		0.026	
	(2.65)		**(3.68)**		2.65	
tractor per worker	0.032		**0.079**		0.059	
	(1.76)		**(5.63)**		4.18	
land per worker	0.970		**0.934**		0.889	
	(30.33)		**(38.42)**		35.77	
φ (Labor)	0.249		**0.050**		0.016	
	(3.74)		**(0.81)**		0.26	
Technology levels	μ_i :	θ_i :	**μ_i**	**θ**	μ_i	λ_t
Bangladesh	-0.157	0.008	**0.366**	**0.008**	0.294	0.014
	(-1.62)	(4.11)	**(3.76)**	**(6.24)**	3.08	(average)
Brazil	-0.101	0.015	**0.265**		0.189	
	-1.05	(8.06)	**(3.28)**		2.34	
Cambodia	0.353	0.003	**0.339**		0.335	
	(2.23)	(1.77)	**(4.02)**		3.96	
Guinea	-0.056	0.009	**0.057**		0.104	
	(-0.31)	3.30	**(0.56)**		1.02	
Indonesia	-0.018	0.013	**0.539**		0.430	
	(-0.20)	5.39	**(4.98)**		4.03	
Iran	0.629	0.007	**0.512**		0.437	
	(7.40)	3.14	**(9.82)**		8.41	
Laos	0.263	0.018	**0.392**		0.407	
	(1.22)	6.63	**(3.17)**		3.27	
Madagascar	0.556	-0.002	**0.391**		0.372	
	(3.94)	-0.94	**(5.58)**		5.30	
Malaysia	0.645	0.008	**0.477**		0.442	
	(4.41)	3.85	**(5.11)**		4.80	
Mali	-0.042	0.009	**0.038**		0.065	
	(-0.36)	4.17	**(0.55)**		0.95	
Nepal	0.352	0.001	**0.380**		0.346	
	(3.20)	0.22	**(7.32)**		6.64	
Nigeria	-0.226	0.008	**0.063**		0.043	
	(-3.15)	(2.65)	**(1.52)**		1.07	
Peru	1.067	0.005	**0.725**		0.654	
	8.68	2.48	**(8.34)**		7.51	
Philippines	0.038	0.013	**0.365**		0.313	
	0.37	6.55	**(6.15)**		5.36	
Sri-Lanka	0.627	0.006	**0.498**		0.452	
	4.63	3.48	**(6.60)**		6.03	
Tanzania (base)						
-2Res. Log likelihood	-663.1		**-701.4**		-591.0	
AIC	-661.1		**-699.4**		-589.0	
BIC	-656.7		**-694.9**		-584.6	

Note: Numbers in parenthesis and below the coefficients are t-values. The model (1a) has residual of the form $\mu_i + \theta_i * t$; (1b) has $\mu_i + \theta * t$ and (1c) has $\mu_i + \lambda_t$.

Table 3 summarizes the results in Group 2, net rice exporters among developing countries. Here, model (1a) gives the best fit, i.e., countries differ in both their levels of

TFP and in their average annual TFP growth. One possible reason why model (1a) is superior to the other two models is that the net exporters of rice are less homogenous than the other two groups in terms of annual TFP growth. The country-specific effects on TFP are all statistically significant in eight out of eleven countries. The highest country-specific effects of TFP levels are found in the rice sectors of Suriname, Uruguay, and Argentina. The lowest specific country effects on TFP levels, which are below the TFP level of Vietnam, are in China and India. Colombia, Uruguay, and Guyana have had the fastest TFP growth. Compared with Vietnam, TFP growth in Pakistan and Thailand is relatively low. Here model (1b), though inferior to (1a), provides similar results. Moreover, results under model (1b) show that, overall, TFP in rice sectors for countries in Group 2 grew at almost one percent per year on average for the period 1961-2002. The coefficient on labor for Group 2 is positive and significant, indicating that the rice sectors in these rice-exporting countries have also benefited from their investment in R&D and innovation in the rice and agricultural sectors, so that rice production shows an IRS technology. This is consistent with the rapid increase in paddy yields that countries such as Egypt, China, Uruguay, and Vietnam have achieved in the last four decades.

Table 4 presents the results for the low-income rice-producing and importing countries in Group 3. Here, as for Group 1, model (1b) best represents the data. All of the coefficients representing country-specific effects of TFP indexes are statistically significant. The highest values of country-specific effects are in Peru, Indonesia and Iran. The coefficient on common time trend θ is positive and significant, indicating that, on average, TFP growth in rice sector for Group 3 is about 0.8 percent per year, almost half of the TFP growth in Group 1. This result shows that, here, the 'catching-up' hypothesis does not hold, as countries in Group 3 started at lower TFP levels and their TFPs have grown at only a slower rate than that of Group 1 and Group 2.

(c) Synthesis: Productivity gap

From the estimation results obtained so far, a time-series on estimates of TFP level index and growth rate for rice productivity for each country group can be constructed. For this, I employed the group results under model (1a), whose feature allows country- and time-specific effects for each time period. I used μ_i as the starting TFP level and added λ_t level each year. Appendix C presents the levels and growth rates of TFP based on these estimates for the three groups of countries between 1961 and 2002. The estimates of TFP levels are plotted in figure 2, which shows the widening TFP gap, especially between Group 3 and Group 1. Such information on TFP indexes and gap among the three groups of countries will be used in the estimation of the link between policy distortions and productivity.

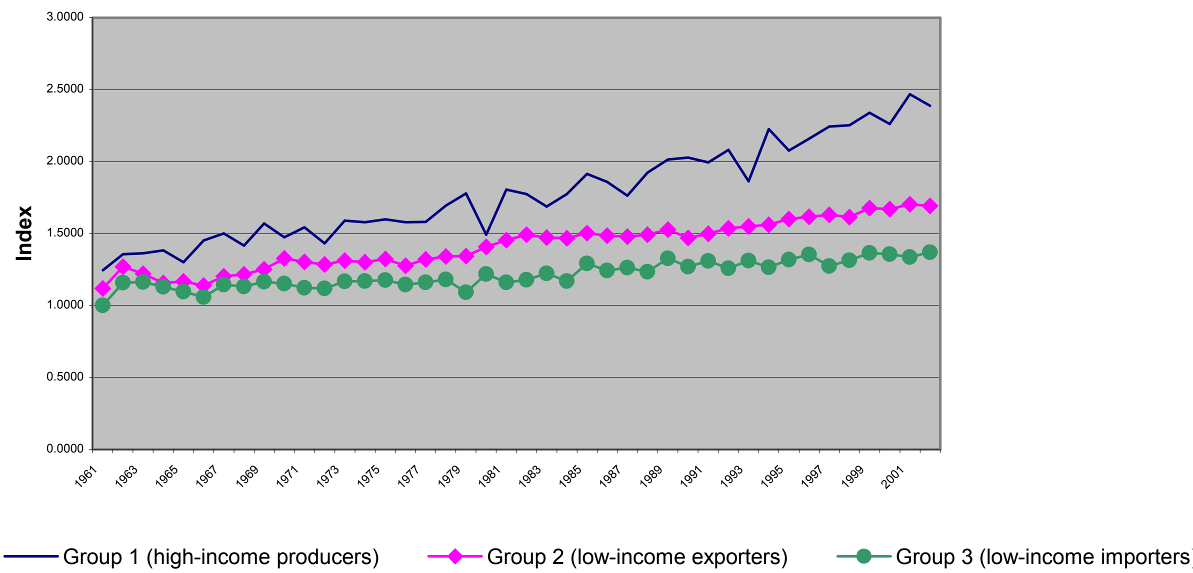

Figure 2. Estimated TFP index levels for main rice-producing countries

Impacts of policy distortions on productivity

Table 5 presents the parameter estimates of the model in (7), which links policy distortions and productivity. Complete data on PSEs were only available for the period 1982-2002 in eight rice-producing countries: Australia, China, India, Indonesia, Japan, Korea, Vietnam, and the United States.

The coefficient of the producer-support gap is positive and significant at 10% level for the entire period of 1982-2002 (*column* 1, table 5), indicating that the rice-productivity gap has increased as rich countries heavily subsidized and poor countries taxed (or only slightly subsidized) their rice production and exports. This confirms the hypothesis that both heavy subsidies in rich countries and taxation of rice production in developing countries have depressed the prices received by developing countries' poor farmers; as poor farmers' revenues and profits shrunk, they were unable to cover the costs associated with technology adoption (including the cost of essential inputs) and as a result, their rice productivity lagged behind.

Table 5. Parameter Estimates on the Link between Rice-Productivity Gap and Producer Supports

Independent variable: Δ(Productivity)	Coefficients	
Dependent Variables:	**No Break**	**Uruguay-Round Break**
Δ(Support price) 1982-2002	0.015* (1.80)	
Δ(Support price) 1996-2002	n.a.	0.040*** (4.02)
Δ(Support price) 1982-1995	n.a.	0.015* (1.75)
Δ(Openness)[a]	0.102** (2.12)	0.104** (2.16)
Δ(Human capital)	0.021 (0.21)	0.019 (0.21)
Δ(Irrigation)	0.617*** (11.09)	0.619*** (11.17)
Δ(Fertilizer use)	0.559*** (11.98)	0.562*** (12.06)
Δ(Equipment price)	-0.587*** (-9.95)	-0.588*** (-9..97)
Observations: *NxT* =	8x21=168	8x21=168
AIC	-142	-76.1

Note: (a) Openness is total trade over GDP; Δ(.) denotes gap between average OECD's variable and individual country's variable. The ***, ** and * denote significance levels at 0.01, 0.05, and 0.1. Numbers in parenthesis and below the coefficients are t-values.

There are two possible ways that developed countries' heavy support on rice particularly may affect the rice-productivity gap. On the one hand, the level of support itself increased developed countries' access to technology, hence to a strong productivity shift. On the other hand, producer support, as an implicit export subsidy, depressed the world prices and prices that farmers in small open developing countries received; the low prices reduced these poor farmers' revenues and their ability to invest in new technology. As a result the productivity gap between developed and developing countries widened.

Because of the somewhat weak significance of the coefficient of the producer-support gap, and also to check whether the estimate is sensitive to the implementation of the 1995 Uruguay Round Agreement on Agriculture, I decided to split the time period into two parts, before and after 1996. This is also because the data show that starting in 1996 the average PSE per ton in OECD countries started to fall while developing countries continued to move from taxation to lightly subsidizing rice production.[6]

The results in table 5, column 2 show that the coefficient of the producer support gap remains positive, but their values and levels of significance are indeed different before and after 1996. The coefficients are positive in either period, but the effect is stronger and statistically more significant for the period after 1996. Before the start of the Uruguay Round Agreement on Agriculture, the increase of the gap in levels of producer support by 10 % had increased the productivity ratio by 0.15 percent. This had necessarily hindered developing countries' efforts to access available technology during that period. After the Uruguay round, however, a 10 % decrease in the difference between supports in developed and developing countries has decreased the index of productivity gap by 0.4 percent. This indicates that the reduction in the level of support

[6] See OECD; USDA; Mullen et al. (2004); Mullen, Orden, and Gulati (2005).

in OECD countries and reduction of taxation of rice production in developing countries did, on average, narrow the rice-productivity gap. In 2002, for instance, average rice PSE per metric ton of milled rice for Australia, US, Japan, and Korea was about 812 USD, whereas that of India was about 76 USD. For the same year, the calculated productivity index for OECD countries and for India were 2.388 and 0.968, respectively. The result implies that if the PSE gap had dropped by fifty percent, i.e., by 368 USD per ton (through any commitment to reduce producer support in the OECD countries), the productivity gap would have shrunk by (2.388/0.968)*0.04*50/100= 0.037 points. If the shrinking of the productivity gap were entirely attributed to India's increase in TFP, India's TFP level index would be 0.983, implying an increase of about 2 percent growth in the rice-productivity index. Such an increase is not negligible, taking into account how little TFP indexes have improved in the last forty years for developing countries. These results and examples show strong evidence for the impact of rice production and trade policies on rice productivity.

For the impacts of the remaining variables, table 5 shows that difference in degree of *Openness*, proxied as the total trade value as a percentage of GDP, positively and significantly increase the productivity gap. This indicates that the spillover effects from trade on R&D and technology for small open economies could help reduce the technology gap. On the other hand, trade protection could hurt technological progress in the rice sector. This is consistent with the new trade theories and the implications for poor countries of opening their economies and facilitating technological transfer through trade in physical and financial goods.

The ratio of total trade to total GDP may, however, seem too broad a representation for openness in a sub-sector of agriculture like rice, and the results could be sensitive to the choice of proxy used to represent openness.[7] For these reasons, I attempted to use 'rice openness,' which is ratio of rice total trade to rice production, as a proxy. From this new proxy, results showed that the coefficient on openness became 0.013; although it remained highly significant at a level of 5%, it had become negative, meaning that increased protections in the rice sub-sector helped increase rice productivity. Although such a finding goes against the conventional idea that openness in poor countries through the R&D spillover effects should allow them to close the productivity gap, it is not entirely surprising, especially for the rice trade. It is consistent with arguments (e.g., Rodrik, 1992) that openness may not always guarantee closing of the TFP gap. More important, it is consistent with reality in the rice trade because the high income countries, especially Japan and South Korea, and to a lesser extent the United States, have achieved high rice TFP growth while the degrees of openness of their rice markets are among the lowest. The explanation is that for many developed countries, their high import protection has kept their farmers' income high, enabling these farmers to cover the cost of technology adoption. In contrast, small open countries' rice farmers lost market share and income to the cheaper imported rice and could no longer afford the cost associated with technology adoption. In the end, increased rice protection in developed countries and increased rice openness in developing countries worked toward the widening of the rice-productivity gap.

[7] See Edwards (1997) for explanations of the difficulty of choosing proxies for openness.

Results in table 5 also show that differences in access to agricultural equipment and in infrastructure variables linked to the overall agricultural sector (such as differences in the levels of irrigation and of fertilizer use) between developed and developing countries significantly affect the productivity gap. The only mixed result is on the coefficient of human capital variable; although the coefficient is positive as expected, it is not statistically significant to affect the difference in rice productivity. For the rest, a 10% decrease in the gap of the level of irrigation per unit of arable land is associated with a reduction in rice-productivity gap by 6 percent. Likewise, a 10% decrease of the gap in fertilizer use per unit of arable land would narrow the productivity gap by 5 percent. These results are not surprising. Many developing countries in Group 2 such as China and Indonesia have made consistent and significant efforts in improving agriculture infrastructure such as irrigation dams and input deliveries. These have certainly improved productivity and eventually efficiency in agriculture and in rice farming. Similarly, access to agricultural equipment, proxied as the ratio of equipment price indexes, is another important source of the TFP gap: the productivity gap could be narrowed faster if equipment were more accessible to rice farmers in developing countries. A ten percent reduction of the price of equipment in developing countries relative to price in developed countries would narrow the TFP ratio by about 6 percent.

Conclusions

Agriculture policies in both developed and developing countries have distorted rice production and trade, but the impacts on developing countries' lagging productivity have remained unexplored. Using panel data on thirty-three rice-producing countries between 1961-2002, this article explains how distortions have affected productivity in the rice sub-sector. The thirty-three countries were divided into three groups according to their income or agricultural value-added and rice yields. The analysis avoided using yields to represent productivity and innovatively constructed productivity levels and growth indexes using a dynamic panel model; the residuals measuring total factor productivity levels in the model included fixed-effects and autoregressive components. These indexes were employed in the estimation of an econometric model linking the gap in producer support between developed and developing countries to the productivity indexes.

Results showed that levels of productivity in the rice sector have been significantly higher in high-income countries than in the rest of the world. The average rate of productivity growth in low-income rice-producing/importing countries has been the lowest. Results also indicated that there is a sharp and widening productivity gap among the three groups of rice-producing countries. The total factor productivity growth rates are 1.7%, 1.1% and 0.8% for the groups of rich countries, developing countries exporting rice, and developing countries importing rice, respectively. Such results contradict the 'catching-up' hypothesis because low-income rice-producing countries started at a low technology level but still have low productivity growth and cannot catch the productivity levels in the rich rice countries.

More important, results showed that the support gap, namely high protection and subsidies for rice farmers in developed countries and taxation of rice farming in developing countries, has been one of the main sources of the productivity gap between rice productions in developed and developing countries. The effects of the high distortions before the implementation of the reforms of the Uruguay Round Agreement have strongly contributed to the productivity gap, but the reduction of the distortions after the implementation of reforms agreed to in the Round has helped to close that gap. Gaps in agriculture infrastructure such as irrigation and in input delivery also affected rice productivity gap. Moreover, openness in total trade for developing countries helped reduce rice-productivity gap; estimation results also showed that in the rice sub-sector, import barriers on rice in developed countries combined with openness in rice trade in developing countries have widened the rice-productivity gap between developed and developing countries.

The evidence coming out of these results would have been strengthened if a longer time series and more country data were available. In particular, the estimation of the total factor productivity indexes would have benefited from detailed country or farm data specifying the amount of inputs used exclusively in rice production. The extrapolation of input uses, especially labor use, in the rice sector to obtain these productivity indexes at a country level entails a few biases. One is that labor-intensity differs among crops and rice varieties. Another is that rice labor-intensity and labor use vary by farm and location. But the biases are certainly reduced in the cases of some developing countries where rice is the main agricultural activity. Moreover, the biases are minimal if the growth of the acreage-adjusted labor force follows the growth of labor use for rice because, to compute total factor productivity growth, the pattern of growth of labor use is more relevant than the actual level of labor use. To ensure that the estimates were workable, I performed a correlation test that revealed a strong and positive correlation between the estimated total factor productivity indexes and actual yields.

Despite these limitations born out the lack of data, these results largely indicate that rice production and trade policies have affected productivity, especially in low-income countries. The findings lead to three major implications for developing countries' rice productivity. First, reduction and removal of production and export subsidies and of high protection in developed countries will help rice producers from developing countries to increase productivity. This is because the removal of protection and subsidies can increase the price received by poor farmers, allowing them to earn enough to invest in new technology. Second, removal of developing countries' taxations of rice production and export will lift the cap on farm prices and boost access to technology and productivity growth. Third, the rice-productivity gap will continue to widen if developing countries unilaterally open up their rice markets while the developed countries refuse to reduce protection and subsidies further in the rice sub-sector.

These findings and implications apply to many other highly distorted commodity markets such as maize, milk and dairies, and sugar. The rice example shows that improving the developing countries' productivity levels depends on comprehensive multilateral reforms that remove all distortions in both developed and developing countries. Increased productivity in developing countries is not a prerequisite for their benefits from the multilateral reforms; it is a benefit emerging from such reforms.

Appendix A
Rice production and trade in selected countries, 2002

Country	Yields Paddy Rice (MT/ha)	Paddy production (MT)	Milled rice Net Export (MT)	Agricultural value-added per worker* (USD 1995 constant)
1. Argentina	5.746	713,449	220,745	10,374.550
2. Australia	8.607	1291,000	268,540	36,865.740
3. Bangladesh	3.423	3,7851,000	-942,872	322.218
4. Brazil	3.324	10,457,100	-531,998	5,086.847
5. Cambodia	1.916	13,822,509	-17,227	421.817
6. China	6.186	176,342,195	1,728,144	342.496
7. Colombia	5.011	2,346,940	-62,355	3,636.244
8. Egypt	9.141	5,600,000	463,021	1,331.858
9. Guinea	1.613	845,000	-331,975	293.3051
10. Guyana	3.825	443,700	174,247	4,267.472
11. India	2.683	107,600,096	5,052,370	411.093
12. Indonesia	4.469	51,489,696	-1,967,717	749.192
13. Iran	4.727	2,888,000	-868,789	3,790.597
14. Italy	6.270	1,371,100	504,619	27,654.190
15. Japan	6.582	11,111,000	-626,902	34,140.070
16. Korea	6.350	6,687,225	-151,299	14,743.210
17. Laos	3.086	2,416,500	-26,400	624.339
18. Madagascar	2.141	2,603,965	-61,082	156.128
19. Malaysia	3.090	2,091,000	-518,205	6,929.884
20. Mali	1.971	710,446	-10,076	286.595
21. Myanmar	3.674	22,780,000	723,744	n.a.
22. Nepal	2.675	4,132,600	-14,636	206.351
23. Nigeria	1.024	3,192,000	-1,199,637	742.223
24. Pakistan	3.018	6,717,750	1,670,491	698.227
25. Peru	6.687	2,118,616	-34,175	1,850.983
26. Philippines	3.280	13,270,653	-1,196,157	1,475.778
27. Sri Lanka	3.489	2,859,480	-92,784	710.0172
28. Suriname	3.940	163,410	42,975	3,619.626
29. Tanzania	1.964	640,189	-67,475	190.289
30. Thailand	2.609	26,057,000	7,336,663	878.126
31. United States	7.373	9,568,996	285,701	53,402.960
32. Uruguay	5.863	939,489	650,876	7,874.232
33. Vietnam	4.590	34,447,200	3,201,000	258.498

Note: (*) Year 2001 figures.
Sources: United Nations (FAO); US Department of Agriculture; World Bank.

Appendix B

Data

Countries:

Countries included in this studies are Argentina (1), Australia (2), Bangladesh (3), Brazil (4), Cambodia (5), China(6), Colombia(7), Egypt(8), Guinea(9), Guyana(10), India (11), Indonesia (12), Iran (13), Italy(14), Japan(15), Korea(16), Laos(17), Madagascar(18), Malaysia(19), Mali(20), Myanmar(21), Nepal(22), Nigeria(23), Pakistan(24), Peru (25), Philippines(26), Sri-Lanka(27), Suriname(28), Tanzania(29), Thailand(30), United States(31), Uruguay(32), and Vietnam(33).

We divide these 33 countries in this study into three groups depending on the level of income, agricultural value-added per worker and their position as net exporters or net importers:

Group 1: Australia, EU (Italy), Japan, Korea, and the United States. These are high-income countries with high rice yields and high trade protection as well. Production and export are heavily subsidized in these countries.

Group 2: Argentina, China, Colombia, Egypt, Guyana, India, Myanmar, Pakistan, Suriname, Thailand, Vietnam, Uruguay. These are rice exporting countries with medium to high yield levels.

Group 3: Bangladesh, Brazil, Cambodia, Guinea, Indonesia, Iran, Laos, Madagascar, Mali, Malaysia, Nepal, Nigeria, Peru, Philippines, Sri Lanka, and Tanzania.

These countries are producers and net importers of rice. Their rice yields are among the lowest.

***Variables*:**

The following refers to equation (1) - (1c). Variable sources are in parenthesis

y = log of milled rice production in MT per 1000 worker (FAO);

x's = logarithm of input per 1000 worker:

(i) fertilizer: fertilizer use fro rice for developed countries and the total fertilizer use in MT times the share of harvested rice fields over arable land for developing countries. (FAO, IRRI)

(ii) physical capital: which is the number of tractor uses proxyied as the number of tractors per unit of land* areas harvested (FAO)

(iii) land: rice harvested area in hectares (FAO);

Xk = labor amount of labor in rice production proxyied as the rice-area share of agricultural labor force (FAO, World Bank).[8]

The following variables refer to model in equation (7):

TFP **=** TFP level index (Author);

S = Producer support estimate in USD/MT (OECD; USDA; Mullen, Orden and Gulati, 2005; Nguyen and Grote, 2004; Thomas and Orden, 2004)[9];

***OPEN* =**

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[8] See Carter, Chen, and Chu (1999); Delgado and Chandrashekhar (1987). Also see Evenson, Pray, and Rosegrant (1999) for an equivalent method. Basant and Fickert (1996) used total number of workers times the ratio of a firm labor cost to industry labor compensation to compute labor use in measuring an individual firms' productivity.

[9] See Tangermann (2006) for discussion about use of PSE as an index of agricultural support.

(i) Trade Openness: Trade value over GDP; (Penn World Table by Heston, Summers and Aten (2002), World Bank).

(ii) Rice openness: sum of import and export volume, divided by total production (FAO; US Department of Agriculture; World Bank);

HK = Human Capital is the net secondary enrollment ratio (World Bank);

INFRA = ***Irrigation***: ratio of irrigated land over arable land (FAO),

= ***Fertilizer*** : fertilizer use in MT per ha (FAO, IRRI);

w = Price index (deflated) of agricultural and farm equipment, or herbicide price index (FAO, IRRI, MAFF, US Department of Commerce; US Department of Labor).

Appendix C
Estimates of TFP index level and growth in rice sector (1961-2002)

Year	Country Group I			Country Group II			Country Group III		
	Level	Log-level	Growth	Level	Log-level	Growth	Level	Log-level	Growth
1961	1.2445	0.2187	-	1.1182	0.1117	-	1.0000	0.0000	-
1962	1.3569	0.3052	0.0865	1.2704	0.2393	0.1276	1.1597	0.1482	0.1482
1963	1.3625	0.3093	0.0041	1.2216	0.2002	-0.0391	1.1629	0.1509	0.0027
1964	1.3843	0.3252	0.0159	1.1560	0.1450	-0.0552	1.1308	0.1229	-0.0280
1965	1.3003	0.2626	-0.0626	1.1681	0.1554	0.0104	1.0955	0.0912	-0.0317
1966	1.4514	0.3725	0.1099	1.1384	0.1296	-0.0258	1.0585	0.0569	-0.0343
1967	1.5005	0.4058	0.0333	1.2033	0.1851	0.0555	1.1456	0.1359	0.0790
1968	1.4159	0.3478	-0.0580	1.2174	0.1967	0.0116	1.1329	0.1248	-0.0111
1969	1.5697	0.4509	0.1031	1.2528	0.2254	0.0287	1.1653	0.1530	0.0282
1970	1.4752	0.3888	-0.0621	1.3270	0.2829	0.0575	1.1526	0.1420	-0.0110
1971	1.5428	0.4336	0.0448	1.3021	0.2640	-0.0189	1.1231	0.1161	-0.0259
1972	1.4325	0.3594	-0.0742	1.2861	0.2516	-0.0124	1.1188	0.1123	-0.0038
1973	1.5893	0.4633	0.1039	1.3131	0.2724	0.0208	1.1666	0.1541	0.0418
1974	1.5792	0.4569	-0.0064	1.3002	0.2625	-0.0099	1.1702	0.1572	0.0031
1975	1.5979	0.4687	0.0118	1.3229	0.2798	0.0173	1.1762	0.1623	0.0051
1976	1.5781	0.4562	-0.0125	1.2770	0.2445	-0.0353	1.1463	0.1365	-0.0258
1977	1.5815	0.4584	0.0022	1.3202	0.2778	0.0333	1.1615	0.1497	0.0132
1978	1.6952	0.5278	0.0694	1.3414	0.2937	0.0159	1.1806	0.1660	0.0163
1979	1.7802	0.5767	0.0489	1.3435	0.2953	0.0016	1.0913	0.0874	-0.0786
1980	1.4914	0.3997	-0.1770	1.4082	0.3423	0.0470	1.2182	0.1974	0.1100
1981	1.8049	0.5905	0.1908	1.4537	0.3741	0.0318	1.1616	0.1498	-0.0476
1982	1.7748	0.5737	-0.0168	1.4915	0.3998	0.0257	1.1793	0.1649	0.0151
1983	1.6888	0.5240	-0.0497	1.4715	0.3863	-0.0135	1.2238	0.2020	0.0371
1984	1.7746	0.5736	0.0496	1.4668	0.3831	-0.0032	1.1699	0.1569	-0.0451
1985	1.9150	0.6497	0.0761	1.5034	0.4077	0.0246	1.2912	0.2556	0.0987
1986	1.8597	0.6204	-0.0293	1.4859	0.3960	-0.0117	1.2437	0.2181	-0.0375
1987	1.7644	0.5678	-0.0526	1.4783	0.3909	-0.0051	1.2625	0.2331	0.0150
1988	1.9242	0.6545	0.0867	1.4921	0.4002	0.0093	1.2345	0.2107	-0.0224
1989	2.0154	0.7008	0.0463	1.5270	0.4233	0.0231	1.3286	0.2842	0.0735
1990	2.0283	0.7072	0.0064	1.4702	0.3854	-0.0379	1.2691	0.2383	-0.0459
1991	1.9945	0.6904	-0.0168	1.4995	0.4051	0.0197	1.3099	0.2699	0.0317
1992	2.0824	0.7335	0.0431	1.5358	0.4291	0.0240	1.2594	0.2306	-0.0393
1993	1.8638	0.6226	-0.1109	1.5492	0.4378	0.0087	1.3122	0.2717	0.0411
1994	2.2261	0.8002	0.1776	1.5606	0.4451	0.0073	1.2665	0.2362	-0.0355
1995	2.0782	0.7315	-0.0687	1.6016	0.4710	0.0260	1.3187	0.2767	0.0404
1996	2.1596	0.7699	0.0384	1.6171	0.4807	0.0097	1.3543	0.3033	0.0266
1997	2.2444	0.8085	0.0386	1.6300	0.4886	0.0079	1.2744	0.2425	-0.0608
1998	2.2518	0.8118	0.0033	1.6142	0.4788	-0.0098	1.3146	0.2735	0.0310
1999	2.3400	0.8502	0.0384	1.6776	0.5174	0.0385	1.3652	0.3113	0.0378
2000	2.2613	0.8159	-0.0342	1.6704	0.5131	-0.0043	1.3576	0.3057	-0.0056
2001	2.4689	0.9038	0.0879	1.7038	0.5329	0.0198	1.3359	0.2896	-0.0161
2002	2.3876	0.8703	-0.0335	1.6933	0.5267	-0.0062	1.3696	0.3145	0.0249

Note: Group 1 includes Australia, EU (Italy), Japan, Korea, and the United States. Group 2 includes Argentina, China, Colombia, Egypt, Guyana, India, Myanmar, Pakistan, Suriname, Thailand, Vietnam, and Uruguay. Group 3 includes Bangladesh, Brazil, Cambodia, Guinea, Indonesia, Iran, Laos, Madagascar, Mali, Malaysia, Nepal, Nigeria, Peru, Philippines, Sri Lanka, and Tanzania.

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