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Journal of Rural Economics, Special Issue
(*Nihon Nogyo Keizai Gakkai Ronbun-shu 2013*)

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The Agricultural Economics Society of Japan

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(*Nihon Nogyo Keizai Gakkai Ronbun-shu 2013*)

Nutrient-Income Nexus in Nigeria: A Co-integration Analysis

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1. INTRODUCTION

Food policy analysts consider the level of nutrient intake, in particular calories (energy) as an important indicator of performance when it is related to labour productivity. This observation is taking very seriously in the developing economies, where agriculture accounts for most of the economic activities. For example, Stiglitz [16] highlights the significant role of calorie intake as one of the key drivers of labour productivity and health related issues in any given society. Neeliah and Shankar [12] observe that nutrition is the fundamental prerequisite for human welfare and contributes to human capital development, and that the lack of key nutrients such as calories, protein, iron, calcium, and vitamin is a common phenomenon in most developing countries. Conversely, inadequate nutrient intake has always been used to describe dietary shortage or nutrient deficiency (malnutrition) and perhaps evidence of food insecurity and poverty in the literatures.

In Nigeria, the annual average daily per capita calorie demand has fluctuated between a low of 1,645kcal in 1972 and high of 2,740kcal in 2007 with a long term average of about 2,116 kcal for 1961-2007 (47 years) as shown in Table A of the appendix. But a closer look at the figures in Table A (say for 1990s and 2000s) show that average annual national per capita demand for calorie intake has not only improved significantly for these periods but higher than the FAO recommended 2,400kcal/day for an adult in the country. This probably shows that decline in long-term average relative to the FAO recommendation is not a current problem. Also, Table A reveals that an average daily per capita protein intake of about 48g, which is lower than the FAO recommended daily minimum intake of 0.66 gram per kilogram of idea body weight was obtained within the same period. However, the daily per capita protein intake in the country was at the lowest in 1979 with the value of about 39g, while it was at the highest in 2007 with the value of about 64g. While an average *real* per capita GDP (2000 constant) of about 53,264 Naira was obtained for 1961-2007 as shown in the lower panel of Table A, the Table also reveals that the average point estimates of the *real* per capita GDP in the country is characterized by rising and falling trend in distribution for the same period.

Given that economic growth measured in terms of per capita GDP is viewed as a double-edged sword for nutrition highlight the importance of understanding the relationship between income (per capita GDP) and nutrient intake. In other words, knowledge of how income responds to nutrient intake and vice-versa (i.e., elasticity) is vital in the design of policies to combat malnutrition in poor countries and to improve diets in both rich and poor countries. For example, large nutrient-income elasticity suggests a policy designed to increase the income of the poor and promote economic growth is an effective long-term strategy. Similarly, small nutrient-income elasticity suggests limited scope for income-enhancing economic policies (Dawson and Tiffin [5]; Mushtaq, Gafor and Abedullah [11]; Neeliah and Shankar [12]).

To this end, the objective of the study is to investigate the relationship between per capita national demand for nutrients and per capita national income in Nigeria. Within this context, the study intends to provide answers to the following research questions: (1) Does annual per capita national demand for nutrients viz. per capita calorie and protein intake increase significantly with real per capita national income and what is the magnitude of the elasticity of such relationship in reference to Engel Curve Hypothesis in Nigeria? and (2) Is *real* per capita national income (a measure of labour productivity at national level) affected significantly by annual per capita national demand for nutrients (e.g., per capita calorie and protein intakes) and what is the magnitude of the elasticity of such relationship within the context of Efficiency Wage Hypothesis in Nigeria?

2.0 CONCEPTUAL FRAMEWORK AND EMPRICAL MODEL

The relationship between the demand for nutrients and income has attracted interest among researchers over the years (Ogundari and Abdulai [13]) and this relationship can run in either ways. In this regard, there are two lines of inquiries into the relationship as revealed by Bious [3], which led to the following popular hypotheses in the economic literature. The *first* is Engel Curve Hypothesis, which states that the demand for nutrients (e.g., calorie or protein intake) responds positively to increase in income. The *second* is Efficiency Wage Hypothesis of Stiglitz [16], which states that the efficiency of workers in terms of the effort supplied depends on their wages through the nutrition that their income allows them to purchase.

The first hypothesis is built within the 'conventional wisdom' of the World Bank and other development institutions that income growth can alleviate and eventually eliminate inadequate nutrient intake (World Bank [21]). According to UN [20] and Tiffin and Dawson [19], large nutrient-income elasticity suggests a policy designed to increase income of the poor and promote economic growth is an effective long-term strategy to decrease malnutrition or poverty, especially in the developing countries. Conversely, small nutrient-income elasticity suggests limited scope for income enhancing economic policies as such policies could not alone decrease malnutrition or poverty. Consequently, the joint influences of food prices, household demographic distributions, and household income have been identified as factors likely to enhance household demand for nutrients in the literature by Abduali and Aubert [1]. As also noted by Ogundari and Abdulai [13], when the relationship between nutrient intake and income is significantly not different from zero irrespective of the size of the estimated elasticities, it implies that income mediated policies will have no impacts on nutritional goals.

The second hypothesis is in support of Stiglitz's [16] argument that a rising level of nutrient demand can increase the efficiency of labour and hence, per capita income, such that income growth is constrained by nutrient availability. For example, poor nutrition can spur a cycle leading to poor health, losses in labour productivity due to inadequate nutrition can cause 6-10% reduction in per capita GDP, which in turn results in low productivity and diminished income growth (UN [20]).

A search in the literature shows that several studies have provided elasticity estimates for the first hypothesis at micro level by Abdulai and Aubert [1], Bocoum and Dury [4], Orewa and Iyangbe [15] etc. and at macro level by Neeliah and Shankar [12], Dawson and Tiffin [5], and Mushtaq, Gafor and Abedullah [11] etc., while many of the studies using macro data employed Granger causality test to validate the hypothesis. By contrast, there were fewer studies on the second hypothesis that provide elasticity estimates for Efficiency Wage model with all using micro data such as Strauss [17] and Behrman, Foster and Rosenzweig [2]. Although, studies at macro level by Dawson and Tiffin [5], Tiffin and Dawson [19], and Mushtaq, Gafor and Abedullah [11] employed Granger causality test to test Efficiency Wage Hypothesis, they provide no elasticity estimates for Efficiency Wage model.

Given the number of studies on the relationship between nutrition and income at macro level (see for detail; Ogundari and Abdulai [13]), a weak consensus concerning whether income (economic growth) alone is or not an effective long-term strategy to combat malnutrition in developing economies still exists in the literature.

To this end, this study aims to contribute to the existing literature in two ways at macro level. *First*, while most of the previous studies focused on calorie as the single macronutrient of interest, we also consider the demand for protein. *Second*, while most of the previous studies focused on first hypothesis and provided elasticity estimates for the Engel Curve model, the present study incorporates the analysis of the second hypothesis with the aim of providing elasticity estimates for the Efficiency Wage Hypothesis. However, the focus of the present study on macro-analysis is not only to provide a national estimate of the nutrition-income transition and vice-versa, but also to allow the results of the nutrient-income relationship to be generalized or vary at macroeconomic level, which is very crucial for designing national food security program.

2.1. *Engel Curve Hypothesis*

This hypothesis follows the framework developed by Dawson and Tiffin [5], Tiffin and Dawson [19], and Mushtaq, Gafor and Abedullah [11], where the sole determinant of the demand for nutrients NT_t is *real* per capita income Y_t and this is implicitly defined as $NT_t = f\left(Y_t\right)$. In their studies, Dawson and Tiffin [5], Tiffin and Dawson [19], and Mushtaq, Gafor and Abedullah [11] observed that the inclusion of weighted price index in the relationship is significantly not different from zero. The authors end up estimating parsimonious Engel Curve model with *real* per capita GDP as sole determinant of aggregate calorie intake in their respective studies.

Taking the logarithm of the relationship gives a specification that is consistent with Engel Curve model and serves as the empirical model to address the first research question of this paper as

$$\log NT_t = \mu_0 + \beta_1 \log Y_t + \varepsilon_t \qquad t = 1,2,......47 \qquad (1)$$

2.2. *The Efficiency Wage Hypothesis*

Also, following the framework provided by Stiglitz [16], the sole determinant of *real* per capita national income Y_t represented by *real* per capita GDP is per capita national demand for nutrients NT_t and this is implicitly defined as $Y_t = g\left(NT_t\right)$. And, taking the logarithm of the relationship gives a specification that is consistent with Efficiency Wage Hypothesis employed as empirical model to provide answer to the second research question of this paper as

$$\log Y_t = \alpha_0 + \gamma_1 \log \mathrm{NT}_t + \eta_t \qquad t = 1,2,......47 \qquad (2)$$

where, $NT_t = [C_t, P_t]'$ is a vector of endogenous variables, which represents nutrient intake considered in the present study.

In this regard, C_t represents daily per capita calorie intake and P_t represents daily per capita protein intake. The parameters β_1 and γ_1 represent estimated nutrient-income and income-nutrient elasticities, respectively; μ_0 and α_0 are the intercepts of the regressions, while ε_t and η_t are white noise error for the equations (1) and (2), respectively.

In line with co-integration analysis, estimation of equations (1) and (2) follow the framework of Vector Auto-regression (VAR) defined as

$$Z_t = \mu + A_1 Z_{t-1} + A_2 Z_{t-2} + \ldots\ldots + A_{k-1} Z_{t-k+1} + \varepsilon_t \qquad (3)$$

where Z_t is a vector of I(1) endogenous variables such that $Z_t = \left[NT_t, Y_t\right]'$ which is a (2x1) vector; μ is a (2x1) vector parameters; ε_t is a (2x1) vector of white noise errors with $E\left[\varepsilon_t\right] = 0$ and k is the number of lags.

3. THE DATA

The data used for the study represents annual time series for 1961-2007 (47 years), which covered national daily per capita calorie intake in kilocalories and daily per capita protein intake in gram derived from FAOSTAT database on Nigeria. In addition, we supplemented the data with *real* per capita national income represented by the *real* per capita GDP (2000 constant price) in local currency unit (Naira) from the World Bank's World Development Indicators (WDI) database covering the same period of years. Thus, presented in Table A is the trends and pattern of average national daily per capita calorie and protein intake across selected food groups and *real* per capita GDP in Nigeria for 1961-2007 as extracted from these database.

A major issue of concern in many economic data in time series is the fact that they can be non-stationary as noted by Harris [8]. In this case, using ordinary least squares (OLS) regression in estimating non-stationary time series data will lead to spurious results. Given this, the data generating process (DGP) for time series data requires that we check for the property of the series such as unit root and existence of co-integration relationship between the pair of series prior to empirical analyses. The former is essential to overcome the problem of spurious regression, while the later is important to investigate if there is evidence of a meaningful long-run relationship between the pairs. This is important because co-integrating relationship cannot exist between two variables, which are integrated of a different order. In view of this, we make an attempt to test for the order of integration of the variables used in this study using Johansen's [9] trace test approach.

In testing for the presence of unit root in the series, which has been expressed in logarithm, we employ both the Augmented Dickey-Fuller (ADF) test of Dickey and Fuller [7] and Said and Dickey [15] and the KPSS test of Kwiatkowski, Philip, Schmidt and Shin [10] with maximum number of three lags. The null hypothesis of the ADF test is the presence of a unit root (I (1)), while the alternative hypothesis is stationarity in the series (I (0)). On the other hand, the null hypothesis for the KPSS is stationarity (I (0)), while the alternative hypothesis is a unit root in the series (I (1)). The number of the lags is guided by the Akaike Information Criterion (AIC) to ensure that the serial correlation in the series is absent. The tests were carried out for two specifications in the data; 1) with constant only, and 2) with constant and trend as shown in Table 1. Thus, presented in Table 1 are the results of the unit root test, which show that the series are non-stationary (I (1)), while the series become stationary after first differences (I (0)) for both specifications.

Table 1: Unit Root Tests

Variable	ADF				KPSS			
	Constant		Trend + constant		Constant		Trend + constant	
	Statistics	CV	Statistics	CV	Statistics	CV	Statistics	CV
C_t	-0.3011	-2.86	-2.5582	-3.41	1.9006	0.463	0.4247	0.146
ΔC_t	-5.4568		-5.7283		0.2164		0.0655	
P_t	-0.4766		-3.1039		1.9015		0.4270	
ΔP_t	-5.9387		-6.3212		0.2047		0.0384	
Y_t	-1.4199		-1.6954		0.6525		0.1799	
ΔY_t	-4.6109		-4.5601		0.0808		0.0804	

CV implies critical value at 5% level of significance

As usual in time series analysis and following the result of the unit root tests, we sought to determine the existence of co-integration relationship between the pair of the series using the Johansen's [9] trace statistics. The trace statistic is designed to test the null hypothesis of at most r co-integrating vectors against the alternative that the number of co-integrating vectors is greater than r. To this end, Table 2 presents the result of the co-integration relationship as the likelihood ratio (LR) tests with maximum three lags showing that the null hypothesis of no co-integration vector ($r=0$) between the pair of the series for the Engel Curve model of equation (1) and Efficiency Wage model of equation (2) are rejected at 5 % level of significance. Further, the null hypothesis of one co-integration vector (r=1) between the pair of the series was also rejected in favor of at most two co-integration relationship ($r=2$).

Table 2: Trace Statistics

Equation tests	Ho	H_1	Trace statistics	CV of Trace of statistics
	$r=0$	$r=1$	6.22	15.41
C_t, Y_t	$r=1$	$r=2$	0.08	3.76
Y_t, C_t,	$r=0$	$r=1$	4.18	15.41
	$r=1$	$r=2$	0.18	3.76
	$r=0$	$r=1$	6.15	20.16
P_t, Y_t	$r=1$	$r=2$	0.11	3.76
Y_t, P_t,	$r=0$	$r=1$	4.59	15.41
	$r=1$	$r=2$	0.21	3.76

CV implies trace statistics with critical value at 5% level of significance

4.0 RESULTS AND DISCUSSION

4.1. *Estimates for the long-run equilibrium relationship*

In order to provide answers to the first and second research questions of this paper, we estimated both equations (1) and (2) using OLS and the results are presented in Table 3. The estimated parameters β_1 and γ_1 are the elasticities of interest in the study. For the Engel Curve model represented by equation (1), the per capita demand for calorie and protein intake has positive and significant long-run income elasticity of about 0.326 and 0.312, respectively. According to Deaton [6], calorie-income elasticities ranging from 0.30-0.40 is not too low but not high enough to identify the role of income in improving nutrition. In contrast, Subramanian and Deaton [18], argue that calorie-income elasticities > 0.40 is substantially high enough to identify the role of income in alleviating and eventually eliminate inadequate nutrition. In other words, the higher the estimated nutrient income elasticity, the most likely to conclude that income will play a major role in alleviating malnutrition as percentage increase in income to attain optimum nutrient level decreases with improvement in the elasticity. Since, nutrient- elasticities obtained in the present study are within 0.3-0.4, this suggests that income enhancing economic policies could not alone decrease malnutrition or food-poverty in Nigeria. According to Abdulai and Aubert [1], the joint influences of food prices, household demographic distributions, and household income have been identified as factors likely to enhance household demand for nutrients. A search in the literature shows that the estimated calorie-income elasticity is similar to 0.31 obtained for Zimbabwe also from Africa by Tiffin and Dawson [19] and 0.34 obtained for India by Dawson and Tiffin [5] and higher than 0.21 obtained for Pakistan by Mushtaq, Gafor and Abedullah [11].

For the Efficiency Wage model represented by equation (2), the results show a positive and significant long-run calorie and protein elasticity of about 0.305 and 0.326, respectively. A search in the literature however, shows that there is no study that provides elasticity for Efficiency Wage model at macro level from which the findings of the present study could be compared.

Table 3: Long-Run Co-integration Relationship between pair of the series

Nutrient	*Engel Curve Model*		*Efficiency Wage Model*	
Demanded	μ_0	β_1	α_0	γ_1
Calorie	1.7814** (0.6904)	0.3258** (0.1462)	3.7087***(0.4545)	0.3045** (0.1369)
Protein	0.2036 (0.6526)	0.3119** (0.1382)	4.1746***(0.2423)	0.3260** (0.1444)

*Figure in parentheses are standard error; *, **, *** implies significant at 10%, 5%, & 1%, respectively.*

4.2. *Granger Causality Test*

According to Neeliah and Shankar [12], co-integration relationship such as equations (1) and (2) reveals nothing about direction of causation, but only that a long-run relationship between the variables exists or not. In other words, it implies Granger causality runs in at least one direction. Guided by this, the study employs the standard Granger-causality test to investigate the direction of causality between the pair of the series. And, the results show that the hypothesis that *real* per capita GDP does not Granger cause the demand for nutrient intake viz. calorie and protein was rejected with p-values of 0.0041 (F-statistics: 5.7908) and 0.0062 (F-statistic: 5.6283), respectively with three lags. Further, the hypothesis that nutrient intake viz. calorie and protein does not Granger cause real per capita GDP could not be rejected with p-values of 0.2461 (F-statistic: 1.0204) and 0.3749 (F-statistic: 1.2798), respectively also at maximum 3 lags. The implication of these findings is that causality only runs from *real* per capita GDP to annual per capita nutrient intake (i.e., $GDP_t \rightarrow NT_t$) and not from annul per capita demand for nutrients to *real* per capita GDP (i.e., not $NT_t \rightarrow GDP_t$). That is unidirectional causality exist from per capita national income to the per capita national demand for nutrients in the study. A search in the literature shows that these findings are the same as Dawson and Tiffin [5] and Mushtaq, Gafor and Abedullah [11] for India and Pakistan, respectively, who found that causality only runs from income to calorie consumption, but different from Tiffin and Dawson [19] who found bidirectional causality for Zimbabwe, while Neeliah and Shankar [12] found no evidence of causality in both directions.

Therefore, using the results of Granger causality test as a guide, the estimated long-run nutrient-income elasticities found to be significant and within 0.30-0.4 in magnitude from the Engel Curve model of Table 3, implied that limited scope exist for policies aimed at using income to reduce malnutrition alone in the country as other factors such as food prices and household demographic distribution in addition to income are more likely to play significant influence in increasing the consumption of nutrients in the country. Also, considering the estimated nutrient elasticity of income generation found to be significant and relatively large in the Efficiency Wage model of Table 3, the results of Granger causality test suggest that income generation is unconstrained by the demand for nutrients in the study.

5.0 CONCLUSIONS

The paper uses time series data for 1961-2007 to investigate the long-run relationship and causality between annual per capita national demand for nutrients and per capita national income using co-integration analysis in Nigeria. The results of co-integration analysis reveal a long-run income elasticity of demand for calorie and protein of 0.326 and 0.312, respectively and long-run calorie and protein elasticity of income generation of 0.305 and 0.326, respectively. The elasticities are significantly different from zero. While the Granger causality test shows that causality runs from *real* per capita national income to per capita national demand for nutrients, the analyses provide no support for any causality from per capita demand for nutrients to *real* per capita national income in the study. Although the former support the Engel Curve Hypothesis, the fact that the estimated long run nutrient-income elasticities are less than 0.4 in magnitude, suggest that policies aimed at alleviating inadequate nutrient intake should not focus on income alone in the country. On the other hand, the latter suggests that the Efficiency Wage Hypothesis is not supported despite the fact that the estimated nutrient elasticity of income generation is significant and relatively large in the study, which thus implies that income generation is unconstrained by the demand for nutrients.

Finally, the future research is to extend the data to all the countries in sub-Saharan Africa (SSA) in an attempt to understand if there is evidence of long-run equilibrium relationship and causality between annual per capita national demand for nutrients and per capita national income in the region. We believe this result could be very useful for food and nutrition policy decisions, since individual country level estimates may not be ensued at the regional level.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support of the JSPS towards the first authors' postdoctoral fellowship at Kyushu University, Fukuoka and also for providing research grant with ID No. 24-02406.

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Appendix

Table A: Average daily per capita calorie and protein demand and per capita GDP in Nigeria, 1961-2007

Variables	1960s	1970s	1980s	1990s	2000s[a]	POOLED
	Mean	Mean	Mean	Mean	Mean	Mean
	Daily per capita Calorie consumption in Kilocalorie					
CALORIE	1905.44	1778.78	1914.69	2507.94	2628.35	2116.32
	Daily per capita protein consumption in gram					
PROTEIN	43.62	40.72	44.52	55.24	59.72	48.06
	Real per capita GDP (constant 2000) in LCU (Naira)					
INCOME	42,055.07	60,415.22	49,542.91	53,708.58	61,030.73	53,264.01

[a] *the 2000s covered 2000-2007*

Impact of Adopting a New Cash Crop

A Randomized Rice Seed Provision Trial in the Kenyan Highlands

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1. Introduction

During the first decade of the 21st century, most countries in Sub-Saharan Africa (SSA) experienced rapid economic growth and urbanization. However, the majority of the population still resides in rural areas and remains poor (AUC, UNECA, AfDB, and UNDP [2]). They have not benefited from economic growth, partly due to low agricultural productivity. Therefore, improved agricultural technology is required to alleviate poverty and sustain economic growth in SSA (Otsuka and Larson [10]). Historical experience tells us that technological innovation is the engine for increasing agricultural productivity (Hayami and Godo [6]). However, unless farmers adopt new technologies, innovation cannot be realized (Gollin, Morris, and Byerlee [5]). In fact, although a good number of agricultural technologies have been developed for SSA, they do not enhance productivity very much, because their adoption rate is low or because they are not adopted properly. Since the problems related with technology adoption are well recognized, there have been numerous studies on its constraints and impacts (some examples will be provided in the following literature review).

This paper analyzes the adoption of NERICA (New Rice for Africa) in Kenya. NERICA is the name of a group of improved rice varieties suitable for the upland conditions in SSA (Diagne [3]). It was developed by the Africa Rice Center in the 1990s and was introduced in many SSA countries during the first decade of the 21st century. The main research question is why NERICA has not been widely adopted in Kenya unlike its neighbor Uganda, and the hypothesis is that this is simply because NERICA seeds are not available in Kenya. The background of this research question is as explained below.

Traditionally, upland rice was not cultivated in Eastern and Southern Africa. Even today, upland rice is rarely cultivated, although urbanites as well as farmers in rural areas consume rice.[1)] In Uganda, however, upland rice cultivation became popular during the last decade, because after NERICA was formally released in 2002, the government began to distribute NERICA seeds widely as in-kind credit in 2004 (Kijima, Sserunkuuma, and Otsuka [8]). On the other hand, in Kenya, where upland rice was seldom cultivated, like in Uganda, NERICA rice varieties had not been officially registered as new rice varieties until March 2009, and there had been no formal dissemination until then. Even in February 2010, at the time of the first planting season after registering NERICA, NERICA seeds continued to remain unavailable in the market and extension offices in Kenya. It seems obvious then that the availability of NERICA seeds is the cause for the difference in upland rice cultivation between the two countries today. However, will Kenyan farmers plant the NERICA seeds if they are available? This paper attempts to answer this question.

Typical studies on technology adoption depend on household survey data collected after farmers are exposed to a new technology or a set of new technologies through formal or informal channels of technology dissemination (for example, Diagne [3] and Kijima, Sserunkuuma, and Otsuka [8]). Moreover, in a few cases where household data before the introduction of the technologies are fortunately available, the adoption and its impact can be investigated by comparing the situation before and after the introduction (for example, Kijima, Otsuka, and Sserunkuuma [7]). In either case, technology adoption is self-selected by farmers, and thus, the endogeneity has to be properly controlled for in order to assess its impact. Such approaches in the existing literature cannot be applied to the NERICA case for Kenya, since no farmer had cultivated NERICA seeds in February 2010, when the household survey was conducted.[2)]

Given this situation, our study conducts an experimental impact assessment of NERICA dissemination in Kenya by employing the randomized control trial (RCT) approach. The use of this approach for impact assessment has increased in recent times, because it can avoid the endogeneity problem typical to technology adoption in standard household survey data (Duflo, Glennerster, and Kremer [4]). The additional advantage of using the RCT approach is that it can deal with a non-existing technology when it is randomly assigned. To our best knowledge, no existing literature deals with randomized provision of seeds of a new crop.[3)]

2. Data Collection

We intentionally selected 14 communities (sub-locations being the smallest administrative unit in Kenya) around the Mwea irrigation scheme in the Kenyan highlands.[4)] Mwea is the largest irrigated paddy field in Kenya located about 100 km northeast of Nairobi and produces 50% of Kenya's rice. Rice growing in irrigated fields and rice millers' clusters located near Mwea are common sights for farmers in the communities around Mwea. That is, rice is not only a well-known staple food item, but it is also recognized as a promising cash crop with a high demand. However, upland rice is rarely cultivated in this area, and hence, NERICA was a totally new crop for them.

Through the extension office at each sub-location, we contacted farmers' groups that were interested in growing upland rice in each community, and we randomly selected one group per community in February 2010. Hence, we selected a total of 14 farmers' groups from 14 communities distributed around the Mwea irrigation scheme. Then, we randomly selected 10 member farmers who accepted upland rice cultivation (accepting farmers) and 10 member farmers who rejected it (rejecting farmers) from each of the 14 farmers' groups. Thus, the total number of sample households amounts to 280. The accepting farmers were willing to receive NERICA seeds under the condition that he/she would grow NERICA by himself/herself in the approaching rainy season.

Randomization took place among the accepting farmers. Out of the 10 accepting farmers of each farmers' group, 5 randomly selected farmers were provided with 10 kg of NERICA 4 (one of the NERICA varieties registered in Kenya) seeds for free.[5)] The remaining 5 accepting farmers did not receive any seeds and were promised that they would be provided seeds next year, that is, in February 2011. Note that 10 kg of NERICA seeds suffice for 0.5 acre, according to the recommended seeding rate by dibbling or drilling. This quantity is considered large enough to have a significant impact from the adoption of a new crop on a household, since the total acreage of a household is about 2 acres on average. However, our randomized seed provision cannot avoid two issues with the RCT. One is incompliance: Those who receive the NERICA seeds will not use all the seeds or will not plant the seeds at all, despite our request to do so. The other is spillover: Those who receive the NERICA seeds will give some or all the seeds to others who were not selected. We asked farmers to plant all the NERICA seeds by themselves, but of course, this was not enforceable. Thus, our impact assessment is carried out with potential incompliance and spillover, but we consider that our situation is not too distant from reality.

We conducted household surveys for all 280 sample households in February/March 2010 and February/March 2011. The first survey was intended to collect information before the random assignment of the NERICA seeds (i.e., crop production during the rain season in 2009), and the second survey collected information after the dissemination of the seeds (i.e., crop production during the rain season in 2010). Since there are two cropping seasons in the Kenyan highlands, namely the long rain season (from March to June) and the short rain season (from October to December), each household survey covered two preceding cropping seasons in a year. Upland rice is usually cultivated during the long rain season unless irrigation is available.

Table 1 Comparison between Accepters and Rejecters of NERICA before Intervention[1]

	Member Farmers		Is the Difference Significant?
	Accepting NERICA (N = 128)[2]	Rejecting NERICA (N = 137)[2]	
Household Characteristics			
Male Household Head (%)	79.7	80.3	
Age of Household Head	52.2 (15.2)	53.1 (15.4)	
Years in School of Household Head	7.98 (4.54)	7.30 (4.64)	
Number of Household Members	4.77 (2.06)	4.76 (2.05)	
Number of Adult Members (> 15 years old)	3.29 (1.80)	3.09 (1.68)	
Value of Asset (Ag and Nonag) Holdings (10^4 Ksh)[3]	8.32 (10.8)	8.70 (21.4)	
Value of Livestock Holdings (10^4 Ksh)[3]	4.31 (6.24)	4.02 (5.33)	
Estimated Value of Houses Owned (10^5 Ksh)[3]	2.88 (4.56)	3.61 (9.42)	
Land Use during Major Rain Season of 2009			
Total Acreage under Cultivation (acres)	1.94 (1.57)	1.94 (3.47)	
Maize Planted Area (acres)	1.39 (1.02)	1.53 (2.22)	
Beans Planted Area (acres)	1.28 (1.07)	1.36 (1.64)	
Paddy Rice Planted Area (acres)	0.03 (0.24)	0.02 (0.15)	
Banana Planted Area (acres)	0.16 (0.49)	0.17 (0.49)	
Coffee Planted Area (acres)	0.11 (0.48)	0.06 (0.25)	
Other Tree Crops Planted Area (acres)	0.12 (0.48)	0.28 (2.02)	
Upland Rice (NERICA) Planted Area (acres)	0 (0)	0 (0)	
Knowledge and Experience Regarding Rice			
Heard about Rice for Upland Conditions (%)	28.1	16.8	**
Seen Rice Growing in Upland Fields (%)	11.7	5.1	*
Have Cultivated Rice (%)	12.5	2.2	***

[1] Standard deviations are in parentheses. ***, **, and * indicate significance at 1%, 5%, and 10% respectively.
[2] Out of 140 farmers, data of 12 farmers accepting upland rice and 3 farmers rejecting upland rice were excluded as they were incomplete.
[3] Ksh stands for Kenyan Shilling.

3. Results

3.1 Comparison between Accepters and Rejecters

In order to know who accepted NERICA production among the farmers' groups, we compare accepters with rejecters. As shown in Table 1, there is no difference between them in terms of household characteristics and land use. However, significant differences exist in terms of the knowledge and experience pertaining to rice (including paddy) cultivation. Thus, it is clear that only their past experience of rice cultivation makes farmers accept NERICA production, although most of them have never seen this particular strain of rice.

3.2 Comparison between Seed Receivers and Seed Non-Receivers

As explained, the RCT design of this study requires a random assignment of NERICA seeds. As shown in Table 2, farmers who were supposed to be randomly selected for NERICA seed provision are more likely to be male and educated and have more household members and livestock. In addition, they have larger acreages of maize and other tree crops, and hence, larger total acreage as well. These results raise doubts about the efficacy of the RCT implementation; very likely this is the result of manipulation in seed distribution within farmers' groups, which we could not fully control.

Table 2 Comparison between Seed Receivers and Non-Receivers before Intervention[1]

	Farmers Accepting NERICA		Is the Difference Significant?
	Receiving NERICA Seeds (N = 62)[2]	Not Receiving NERICA Seeds (N = 66)[2]	
Household Characteristics			
Male Household Head (%)	90.3	69.7	***
Age of Household Head	52.6 (14.1)	51.8 (16.2)	
Years in School of Household Head	9.45 (4.01)	6.61 (4.61)	***
Number of Household Members	5.08 (2.39)	4.47 (1.67)	*
Number of Adult Members (> 15 years old)	3.68 (2.05)	2.92 (1.44)	**
Value of Asset (Ag and Nonag) Holdings (10^4 Ksh)[3]	8.16 (9.39)	8.47 (12.1)	
Value of Livestock Holdings (10^4 Ksh)[3]	5.59 (8.13)	3.11 (3.88)	**
Estimated Value of Houses Owned (10^5 Ksh)[3]	3.37 (3.88)	2.43 (5.11)	
Land Use during Major Rain Season of 2009			
Total Acreage under Cultivation (acres)	2.41 (2.88)	1.50 (1.03)	***
Maize Planted Area (acres)	1.60 (1.14)	1.20 (0.87)	**
Beans Planted Area (acres)	1.43 (1.23)	1.13 (0.89)	
Paddy Rice Planted Area (acres)	0.06 (0.34)	0.00 (0.03)	
Banana Planted Area (acres)	0.22 (0.64)	0.11 (0.29)	
Coffee Planted Area (acres)	0.18 (0.66)	0.05 (0.19)	
Other Tree Crops Planted Area (acres)	0.22 (0.66)	0.00 (0.08)	**
Upland Rice (NERICA) Planted Area (acres)	0 (0)	0 (0)	
Knowledge and Experience Regarding Rice			
Heard about Rice for Upland Conditions (%)	35.5	21.2	*
Seen Rice Growing in Upland Fields (%)	14.5	9.1	
Have Cultivated Rice (%)	17.7	7.6	*

[1] Standard deviations are in parentheses. ***, **, and * indicate significance at 1%, 5%, and 10% respectively.
[2] Out of 70 farmers, data of 8 farmers receiving upland rice seeds and 4 farmers not receiving upland rice seeds are excluded as they were incomplete.
[3] Ksh stands for Kenyan Shilling.

3.3 Regression Analysis Method

In order to understand why NERICA has not been widely adopted in Kenya unlike its neighbor Uganda, this paper analyzes the impact of receiving NERICA seeds on the acreage of NERICA and other crops. As discussed in the previous section, we suspect a sample selection bias in NERICA seed provision. Therefore, in order to control for the bias, we adopt the propensity-score (PS) weighted difference-in-difference (DID) method (Hirano, Imbens, and Ridder [7]). It is a least squared regression weighted by the PS and is known to yield a fully efficient estimator for DID.

The impact of the NERICA seed provision can be estimated by the first-differenced model given below.

$$\Delta A_{it} = \delta + \beta N_i + \mu \Delta \mathbf{X}_{it} + \Delta \varepsilon_{it} \quad (1)$$

where $\Delta A_{it} = A_{it}\text{-}A_{it-1}$ is the change in acreage of a particular crop, such as maize, or the change in total acreage under cultivation of farmer i between $t\text{-}1$ (year 2009, before NERICA seed distribution) and t (year 2010, after NERICA seed distribution).[6)] The explanatory variables are N_i or the seed receiver dummy variable taking 1 for farmers receiving NERICA seeds and 0 for farmers not receiving them, and $\Delta \mathbf{X}_{it} = \mathbf{X}_{it}\text{-}\mathbf{X}_{it-1}$ or the vector of variables of the change in farmer/household characteristics between 2009 and 2010. The coefficient of the seed receiver dummy (β) provides the DID estimator for the impact of the NERICA seeds. Equation (1) is estimated by OLS with a weight that equals 1 for farmers receiving NERICA seeds and $P(\mathbf{X}_{it-1})/(1\text{-}P(\mathbf{X}_{it-1}))$ for farmers not receiving them, where P( ) gives the estimated PS. We assume that the PS depends on observable farmer/household characteristics in year 2009, before the farmers received NERICA seeds ($\mathbf{X}_{it-1}$).

Table 3 Determinants of Receiving NERICA seeds[1]

	Without Location Dummies	With Location Dummies
Household Characteristics before Intervention		
Male Household Head (dummy)	0.17 (0.04)***	0.17 (0.04)***
Age of Household Head	0.00 (0.00)	0.00 (0.00)
Years in School of Household Head	0.04 (0.01)***	0.04 (0.01)***
Number of Household Members	0.00 (0.03)	-0.00 (0.03)
Number of Adult Members (> 15 years old)	0.03 (0.03)	0.05 (0.03)
Value of Asset (Ag and Nonag) Holdings (10^6 Ksh)[2]	-0.72 (0.32)**	-0.67 (0.34)*
Value of Livestock Holdings (10^5 Ksh)[2]	0.16 (0.03)***	0.16 (0.03)***
Estimated Value of Houses Owned (10^5 Ksh)[2]	-0.61 (0.96)	-0.69 (1.14)
Knowledge and Experience Regarding Rice		
Heard about Rice for Upland Conditions (%)	0.20 (0.08)**	0.22 (0.09)**
Seen Rice Growing in Upland Fields (%)	-0.60 (0.31)*	-0.44 (0.34)
Have Cultivated Rice (%)	0.54 (0.29)*	0.48 (0.30)
Dummies for Location[3]	No	Yes
Number of Observations[4]	128	128

[1] The figures are marginal effects estimated by the Probit regression. Robust standard errors clustered by location dummies are in parentheses. ***, **, and * indicate significance at 1%, 5%, and 10% respectively.
[2] Ksh stands for Kenyan Shilling.
[3] Sample households spread over 7 locations, the second smallest administrative unit in Kenya.
[4] This number includes 62 receivers and 64 non-receivers of NERICA seeds.

3.4 Determinants of Receiving NERICA Seeds

First, it will be interesting to see the result of the probit estimation used for estimating the PS (Table 3). As expected from Table 2, male and educated household heads are more likely to receive NERICA seeds and the value of livestock holdings has a positive effect on their reception. However, unlike Table 2, the number of household members, either total or adults, has no significant influence. This may be because male-headed households have significantly more members than female-headed households in our sample. On the other hand, households with more assets (both agricultural and nonagricultural, such as vehicles) are less likely to receive NERICA seeds, probably because relatively wealthy households do not need a new cash income source to the same extent as less wealthy ones. As for the knowledge and experience of rice production, the three variables are significant without location dummies, but only one variable remains significant once thelocation dummies are included. This implies that experience and knowledge of rice depend more on the plantation site than on the individual. It is interesting to see a negative effect of "Seen Rice Growing in Upland Fields," because it indicates that farmers who may have seen upland rice trials conducted in nearby villages are more reluctant to adopt it. That is, past trials may not have been successful enough to attract farmers.[7)]

3.5 Impact of Receiving NERICA Seeds

The PS is obtained by using the Probit regression with location dummies. Out of 128 sample households, 107 households remain in the common support region, which is divided into 5 blocks and satisfies the balancing property. Thus, using the households in the common support region, equation (1) is estimated with the PS-based weight (as explained in the previous section) for each crop separately. The results are presented in Table 4.

First, we confirm that those who received NERICA seeds increased NERICA acreage by 0.36 acres on average. Those farmers may have also reduced maize and bean acreages, since the estimated parameters for maize and beans are relatively large (-0.29 and -0.15 respectively). NERICA is supposed to replace such existing food crops. However, the reduction is not statistically significant due to large standard errors. This result implies that farmers tend to replace such food crops with NERICA, but the crop being replaced varies depending on each farmer's decision. In fact, NERICA does not seem to replace any specific crop and the replaced crop appears to depend on each farmer's crop rotation and diversification practices.

Regarding the concern about incompliance, all the farmers who received NERICA seeds planted them, and hence, there was no case of incompliance. However, among the 62 farmers who received NERICA seeds, only 20 farmers used 10 kg of seeds, and accordingly, their average seeding rate was 6 kg per 0.36 acre of land or 16.7 kg/acre. This is less than the recommended rate (20 kg/acre), but we consider that their technological compliance is quite high, indicating their seriousness to adopt NERICA. On the other hand, since many farmers did not use all the seeds, we expect a spillover from the treated farmers. We find that only one farmer planted NERICA seeds in 2010 from among the 66 control farmers who did not receive NERICA seeds. However, 6 of the 137 member farmers who had rejected the NERICA seeds when we had offered them planted the seeds in 2010. Thus, as expected, there is a spillover from the intervention, but it does not affect the impact assessment of NERICA seed provision very much.

In addition to NERICA acreage, the results indicate that NERICA seed provision has a significantly negative effect on the change in tree crop acreage. This result contrasts with our intuition, since farmers will not easily convert tree-planted plots into annual crops like NERICA. However, this result can be attributed to only 5 cases, where farmers started or stopped tree plantation between 2009 and 2010 and for the majority, NERICA seeds had no effect on tree crops.[8)]

4. Conclusions

Our analyses confirmed that the availability of seeds acts as a constraint against NERICA adoption in the Kenyan highlands. This may not be surprising, and in fact, appears to be very obvious. However, considering that many new technologies, including new crop varieties, are not adopted even if they are available, the results suggest that the farmers' demand for new cash crops, which is strong at our study site, probably drives NERICA adoption. This view is supported by the high compliance rate among the receiving farmers and the moderate spillover to the neighboring farmers. However, the results also indicate that male and educated farmers tend to receive NERICA seeds, which implies that such farmers are willing to take the higher risk entailed in pursuing opportunities for new income. This is also consistent with existing literature on technology adoption.

Note that this paper analyzes the impact of NERICA seed provision on upland rice production only. Its impact on household income will be investigated in future research.

Table 4 Impact of NERICA Seed Receiving on Crop Acreage[1]

	ΔTotal Acreage	ΔMaize Acreage	ΔBeans Acreage	ΔPaddy Acreage	ΔBanana Acreage	ΔCoffee Acreage	ΔTree Crops Acreage	ΔNERICA Acreage
NERICA Seed Receiver Dummy	-0.21	-0.29	-0.15	-0.01	0.02	-0.08	-0.19**	0.36***
	(0.22)	(0.18)	(0.20)	(0.00)	(0.06)	(0.06)	(0.05)	(0.01)
ΔMale HH Head[2] (dummy)	0.97	1.28	1.32	-0.05	-0.54	-0.19	0.24	0.16*
	(2.42)	(1.01)	(1.09)	(0.04)	(0.66)	(0.29)	(0.60)	(0.05)
ΔAge of HH Head[2] (years old)	-0.10	-0.11	-0.11	0.00	-0.04	0.02***	-0.03	-0.01***
	(0.05)	(0.05)	(0.05)	(0.00)	(0.06)	(0.00)	(0.05)	(0.00)
ΔYears in School of HH Head[2] (years)	0.06	-0.02	-0.01	0.01	0.09	0.05	-0.04	-0.00
	(0.18)	(0.08)	(0.08)	(0.01)	(0.09)	(0.04)	(0.11)	(0.01)
ΔNumber of HH[2] Members	-0.01	-0.03	0.12	-0.01**	-0.12	0.17*	-0.06	-0.04**
	(0.16)	(0.31)	(0.26)	(0.00)	(0.11)	(0.07)	(0.04)	(0.01)
ΔNumber of HH[2] Adults	-0.32	-0.34	-0.43*	-0.00	0.16	-0.10	0.11	0.02
	(0.15)	(0.17)	(0.17)	(0.01)	(0.17)	(0.05)	(0.08)	(0.02)
ΔValue of Ag/Nonag Assets (10^6 Ksh)[3]	-1.99	-2.05***	-1.54	0.15	1.57*	-1.24**	-0.11	-0.14
	(1.38)	(0.40)	(0.76)	(0.09)	(0.61)	(0.37)	(0.99)	(0.12)
ΔValue of Livestock (10^5 Ksh)[3]	1.10	0.80	-0.80	-0.00	0.08*	0.07	0.12	0.01
	(0.56)	(0.61)	(0.57)	(0.00)	(0.03)	(0.05)	(0.06)	(0.01)
ΔValue of Houses Owned (10^7 Ksh)[3]	-5.47**	-2.96	-1.86	0.09	5.15**	-0.16	1.24	-0.60*
	(1.60)	(2.38)	(2.80)	(0.15)	(1.26)	(0.74)	(1.40)	(0.23)
Constant	-0.05	0.13	0.15	-0.02	0.00	-0.04	0.08*	-0.00
	(0.12)	(0.23)	(0.19)	(0.01)	(0.06)	(0.02)	(0.03)	(0.01)
R^2	0.29	0.22	0.21	0.01	0.19	0.27	0.12	0.77
Number of Observations[4]	107	107	107	107	107	107	107	107

[1] Heteroskedasticity-robust standard errors clustered by 5 blocks appear in parentheses. ***, **, and * indicate significance at 1%, 5%, and 10% respectively.
[2] HH stands for household.
[3] Ksh stands for Kenyan Shilling.
[4] We select households located in the common support region based on the PS.

Note

This paper is part of the output for "Practical Study on Rice Promotion in the East African Highlands" funded by Strategic Funds for the Promotion of Science and Technology of the Japan Science and Technology Agency (JST). The field work and data collection are also supported by the Institutional Program for Young Researcher Overseas Visits and Grants-in-Aid for Scientific Research (A) of the Japan Society for the Promotion of Science (JSPS).

1) Unlike in West Africa where rice is one of the traditional staple foods and upland rice is grown mainly for self-consumption, in Eastern and Southern Africa, rice is imported or specifically grown in large irrigated schemes, and hence, even upland rice like NERICA is considered to be a cash crop.

2) Exceptions include the small-scale trials that were conducted before the official registration of NERICA. However, no such trial had been conducted at our study site as of February 2010.

3) However, there is a study on randomized distribution of voucher for accessing to certified seeds of a rice variety in Nigeria (Awotide et al. [2]). Their study is different from ours in two points. First, their seed voucher was given to farmers who had already grown rice, while we provided seeds to farmers without experience of upland rice cultivation. Second, they distributed only vouchers and it depended on farmers whether they use the voucher to get certified seeds. Our study distributed NERICA seeds and it depended on farmers whether they plant them.

4) We selected 7 communities located in the north of Mwea and 7 communities located in the south of Mwea. All the communities are situated in a zone with rainfall and temperature patterns favoring the growth of upland rice. Note that

the low temperature during the time of flowering serves as a constraint against growing rice, since the elevation of the Kenyan highlands is high (between 1,000 and 1,500 m above sea level).

5) We purchased the seeds from the Mwea Irrigation Agricultural Development (MIAD) Centre in Mwea. They multiplied the seeds under irrigated conditions in order to supply them to farmers in the irrigation scheme. The seeds were not certified; when we purchased them in February 2010, Kenya did not have a seed certification system for rice. Commercial availability of the NERICA seeds was not possible at the time due to the lack of seed certification.

6) Since the land rental market is well developed at our study site, we assume that farmers adjust the total acreage every year by relying on the rental market. In fact, of the 627 fields used by our 280 sample households during the 2009 cropping year, 94 fields were rented in or leased in, with 25% of them being rented in for the first time in 2009. If we consider the years 2007, 2008, and 2009, about 45% of rental fields started being rented in during this period.

7) This point will be investigated in a future paper using our data, since almost all the farmers who received the NERICA seeds and grew them in 2009 could not harvest anything due to rainfall shortage in the growing stage. This failure would have had a significant negative impact on other farmers in the same farmers' group and living in the neighborhood.

8) As shown in Table 1, on average, tree plantation is smaller among NERICA-accepting farmers than among NERICA-rejecting farmers. It means that farmers without cash crops tend to accept NERICA as a new cash crop. In fact, among the 107 farmers in the common region, only 8 farmers had tree crops in 2009 (before the intervention), and for unknown reasons, all the 8 farmers received NERICA seeds. Then, 3 farmers who did not receive NERICA seeds started tree plantation in 2010, while 2 farmers out of the 8 farmers who had had tree crops in 2009, lost them in 2010. Thus, the significant impact of NERICA seeds on tree crop acreage is attributed to these 5 cases.

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Economic Impacts of Pond Water Irrigation on Household Income in Rural Southern Laos

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1. Introduction

Farming systems in rural areas of Lao PDR can be broadly categorized into two systems: lowland rain-fed and/or irrigated farming systems, mainly in the central and Southern regions, and upland swidden farming systems, predominantly in the Northern mountainous areas (Bourdet, Y [2]). About 85 percent of the total population are living in rural areas and engaging in subsistence agriculture, dominantly the rice cultivation with an average land holding of about 1.6 hectares (Ministry of Agriculture and Forestry [6]). It is estimated that 93 percent of cultivated area is devoted to rain-fed rice production, in particularly, glutinous (sticky) rice which is characterized as water-consuming crop.

Since 1990s, the Government began providing special financial supports to the surface water irrigation infrastructure development such as electric pumping systems from along the Mekong's major branches and the Mekong itself, weirs, retention reservoirs and some hydropower dams including irrigation (Asian Development Bank, [1]). The main expansion in irrigated areas occurred in the central and southern regions, which are mostly lowland rice-farming regions (Ministry of Agriculture and Forestry [6]). However, many potential agricultural land are not still irrigated, particularly in rural farming areas where are not well endowed with water resources relying only on rainfall water (Jusi and Virtanen [4]).

In rural southern Laos, water for agriculture is scarce especially in the dry months from December to May although water is adequate during the rainy season. The farmers construct farm ponds/reservoirs to collect water during the rainy months and utilize the stored water to augment insufficient water supply during the dry season. A number of ponds or reservoirs are already used by farmers but their use and management are still an issue. Water from the ponds can be used for irrigation of crops, fish culture, and drinking water for livestock. Producing high value crops (vegetable, maize or even pond fish) and selling to local market can generate an extra income for rural poor household (Ireson, [3]).

The concept of irrigation from pond for community-based development was developed during 1980s in Asia. Ponds are small reservoirs that allow farmers to capture rainfall, store surplus water for agricultural production such as cropping and animal husbandry (Mushtaq, S., et al.,[15]). In case of large scale storage capacity, ponds are considered as helpful in reducing floods, recharging groundwater and providing drainage in high rainfall periods. An irrigation pond (called tank in Southern India and Sri Lanka) is a durable asset providing a stream of benefits for several years (Pandey, [7]). Farm ponds for water resource rehabilitation are strongly promoted in th integrated farming system (Penning de Vries, F., et al., [9]-[10]). In China, water conservation projects have been implemented by introducing of water saving irrigation (WSI) which is contributed to reduce water use by maintaining agricultural production despite a considerable decrease in water deliveries, by relying on local water resource such as ponds (Mushtaq, S., et al., [16]). According to Li et al., [6], supplementary irrigation water provided at critical stages of crop growth is a practice which can generate significant increase in crop yields and in income associated.

It is important to understand the economic impact of farmstead pond expansion on the decomposition of farm household income under rice-based farming systems. To our knowledge, there is no research examining the impacts of homestead ponds on production and farm income in Lao PDR. Drawing on household surveys in 2012, the original contribution of this paper is firstly to investigate the multiple-purpose of farm pond and secondly to evaluate the economic impact of pond irrigation on net farm income and total household income between farmers who have a pond and those have no pond on their farmsteads. In section 2 provides a description of study areas, sampling and data collection methods. Section 3 describes a summary of descriptive variables used and the econometric methodology. Section 4 presents the empirical results. Finally, section 5 concludes and discusses policy recommendations.

2. Study area and data collection method.

Southern Lao PDR has a tropical monsoon climate characterized by alternating wet season (April - November) and dry season (December - March). The annual rainfall average is 1000-1500 mm, more than 85% of rain falls during the months of May-September. The study area comprises 4 districts which are namely Outhoumphone, Champhone, Phonthong and Sukhuma districts, where numerous ponds are located. In total 23 villages were selected according to the suggestions of the districts agricultural offices and our field visit. We collaborated with the heads of villages to have lists of all farmers in each district. A farmer is selected based on 2 criteria, first he is a rice farmer and second, he has a pond and regularly uses it for cropping on his farm. With the list of farmers provide by the village's head, 222 households were randomly selected and surveyed: pond-farm (188 households) and no-pond farm (34 households). A structured questionnaire were developed and pretested before conducting field survey in July, 2012. Then, the field survey has been carried out in August-September 2012. The questionnaire covers socio-economic characteristics of household, cropping farming patterns, farm inputs and outputs, sources of water and its multiple-purposes, pond characteristics and irrigation, and pond management).

We examine the impact of pond on per capita income for various sources of household incomes because our overall objective is to assess the potential of farmstead pond for poverty reduction. If a farmer draws labour and land resources away from other activities, focusing on crop income issued from pond irrigation may overstate the impact on household well-being. Some findings from the field survey are presented in table 1.

Table 1: Averages of characteristics of the farms in our survey (mean and standard deviation[a])

Case/feature	Pond farms in Phonthong	Pond farms in Sukhuma	Pond Farmsin Champhone	Pond farms in Uthoumphone	No-pond Farms
Total Farm size (ha)[b]	3.0 (2.1)	2.1 (1.1)	4.1 (3.4)	4.5 (2.5)	1.7 (1.4)
Paddy land (ha)	2.7 (1.7)	1.9 (0.9)	3.1 (1.9)	3.7 (2.1)	1.6 (1.0)
Pond area (m2)	1325 (1044)	1039 (1551	2442 (8265)	2014 (2577)	
Water Storage Capacity (m3)[c]	3265 (3324)	1798 (2790)	4422 (14267)	4282 (6332)	
Pond category[d]	medium	medium	medium	medium	
Household size (heads)	6.2 (1.7)	6.5 (1.4)	6.2 (1.5)	6.9 (1.9)	6.4 (1.9)
Member aging (15-60 years old)	4.2 (2.1)	4.7 (1.7)	4.3 (1.3)	5.2 (1.6)	3.9 (1.9)
Rice yield (tons/ha)	1.7 (1.0)	2.5 (2.0)	1.9 (0.8)	2.0 (0.9)	1.9 (0.7)
Livestock (millions LAK[f])	3.5 (8.7)	8.2 (8.2)	7.9 (8.5)	13.9 (10.5)	3.4 (6.3)
Produce	Vegetable, rice, fish	Rice, vegetable, fish	Rice, Vegetable, fish	Vegetable, rice, fish	Rice, vegetable
Farm income (% of total without livestock)	57	39	54	52	45

Note: [a] standard deviation is in the parenthesis. [b] total certificated land hold by a farmer, [c] this is equivalent to the dimension of pond (water volume is equal to surface area multiplied by depth), [d] classification of pond capacity: small pond has a storage capacity is less than 1,000 m^3, medium pond has a storage capacity between 1,000 and 10,000 m^3, while large pond has more than 10,000 m^3 (Muzhtaq, S., et al., [15]), [f] LAK is a Lao currency, 1US$ is equal 8,000 LAK (exchange rate provided by the Lao Exterior Commercial Bank, September, 2012).
Source: Author's calculation based on survey in 2012.

Average of farm size of pond farms in Sukhuma district is slightly higher than in the group with no-pond farms. The household size is in average around 6 to 7 members per households. In term of rice productivity, the highest yield is in Sukhuma district, 2.5 tons per ha. The average of rice yield in the other districts is approximately 2 tons per ha. The size of pond differs from district to district with an average ranging from 1,324 m^2 to 2,442 m^2. We can categorize the capacity of pond surveyed in 4 districts as medium according to the classification of pond by Muzhtaq, S., et al., [15]. In the research on pond in Thailand suggest that a value of 1,260 m^3 is the target size (Penning de Vries et al., [11]). Farm income counts more than 40% of total farm income for interviewed farmers. Rice is the main source of income.

In southern Laos, 72% of the study area is plain flat area. Farmers who have a big pond have more capital and resource assets (mainly draft animal). They sell animal to pay for construct a pond. For the no-pond or very small pond farmers, most of them are poor and living in the remote areas, even in the same village, many of them are lack of capital asset to pay for construction of pond.

3. Empirical framework

3.1. Data source

The main variables used in this empirical study are presented in Table 2. 85% of total households surveyed have a pond on their farm (pond farm). Within these pond farms, only 72% use pond water to irrigate their crops mainly vegetable and pond fish raising. The average of farm land is 3.14 ha per household.

Table 2: A summary of main variable from a survey of 222 household in Southern Laos, 2012.

Variables	Variable description	MEAN	Standard deviation
CROPNET	Net crop income (million LAK ha^{-1})	25.6	62.2
PONDFARM	Dummy (1 if farm having a pond, 0 otherwise)	85%	NA
IRRSTATUS	Irrigation status (1 if irrigated from pond, 0 otherwise)	72%	NA
WSCLAND	Water storage capacity of pond per farm land, (m^3 ha^{-1})	1133	1884
DISTHOME	Distance of pond from home (m)	404	920
SURIRR	Crop surface irrigated by pond water (ha)	0.12	0.18
SHOCK	Natural disasters for crop (1 if drought is experienced, 0 otherwise)	49%	NA
FARMSIZE	Farm land holding by a household (ha)	3.15	2.48
AGE	Age of family head (year)	48.8	10.9
SCHYRS	Average education years of adult member aging 15-60 (year)	7.3	3.5
HHSIZE	Household size	6.4	1.7
ADULTS	Number of adult member aging 15-60	4.46	1.78
DEPENDENT	Number of dependent member s	1.98	1.43
LANDPERS	Farm land area per person (ha)	0.52	0.45
PONDPERS	Pond area per person (ha)	0.04	0.19
WSCPERS	Water storage capacity of pond per person, (m3)	514	1264
IRRPERS	Irrigated surface per person (ha)	0.020	0.033
FARMINC	Crop income per person (million LAK)	1.19	1.14
LIVESINC	Livestock income per person (million LAK)	0.42	0.91
OFFFARMINC	Off-farm income per person (million LAK)	1.53	1.65
TOTALINC	Total income per person (million LAK)	3.14	2.24
AGRMACH	Value of agricultural machinery per person (million LAK)	0.76	1.17
DRAFT	Value of draft animals per person (million LAK)	1.22	1.44
DISTOWN	Distance from Capital city (km)	50	17
RAINFALL	Annual rainfall (mm)	1739	315
RICEMLFAC	Presence of Rice Milling Factory nearby the village	50%	NA

3.2. Model specifications

In general, Pond irrigation contributes to income generation in two ways: (1) to increasing the crops yields, and (2) to enabling farmers to diversify crops and switch to high-value crops such as vegetable and fruits. To investigate the relationship between pond irrigation and income generation for the poor, we develop an empirical model that accounts for pond-specific characteristics and household features. The observed variation in net income issued from using pond within a farm could be largely attributed to household features and pond characteristics. The net crop income estimation function is specified as follows:

$$Y_i = \alpha + \beta I_i + \gamma P_i + \rho H_i + e_i \qquad i = 1,2,\ldots\ldots\ldots 222 \qquad (1)$$

Where Y_i denotes the net crop income generated on farm of *ith* household. I_i refers to the status of pond irrigation on *ith* household. P_i denotes the characteristics of pond including pond ration, capacity of water storage, area irrigated by pond water, distance of pond from home, and experiences in drought. H_i represents a group of household factors including both household level variables (e.g. household size, average of education, average age of household members and farm size) and village variable (distance from capital city, distance from Rice milling factory). e_i is the usual well-behaved error terms, which is uncorrelated with the vector of independent variables. α, β, γ and ρ are the coefficients to be estimated. The empirical model is in log-linear form:

Log (Net crop income) = F (PONDFARM, IRRSTATUS, WSCLAND, SURIRR, DISTHOME, HHSIZE, AGE, SCHYRS, ADULTS, FARMLAND, DISTOWN, SHOCK, RICEMLFAC) *(2)*

To account for heteroskedasity, we estimate Eq.2 by Ordinary least Square (OLS) using robust standards errors (White, [17]). It might exist heterogeneity of households in the study areas. The study also applies the household fixed effect model to capture this problem in order to capture selection bias. This technique also allows us to make a comparison with the results from OLS regression.

To study the importance of pond irrigation on decomposition of household income, per capita income is used in the model. The main factors affecting the household income structure were grouped in four categories: Land assets, Human capital, and other household asset and village characteristics. For land asset, we expressed the total land area per household member, irrigated area per person, pond area and water capacity per person. These reflect the total land resource holdings. For human capital, we used the average level of education in the household, the average aged of household members and the number of dependent. This variable helps to capture the household structure and also have an impact negative on total household income. The other assts are reflected by the value of draft animal holding and value of machinery per person. The village features are captured by the distance from the downtown of the province, rainfall, natural disasters occurred during last three years and presence of rice milling factory in the district. The ordinary Least Squares with standard robust errors are regressed to the impact of pond irrigation on crop income and household income. We observed that some households do not derive income from livestock, off-farm work and other activities. These income equations are estimated by Tobit model. Similar model used by the Sadoulet and De Janvry, [12]. The Tobit model is described as follows:

$$Y_i = Y_i^* \text{ if } Y_i^* > 0 \text{ and } 0 \text{ otherwise}$$
$$Y_i^* = \beta' X_i + \varepsilon_i \qquad (3)$$

where Y_i is an observed, but censored, variable measuring farm household livestock and off-farm income, Y_i^* is a latent variable, X_i is a vector of explanatory variables that influence income, β' is a vector of parameters to be estimated, and ε_i is random disturbance term with mean 0 and variance σ^2. The empirical model is specified as follows:

INCOME (of various sources) = *F* (PONDFARM, PONDPERS, WSCPERS, IRRPERS, LANDPERS, AGE, SCHYRS, ADULTS, DEPENDENT, AGRMACH, DRAFT, DISTOWN, RAINFALL, SHOCK, RICEMLFAC) (4)

To account the heteroskedasticity, we estimate the equation (4) by Ordinary Least Squares (OLS) using robust standard errors (White, [17]). Eq.3 for livestock and off-farm incomes are estimated by the Tobit regression.

4. Empirical results

4.1. Pond irrigation and net crop income

In term of benefits of pond, it is interesting to decompose the different sources of incomes generated from a pond shown in table 3. Rice sale in wet season is an important product in all 4 studied areas. For pond farms, sales of dry season vegetable and pond fish represent great proportion of farm incomes and of total household income. These incomes are considered as main source of extra incomes for farmers. Farm income of pond farms is better compared to the non-pond farm. In average, farm income per household, including the value of home consumption, is over 10 million LAK (US$1,250) for farm with a pond and a half less on farms without a pond. Pond farms can have more various sources of incomes and diversify the agricultural production. This is in agreement of the concept of integrated farms have more opportunities for agricultural production due to their larger water availability (Ruaysoonnern, S., and Penning de Vries, F., [12]).

Table 3: Annual income of pond-farms in the four districts and of no-pond farms (in millions LAK)

Source of income	Phonthong district	Sukhuma district	Champhone district	Uthoumphone district	Average pond farms	Average no-pond farms
DS vegetable, sale	5.1	0.4	0.5	1.8	2	0
WS vegetable, sale	2.3	0.2	0.1	1.3	1	0.4
Fish, sale	0.3	0.9	3.3	1.6	1.5	0.0
DS rice, sale	0	0	1.2	0	0.3	0.2
WS rice, sale	5.1	3.5	4.2	6.6	4.8	3.8
Livestock, sales	2.9	0.9	0.6	1.3	1.4	1.2
Farm income (sum)	15.7	5.9	9.9	12.5	11.1	5.9
Off-farm income	7.9	11.5	9.9	9.2	9.6	9.6
Total income	23.6	17.5	19.8	21.8	20.7	15.5

Source: Author's calculation based on survey in 2012.

Income from no-pond farms is less diversified and doubly lower than that from pond farms. Off-farm amounts to 30-51% of total farm income. This fraction tends to be larger on the farm without a pond which consists of payments for part-time or short-time jobs of household members and quite significant of remittances by family members[1]). This implies that such farms are more vulnerable to drought and do not have an extra source of household income (e.g. vegetable growing in dry season). These farmers rely more on off-farm activities.

The regression results show that overall the net crop income on pond farm is 75% higher than on no-pond farm (table 4). Farmers who irrigate with pond water (vegetable) have net income 57% higher than farmers who do not irrigate from pond. This implies by the impacts of numbers of irrigation from pond. The regression results cannot show the impact of the pond storage capacity on crop income because the coefficient of this variable is very small.

The key variable is the surface irrigated by pond. Increasing 1 ha irrigated by pond can significantly increase the net crop income by 44% (estimated by OLS) and by 42% (estimated by the household fixed effect model). From our field observation, pond farmers who irrigate their fields for cropping try to use maximum the pond water for reducing underground pumped water (usually more costly for farmers in term of electricity fees).

Number of adults' member at household has some impact on net crop income. The regression results show that increasing one adult per household increases the net crop income by 10% (significantly at 10% level). This variable explains the importance of family labor on production costs. All household surveyed reported that their children have significant impact on their production outcomes, particularly during the rice production period.

For the village features, natural drought and distance from the city have significant negative impact on the net crop incomes. Farmers who live 1 kilometer far from the city, their net crop incomes reduce significantly by 12%.

Table 4: Estimated parameters of regression models of net crop income in Southern Laos

	Dependent variable= Log (CROPNET)	
	1	2
PONDFARM (dummy =1)	0.75***(0.15)	0.71***(0.10)
IRRSTATUS (dummy=1)	0.57*(0.13)	0.53*(0.13)
WSCLAND (m3/ha)	0.00 (0.00)	0.00(0.10)
SURIRR (ha)	0.44***(0.36)	0.42***(0.36)
DISTHOME (m)	0.003 (0.001)	0.001 (0.00)
HHSIZE (number of family member)	0.002 (0.005)	0.001 (0.005)
AGE (years)	-0.02 (0.01)	-0.01 (0.01)
SCHYRS (years)	0.06**(0.03)	0.11*(0.03)
ADULTS (persons)	0.11*(0.02)	0.09*(0.05)
FARMLAND (ha)	0.03 (0.02)	0.01 (0.12)
RAINFALL (mm)	0.09 (0.02)	0.05* (0.02)
SHOCK (Experience in drought, dummy =1)	-0.10* (0.12)	-0.09* (0.12)
DISTOWN (km)	-0.12*(0.00)	-0.10*(0.0)
RICEMLFAC (km)	0.10 (0.12)	0.09 (0.11)
Constant	0.72***(0.42)	0.70***(0.32)
Observations	213	213
R2	0.42	0.49

Note: The standard errors are in the parenthesis. Column 1 is estimated by OLS with robust standard errors; column 2 is estimated by the household fixed effect model. ***Significance at 1%, **Significance at 5% and *Significance at 10%.

Source: Author's calculation from survey 2012.

4.2. Pond irrigation and total household income

The impact of pond irrigation on total household incomes was estimated with four models in table 5. Results of regression show that pond irrigation significantly affects farm incomes, livestock, and total household income. Pond farms significantly have higher net income per capita than that of no-pond farm. For off-farm income, the Tobit regression shows the significant negative impact of pond irrigation. This can be explained that production activities related to pond require more labor, particularly family members. These family members cannot go out of the farm to find an off-farm income in the city or even in the neighbor country.

Pond area has a negative impact on net farm income per capita. If the pond surface increases one hectare, the net farm income and off-farm income reduce by 0.73 million LAK ($US91.25) and by 0.26 million LAK ($US32.5) per family member, respectively. This implies that if a farmer convert one hectare of farm land to pond, net crop income will be substantially reduced.

On the other hand, the surface irrigated by pond irrigation significantly has impact on the increase of net farm and total household incomes. On average, increasing irrigated area by one hectare on pond farm land increases net crop income by 18.4 million LAK (US$2,312) and total net income by 15.09 million LAK ($US1.888), respectively. This implies that if a farmer increase an area irrigated by pond, crop will be substantially augment.

Our results cannot show the evident impact of pond dimension (water storage capacity) on the decomposition of total household incomes per capita because the coefficients of this variable are too small to be predicted.

It is surprising that irrigated land by pond irrigation significantly has a negative effect on off-farm income. Increasing irrigated area can generate extra activities on farm and requiring members to work on farm. Regarding to the human capital, there is no significant impact on household income. Only number of dependents significant reduces off-farm income. In terms of village features, distance from capital city significantly affects net crop and livestock income.

Table 5: Estimated parameters of four regression models[a] of various household incomes[b]

	Dependent variable: net income per person (million LAK)			
	FARMINC (OLS)	LIVESINC (Tobit)	OFFARMINC (Tobit)	TOTALINC (OLS)
PONDFARM (dummy=1)	1.02* (0.12)	0.69***(0.21)	-0.68**(0.36)	1.07***(0.33)
PONDPERS (ha)	-0.73* (0.29)	0.15 (0.34)	-0.26 (0.73)	-0.76 (0.71)
WSCPERS (m3/person)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
IRRPERS (ha/person))	18.4***(1.71)	5.94**(2.36)	-6.91*(4.18)	15.09***(4.17)
LANDPERS((ha/person)	0.57***(0.13)	-0.07 (0.16)	0.20 (0.34)	0.13**(0.33)
AGE (years)	-0.001 (0.005)	0.01 (0.01)	0.00 (0.01)	0.00 (0.01)
SCHYRS (years)	-0.003 (0.015)	-0.02 (0.02)	0.04 (0.04)	0.02 (0.04)
ADULTS (15-60 years old)	0.02*(0.03)	0.04 (0.04)	0.11*(0.08)	0.02**(0.08)
DEPENDENT (person)	-0.10*(0.05)	0.07 (0.05)	-0.34***(0.11)	-0.26**(0.11)
AGRMACH (million LAK/person)	0.03*(0.04)	0.13** (0.05)	0.35***(0.11)	0.21*(0.10)
DRAFT (million LAK/person)	-0.07* (0.04)	0.13***(0.04)	0.04 (0.09)	-0.04 (0.09)
DISTOWN (km)	-0.012**(0.005)	-0.04***(0.01)	0.05**(0.02)	0.01*(0.01)
RAINFALL (mm)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00(0.00)
SHOCK (drought, dummy=1)	-0.22*(0.11)	0.03 (0.13)	0.86***(0.27)	-0.62**(0.31)
RICEMLFAC	0.25*(0.15)	-0.71** (0.28)	0.79 (0.59)	0.42**(0.37)
Constant	1.53**(0.64)	2.75**(1.25)	-5.41**(2.55)	-0.10 (1.53)
Observations	213	213	213	213
R2	0.60			0.46
sigma		79.29	168.88	
Wald $X^2_{(15)}$		126.19	46.37	

Note: [a] 9 households is excluded due to production issued from rent land. [b] the standard errors are in the parenthesis. ***Significance at 1%, **Significance at 5% and *Significance at 10%.
Source: Author's calculation from survey 2012.

The value of farm machinery per capita has a significant impact on total household incomes. This value can be explained by the hand tractor and irrigation pumping system owned by the famers. From the regression results, if the value of farm machinery increase one million LAK ($US125), the total household income increase by 21 million LAK ($US26.25) per capita. This variable also has a significant impact on off-farm income per capita. From our field observation, farmers who have high value of farm machinery (hand tractor) earn more extra off-farm income by providing services for other farmers during the production calendar such as soil preparation, water pumping for rice seedbed, or even transports of harvested crops. Distances from the city and natural disaster also have significant impact on off-farm income. All farmers surveyed reported that their children left the village to find job when drought occurred in their village.

5. Concluding remarks

In southern Laos, small-scale pond is common used within a farmstead level. Its multiple purposes are well known in term of supplemental irrigation and food supply (pond fish) at home consumption. Diversification of cropping patterns on pond farms provides us a pool of essential elements for further steps of research on farmstead ponds' productivity in rural areas.

The results from our research show that there are significant differences in household income from famers with a pond and that without a pond. The premise is that resource water can be developed on many homesteads by construction of ponds: this can support more sustainable production systems, higher productivity and income, and greater well being of the family. Based on this result, it is important to continue a research on the question of what is the best choice of resource allocation in term of cropping land and water land on farmstead. Research on economic model of pond water use is needed to investigate. Utilizations and management of Pond have not been empirically studied a farm level. Research on modeling of water use efficiency from pond irrigation concept is needed in order to bear some hints for policy making.

Notes:

1) Nine of ten households have their family members at least 1, working in Thailand and sending money to the family.

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The Determinants of Food Security in Indonesia

— A Case of Households in the North Luwu of South Sulawesi Province —

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1. Introduction

Food security is a complex phenomenon that can undermine people's health and productivity; in Indonesia, food security is relatively low in a particular region, and this remains a serious problem. However, there are different foci between the national and household levels when discussing food security in Indonesia. At the national level, the issues of concern are more about food availability and accessibility, especially in eastern parts of the country. Another issue at this level is the impact of economic crises on the national food security status. On the other hand, food security problems at the local household level are no longer dominated by issues pertaining to shortages or difficulties in accessing food; rather, the focus is shifting to aspects of dietary diversity. One of the reasons that this aspect is becoming more important is because the diversity of food served in a household is a coping mechanism used to counter the effects of food security problems at the national level (Usfar et al. [23]). Nevertheless, there has been limited research in Indonesia on dietary diversity as a function of household food security status, and its socioeconomic determinants. Most studies on household food security and dietary diversity have been done separately and are now obsolete, as they were conducted in response to Indonesia's 1997 economic crisis (e.g., Frankenberg et al. [6]; Hartini et al. [9]; Skoufias et al. [19]) or focused on one area of Indonesia (Hartini et al. [10]; Matsumoto et al. [12]; Ngwenya and Ray [14]; Studdert et al. [20]). Moreover, in measuring household food security status, most of those studies rely on methodologies that examine caloric availability or deprivation; such metrics provide a partial picture of the situation, at best.

The current study looks to provide the newest information and extend our understanding of household food security in a particular region of Indonesia – one not previously examined – by examining household food-security status in terms of dietary diversity and its socioeconomic determinants. The results of this study offer opportunities to compare household food security figures, both nationwide and worldwide. In particular, analyzing key determinants is very important, as doing so will provide vital indicators that can be used to design food policy programs. For example, knowledge of how dietary diversity responds to economic factors such as income will provide policy-makers with crucial information on whether or not income-enhancing policies are capable of increasing food security at the household level. Another issue is the effect of food knowledge on dietary diversity: if food knowledge has a positive impact even among income-poor households, the food security of poor households can be improved through the delivery of education programs. To observe dietary diversity in terms of the larger issue of food security, this study will make use of household food dietary diversity score (DDS) data captured by the Food and Nutrition Technical Assistance Project (FANTA) of USAID (Swindale et al. [21]). Therefore, this study is the first to examine DDS data and the socioeconomic determinants of dietary diversity, within the context of Indonesia.

The DDS is a dietary diversification indicator that has recently become increasingly popular as an effective food and nutrition indicator, for three basic reasons. First, the DDS defines both "food" and "nutrition security" while emphasizing the importance of both macronutrients, which are needed by the body in large quantities in order to supply energy (e.g., carbohydrates, fats, proteins, and water), and micronutrients, which are needed only in very small quantities to release energy (e.g., vitamins and minerals) (Food and Agriculture Organization [5]). In principle, dietary diversity indicators capture the consumption of both nutrient types, or of a more balanced diet, generally speaking (Ruel [17]). Second, economic theories of demand as well as psychological theories suggest that individuals will diversify into higher-value, micronutrient-rich foods only when they have satisfied their basic caloric needs. In other words, as poor people become richer, they gravitate away from relatively tasteless staple foods and toward micronutrient-rich foods that impart greater taste and therefore utility. Third, the execution of DDS-oriented research is relatively cost-effective (Headey and Ecker [11]). Although DDS may be sensitive to seasonal effects, surveys that capture data for DDS analysis can be executed without incurring large costs. DDS is an important indicator, as it more accurately reflects dietary quality than does, for example, calorie count; DDS counts the number of different food groups consumed over a given reference period, rather than the number of different foods consumed. DDS is a good indicator of changes in household per-capita consumption and household per-capita caloric availability, which are measures of the access component of household food security (Haddinot et al. [7]). If a household consumes, for example, an average of four different food groups, its household members' diets will bear some diversity in terms of both macro and micronutrients.

The aforementioned explanations suggest that the DDS is a dietary diversification indicator that is relatively fairer than other quantitative measurement methods in assessing household food security status–that is to say, caloric availability or deprivation, which is one of the oldest indicators of food security. Matsumoto et al. [12] researched micro-level food security in the Java area of Indonesia, and used the calorie-based method in doing so. They found there to be some socioeconomic factors that affect food expenditure among these households; however, they also found there to be strong theoretical and empirical reasons as to why caloric availability is a poor predictor of food security, especially in the Indonesian case. In reviewing the literature pertaining to the 1998 Indonesian financial crisis – which led to a nearly 200% increase in rice prices – Headey and Ecker [11] found that all the existing evidence suggests that rice consumption remained stable or perhaps even slightly increased during that time. In contrast, the consumption of high-value foods declined precipitously, as did nonfood expenditures.

2. Data, and Empirical Methods

1) Data

The current study was carried out in the North Luwu, located 440 km from Makassar, the capital city of South Sulawesi Province. South Sulawesi is the major province of eastern Indonesia, and it was not greatly affected by the 1997 economic crisis. The North Luwu district has an area of 7,502.58 km^2 and is divided into 11 sub districts, 176 villages, and 703 neighborhoods. According to the most recent census, there were 67,328 households in this district (Biro Pusat Statistik [3]). The household sample used in the current study was chosen randomly from a household list supplied by the sub district ward office of 21 villages/neighborhoods located in suburban areas that have large numbers of households who live below the poverty line. The number of households sampled from each village/neighborhood was determined by considering the total population of that village/neighborhood. Following the validation process, 371 households were included in the analytical process. The survey was conducted at the beginning of the rice-growing season, in March 2012.

Information with regard to the types of food items consumed by the sampled households was gathered through seven-day recall. DDS was determined by classifying those food items within a household's food basket into nine food groups, as per the 2002 Indonesian guidelines from the Food Consumption Development Program (PUP3KP) (Dewan Ketahanan Pangan [4]): grain (rice, corn, sorghum), tuber (potato, sweet potato, cassava, sago starch, taro), animal product (fish, meat, dairy product, egg), oil and fat (coconut oil, palm oil), oily seeds (coconut), nuts (soy bean, peanut, green bean), sweets (sugar, palm sugar), fruits and vegetables, and others (beverages, snacks). For example, in a food basket of a household that had consumed in the previous seven days: rice, corn, potato, cassava, fish, dried fish, palm oil, and sugar, the DDS would be 5; this score is derived from the five groups involved: grain (rice and corn), tuber (potato and cassava), animal product (fish and dried fish), oil and fat (palm oil), and sweets (sugar).

2) Empirical method

Consistent with the objective of this study, as outlined in section 1, we investigate the determinants of DDS-defined food security among households in a particular region of Indonesia, using the framework below:

$$logDDS_i = \tau_0 + \sum_{j=1}^{9} \beta_j logX_{ji} + \varepsilon_i, \quad (1)$$

where *DDS* represents the dietary diversity score defined in logarithm. X_{ji} is the vector of continuous variables, which includes household income (i.e., household head gender, age of the household head, household size, household type, number of households involved in income-generating activities, the sum of all incomes of all family members in the previous month, education level, the aggregate score obtained by a household from a set questions about food knowledge with regard to nutrients, and the food consumption consideration in a household). τ_0 and β_j are parameters to be estimated, and ε_i is the error term of the regression used to capture the effects of exogenous variables that are not included in the model. The parameters of equation 1 were estimated using the Ordinary Least Squares (OLS) technique.

3. Results and Discussion

Table 1 presents the summary statistics of the socioeconomic characteristics of the sample households. The heads of the sample households were mostly male; the heads' average age was 45 years old. On average, the sample households consisted of 4.4 persons, with 1.2 members being involved in income-generating activities. About 44.7% of the sample households were of a farm-household type, with an average household income of about USD112 – a figure substantially lower than Indonesia's gross national income per capita, which in 2012 was USD297 (Biro Pusat Statistik [2]). As many as 24.3% of household heads had not completed elementary education; only 6.2% had an undergraduate diploma. This means that the average formal education of the household heads was only at the high school level. The average score with regard to basic knowledge of food nutrition and preparation was 5.6, indicating that the household heads' food knowledge was at a middle level. Table 1 also shows that the main consideration of the household heads in planning food consumption within the household was glut, followed by affordability and availability. Only 7.5% of the sampled household heads considered nutritional aspects when planning food consumption within the household.

Table 1 Summary statistics: household characteristics of sample area

Summary statistic	Definition	Code	Mean, (%)*	Std. Dev.	Min	Max
- Gender	1=Male; 0=Female	GENDER	91.6			
- Age	Years old	HHH_AGE	45.0	13.2	19.0	90.0
- Household size	People	HH_SIZE	4.4	1.6	2.0	10.0
- Household type	1=Nonfarm; 0=Farm	HH_TYPE	55.3			
- Breadwinning role	People	BREADW_ROLE	1.2	0.4	1.0	3.0
- Household income	Rupiah/Month	INCOME	1,119,960.0	703,174.7	150,000.0	3,750,000.0
- Educational level:						
- Elementary	1=Elementary; 0=Below Elemt.	ELEMENTARY				
- Junior high	1=Junior High; 0=Below Elemt.	JUNIOR_HH	24.3			
- Senior high	1=Senior High; 0=Below Elemt.	SENIOR_HH	33.2			
- Under grad.	1=Under Grad; 0=Below Elemt.	UNDER_GRAD	29.9			
- Food knowledge	Score (0–10)	FKNOWLEDGE	6.2			
- Food consumption consideration:			5.6	1.9	1.0	9.0
- Glut	1=Glut; 0=Nutrient	GLUT	58.8			
- Affordable	1=Affordable; 0=Nutrient	AFFORDABLE	33.7			

Note: USD1 ≈ IDR10,000; JPY1 ≈ IDR110. * when reporting the individual binary variables, the percentage of the sample exhibiting the specific characteristic is reported, instead of the sample mean.

Source: Original field survey, March 2012

Tables 2 to 4 provide more detailed information about the socioeconomic characteristics of the sampled households. From Table 2, it can be inferred that the sample households were greatly burdened by their large sizes; the burden was exacerbated by the fact that, typically, only one person among the household members was involved in income-generating activities (Table 3).

The results within Table 4 imply that, in general, the welfare level of the sample households was quite homogenous, regardless of whether the households were categorized as being non-farm or farm households. In all, 10.2% of the non-farm and farm households were living below the national poverty line, Type I (chronic); however, there were more non-farm households living below the national poverty line, Type II, than farm households. Furthermore, among farm households, the percentage-composition of households in terms of income class might have been very different, had the survey been executed during the post-harvest season. From Table 5, it is clear that the households whose food-knowledge scores were "very poor" or "poor" were low-income households. On the other hand, households with higher incomes tended to have higher food-knowledge scores.

Table 2 Household sizes within the sample

Household size	Frequency	%
Fewer than 4 people	82	22.1
Between 5 and 6 people	146	39.4
More than 7 people	143	38.5
	371	100.0

Source: Original field survey, March 2012

Table 3 Number of members per sampled household involved in income-generating activities

Number of household members	Frequency	%
Only 1 person	287	78.7
More than 1 person	79	21.3
	371	100.0

Source: Original field survey, March 2012

Table 4 Cross-tabulation of income class and household class

Income class	Household class (samples)	
	Nonfarm	Farm
Less than IDR500,000	21 (10.2%)	17 (10.2%)
Between IDR500,000 and IDR999,900	103 (50.2%)	65 (39.2%)
Between IDR1,000,000 and IDR3,000,000	76 (37.2%)	76 (45.8%)
More than IDR3,000,000	5 (2.4%)	8 (4.8%)
	205 (100.0%)	166 (100.0%)

Note: USD1 ≈ IDR10,000; JPY1 ≈ IDR110.
Source: Original field survey, March 2012

Table 5 Cross-tabulation of income class and food-knowledge class type

Income class	Food knowledge class (samples)			
	Very poor (Score 0–2)	Poor (Score 3–4)	Fair (Score 5–6)	Good (Score 7–10)
Less than IDR500,000	10 (58.8%)	19 (19.9%)	6 (6.6%)	3 (1.9%)
Between IDR500,000 and IDR999,900	6 (35.3%)	77 (72.6%)	56 (61.5%)	29 (18.5%)
Between IDR1,000,000 and IDR3,000,000	0 (0.0%)	10 (9.4%)	29 (31.9%)	113 (72.0%)
More than IDR3,000,000	1 (5.9%)	0 (0.0%)	0 (0.0%)	12 (7.6%)
	17 (100.0%)	106 (100.0%)	91 (100.0%)	157 (100.0%)

Note: USD1 ≈ IDR10,000; JPY1 ≈ IDR110.
Source: Original field survey, March 2012

Table 6 presents a brief overview of the DDS distribution of the sample, while Figure 1 shows their distribution in terms of consumption of the nine identified food groups. The statistics in the lower panel of Table 6 show that, on average, the sampled households consumed foods from roughly six different food groups, although there were some households that consumed foods from two food groups, which is still a common situation in Indonesia. However, a closer look at Table 6 reveals also that if six food groups were to be taken as a "rule of thumb," then it appears that approximately 56.1% of the households in the sample could be considered food-secure. This result is almost similar to that of a previous study conducted within the same province but in a different district (Pipi et al. [16]), whose results indicated that the percentage of food-secure households in suburban areas, when measured in terms of food diversification score (FDS), was about 57.5%. FDS is another dietary diversification indicator that uses weighted indicators; it is based on older regulations concerning food consumption in Indonesia, and was originally proposed by Hardinsyah et al. [8].

Table 6 Dietary diversification score of sample households

DDS category	Frequency	%
Household eats 2 food groups	13	3.5
Household eats 3 food groups	19	5.1
Household eats 4 food groups	50	13.5
Household eats 5 food groups	81	21.8
Household eats 6 food groups	65	17.5
Household eats 7 food groups	89	24.0
Household eats 8 food groups	37	10.0
Household eats 9 food groups	17	4.6
Total households	371	100.0
DDS Max	9 food groups	
DDS Min	2 food groups	
DDS Mean + SD	5.8 ± 1.7 food groups	

Figure 1 shows that 100% of the respondents consume rice (grain group); in terms of predominance, this food is followed by the following foods: animal products, mainly eggs and fish (90%); a variety of fruits and vegetable (86%); sweets (82%); tubers (73%); oils and fats (65%); and nuts (16%). As such, the six most prevalent food groups consumed by the sample households were grain, animal products, fruits and vegetables, sweets, tubers, and oils and fats. Similarly, the households that consumed foods from only two food groups were likely to prepare only animal products to complement the grain group.

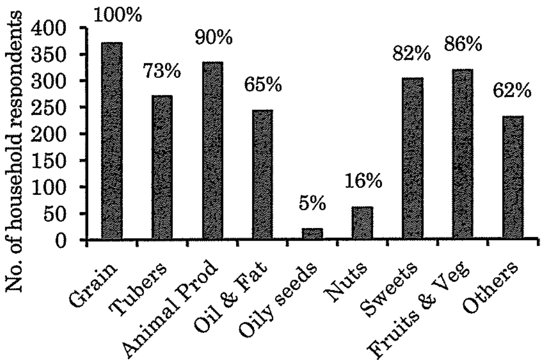

Figure 1 Distribution of food groups consumed by the household respondents

In line with the objective of this study, Table 7 shows the relationship between DDS and the socioeconomic characteristics of the sample households. The R^2 values, as shown in the lower panel of Table 6, indicate that about 89% of the variation in household DDS is jointly explained by the explanatory variables; moreover, the calculated F-statistics of 103.3 imply that all the explanatory variables jointly influence dietary diversity. Therefore, the goodness of fit is satisfactory.

Table 7 Multiple regression analysis results on the determinants of DDS

	Coefficients	Std. error	*P*-value
(CONSTANT)	4.135 ***	0.274	0.000
MALE	0.011	0.032	0.735
HHH_AGE	0.005	0.033	0.882
HH_SIZE	−0.001 *	0.021	0.093
FARM	0.010	0.018	0.551
BREADW_ROLE	0.004 *	0.029	0.090
INCOME	0.403 ***	0.019	0.000
ELEMENTARY	−0.025	0.037	0.501
JUNIOR_HH	−0.028	0.037	0.458
SENIOR_HH	−0.019	0.038	0.615
UNDER_GRAD	−0.049	0.049	0.317
FKNOWLEDGE	0.177 ***	0.028	0.000
GLUT	0.015	0.033	0.650
AFFORDABLE	−0.005	0.035	0.886
R^2	0.889		
Adjusted R^2	0.790		
Std. error	0.155		
F ratio	103.301 ***		0.000

Note: ***significant at $P < 0.1\%$; *significant at $P < 10\%$.

Together with household income and the number of household members involved in income generation, food knowledge significantly increases a household's DDS. This is the most important finding of this study and this is the first study to show that among rural low-income households, food knowledge is a significantly important factor that contributes positively to dietary diversity, even more so than the formal-education level of the household head. It was found in this study, however, that increased household size significantly reduces a household's food security; these results are in line with those of Bezerra and Sichieri [1], Pipi et al. [16], and Muluken et al. [13], each of whom found that family size significantly and negatively correlates with a household's state of food security. These studies also found that the age of the household head has a positive and significant association with food security. On the other hand, neither household head gender nor household type were found to be significant in this study, and in that sense, the results herein differ from those of Oluwatayo [15] and Sarah [18].

Specifically, the results show that a 100% increase in a households' income and in the number of household members involved in income generating activities would increase DDS by about 40% and 0.4%, respectively. Similarly, a 100% increase in the number of household members would reduce DDS by 0.1%. The strong elasticity of household income has being highlighted by Turrel et al. [22]; they even go so far as to say that this factor is always the strongest and most robust independent predictor of dietary behavior. Regarding the food knowledge of a household's members, it was found in the current study that if the food-knowledge indicator were to be increased by 100%, DDS would increase by about 18%. Although the elasticity of this factor was not so high that it would increase the households' food knowledge from a DDS of 5 to the maximum score (i.e., a 100% increase) and DDS may increase by only score point, this result suggests that informal education is very important to rural households in terms of increasing their dietary diversity, given that the formal education levels of the sampled household heads were relatively low. For deeper analysis, the interaction between significant factors was also examined. As the result, only the interaction between household income and food knowledge has a significant contribution to DDS. The interaction between educational level and food knowledge was also checked. However, there was no significant interaction found between it. Therefore, in general, public education programs designed to deliver food knowledge to the populace will be important and make a positive contribution to the dietary diversity of households. Ultimately, whenever household incomes increase and food knowledge is concurrently upgraded, DDS indicators are expected to increase.

4. Conclusions and Implications

This study sought to provide the newest information and extend the general understanding of household food security in a specific region of Indonesia, by examining dietary diversity and its socioeconomic determinants. Data captured through a cross-sectional survey of 371 households in the North Luwu district of South Sulawesi Province, conducted in 2012, were used in our analysis. The analysis itself was executed using descriptive statistics and OLS techniques. The results show that about 56.1% of the sample households consumed, at most, foods from 5.8 different food groups. The top six food groups consumed by the household respondents were grain (rice), animal products (mainly eggs and fish), a variety of fruits and vegetables, sweets, tubers (mostly sago starch), and oils and fats. In addition, this study found that in Indonesia, the variety of food groups consumed by a household is a sound measure of that household's food-security status. Since the execution of DDS-oriented research requires only a simple and low-cost survey set, and given Indonesia's very large area, this methodology makes it possible to conduct household-level food-security monitoring, over larger areas and more rapidly than has previously been the case.

The most important finding of this study is that food knowledge significantly increases a household's DDS, makes this study is the first to show that among rural low-income households, food knowledge is a significantly important factor that contributes positively to dietary diversity, even more so than the formal education level of the household head. Among the sample households, however, it was found that an increase in household size can significantly reduce DDS. Specifically, elasticity estimation results show that the income of a household plays the most important role in increasing DDS (40%), followed by the household's food knowledge score (18%). Therefore, it is implied that national and local governments should promote programs that improve household income, in order to increase DDS and, ultimately, improve nationwide food security. Although the elasticity of the food-knowledge factor was found to be relatively low, public education programs designed to educate the populace on food knowledge – such as community diversification and food security improvement programs from the Department of Agriculture – should be carried out continuously, in order to upgrade households' food-knowledge levels. This study's results show that by increasing household income, the purchasing power of a household can be strengthened; concurrently, food knowledge can be improved.

In future research, it would be interesting to examine DDS in conjunction with another food group classification. The PUP3KP classification could be modified based on regional characteristics, to derive even fairer results from local household base analyses.

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Impact of Trade Liberalization on Growth and Poverty:
The Case of Mongolia

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1. Introduction

Trade liberalization has been implemented globally in various forms, including domestic unilateral reforms, regional or bilateral free trade agreements, and multilateral liberalization agreements. In the case of Mongolia, trade liberalization has been mostly conducted unilaterally, except in relation to the country's entry into the World Trade Organization (WTO). Mongolia is currently the only WTO member country that has not concluded any regional free trade agreements.

In addition, further trade liberalization by way of bilateral and multilateral reforms is critical for connecting Mongolia to world markets. However, because of lack of data, little research has been conducted on the possible effects of trade liberalization on Mongolia's economy and poverty. The newly released Global Trade Analysis Project (GTAP) 8 database, in which Mongolia is first included as an independent region, has created opportunities to conduct comprehensive studies on the effects of trade reforms on the Mongolian economy (Narayanan et al. [4]). However, this study, to the best of the author's knowledge, is the first of its kind on Mongolia.

This study aims to examine and compare effects of various trade reforms on Mongolia's economy and welfare using a macro–micro approach that links the GTAP model with a microsimulation one. Reform types considered are unilateral, bilateral with China and Russia, and multilateral. An important advantage of the macro–micro approach is that it allows for the estimation of welfare impacts of trade reforms at the household level and addresses household heterogeneities. We estimate welfare effects across 11,172 sampled households in the Mongolian Household Socio-Economic Survey (HSES) for 2007–2008.

The rest of the paper is organized as follows. Section 2 discusses trade liberalization efforts and recent trade and poverty trends in Mongolia. Section 3 describes the data and methodology. Section 4 presents and discusses results. Section 5 concludes.

2. Recent trends of trade and poverty in Mongolia

In the early 1990s, trade liberalization was a critical reform conducted in Mongolia during its transition to a market-oriented system. With the main trade policy objectives of supporting sustainable development and economic growth and improving living standards, Mongolia started unilaterally liberalizing its trade regimes in the early transition years and gained access to the WTO in 1997 (Ministry of Foreign Affairs and Trade in Mongolia and United Nations Development Programme [3]).

Although WTO entry provides benefits in terms of an improved and more secure access to international markets, commitments that Mongolia accepted in its terms of accession to the WTO were relatively harsh at its level of development. For example, Mongolia exercised neither the transitional period for its obligations nor the exemption from export subsidy prohibition typically granted to developing countries. The applied tariff rates of Mongolia are approximately 5%, with no significant difference between agricultural and non-agricultural goods (Table 1).

By contrast, duties on Mongolian exports are much higher. The average tariffs for its agricultural and non-agricultural exports are approximately 10.2% and 9.2%, respectively (WTO [7]). In particular, import tariffs imposed by its major trading partners, China (14.8% for agriculture and 7.3% for non-agriculture) and Russia (21.1% for agriculture and 20.6% for non-agriculture), are the highest. Bilateral or multilateral efforts to reduce these would significantly affect the Mongolian economy. In addition to trade reforms vis-à-vis neighboring countries, Mongolia is also pursuing the reduction and elimination of tariffs on its exports under the WTO framework.

Table 1. Most favorable nation applied duties of Mongolia

Product groups	Average	Maximum	Product groups	Average	Maximum
Animal products	4.7	5.0	Minerals, and metals	5.0	5.0
Dairy products	5.0	5.0	Petroleum	5.0	5.0
Fruit, vegetables, and plants	5.2	15.0	Chemicals	5.0	5.0
Coffee, and tea	5.0	5.0	Wood, and paper	5.0	5.0
Cereals, and preparations	5.4	15.0	Textiles	5.0	5.0
Oilseeds, fats and oils	5.0	5.0	Clothing	5.0	5.0
Sugars, and confectionery	5.0	5.0	Leather, and footwear	5.0	5.0
Beverages, and tobacco	5.5	25.0	Non-electrical machinery	4.9	5.0
Cotton	5.0	5.0	Electrical machinery	4.7	5.0
Other agricultural products	5.0	5.0	Transport equipment	5.0	5.0
Fish, and fish products	5.0	5.0	Manufactures, not specified	4.7	5.0

Source: WTO [7]

Accession to the WTO significantly increased Mongolia's foreign trade turnover to approximately 130% of its GDP in 2010 (World Bank [6]). However, export revenues have been extremely volatile, with annual export growth rates ranging from approximately –80% to 40% during 1991–2010 and trade deficits have accumulated (NSO [5]). Such volatility is because export commodities are mainly a few types of minerals and raw agricultural materials (Table 2).

Table 2. Product composition of merchandise trade of Mongolia, 2009–2011

SITC sections	Description	Exports, %			Imports, %		
		2009	2010	2011	2009	2010	2011
0+1	Food, beverages, and tobacco	2.3	2.2	0.7	13.7	11.3	6.8
2+4	Crude materials (excluding fuels), oils, and fats	53.3	51.7	41.1	1.5	1.4	1.1
3	Mineral fuels, lubricants, and related materials	23.2	36.3	53.0	25.5	22.3	18.0
5	Chemicals, and related products	0.1	0.0	0.0	6.7	6.1	4.9
6	Manufactured goods classified chiefly by material	2.5	1.9	1.6	15.0	12.9	14.9
7	Machinery, and transport equipment	1.3	0.8	0.5	32.3	39.4	49.4
8	Miscellaneous manufactured articles	1.0	0.9	0.8	5.4	6.6	4.9
9	Commodities and transactions not classified elsewhere in SITC	16.4	6.1	2.3	0.0	0.0	0.0

Source: National Statistical Office of Mongolia (NSO) [5]
Notes: SITC – Standard International Trade Classification

In addition, export destinations have comprised a few countries, particularly China (Table 3). The share of exports to China has increased significantly in recent years, reaching more than 90% in 2011.

Table 3. Direction of trade by country, 2009–2011

Countries	Exports, %			Countries	Imports, %		
	2009	2010	2011		2009	2010	2011
China	73.9	84.8	92.2	China	25.2	30.3	30.7
Russia	3.6	2.8	2.0	Russia	36.2	32.7	24.6
Canada	7.8	4.9	1.9	USA	4.9	5.0	8.1
Italy	1.7	1.1	1.0	Japan	4.5	6.1	7.4
Korea, Republic of	0.8	1.0	0.8	Korea, Republic of	7.3	5.7	5.4
United Kingdom	6.7	2.3	0.4	Germany	3.3	2.7	4.1
Switzerland	0.1	0.1	0.4	Ukraine	2.0	1.3	2.3
Germany	0.8	0.8	0.3	Canada	0.4	0.7	1.9
Japan	0.2	0.1	0.2	France	2.8	1.7	1.5
France	0.1	0.1	0.2	Australia	0.7	1.2	1.4
Others	4.1	1.9	0.6	Others	12.9	12.6	12.4

Source: NSO [5]

Although the high product concentration and the small number of trading partners clearly indicates a need for diversification, a painful transition process resulting from sharp liberalization marks a new phenomenon, poverty, in this former socialist country. The 2007–2008 HSES estimated a poverty headcount rate of approximately 35% at the national level in 2008, showing little improvement from the 36% rate in 1995 (NSO [5]). Poverty incidence by the urban–rural divide shows, however, that rural poverty has since increased notably. The rural poverty headcount ratio reached 47% in 2008 from 33% in 1995. Because a majority of the rural population is engaged in traditional nomadic livestock herding, agricultural development can help alleviate poverty in Mongolia. In addition, trade liberalization of agricultural commodities and agricultural agreements are expected to affect the domestic agricultural sector significantly.

Given the persisting new phenomenon of rural poverty and the inevitability of more liberalized trade, a major challenge facing Mongolia is improving the living standards of the rural poor while meeting the international trade reform procedures. Therefore, we investigate the effects of various types of trade liberalization on economic growth and household welfare.

3. Data and Methodology

In this study, we apply a macro–micro simulation approach that combines the GTAP model based on the GTAP 8 database with the base year 2007 and a microsimulation model. Mongolia is included as a separate region in the GTAP 8 database for the first time. The original GTAP aggregation is modified to 6 regions and 24 sectors (Table 4). The factors of production are land, natural resources, capital, and skilled and unskilled labor. Land, natural resources, and capital are considered immobile factors, whereas labor is mobile. Capital is set as immobile to match the microsimulation model and to simulate short-term effects.

Table 4. Regions, sectors, and factors

Regions	Sectors			Factors	
	Agriculture and Food		Non-Agriculture	Mobile	Immobile
Mongolia	Rice	Other meat products	Mining of coal	Unskilled labor	Land
China	Wheat	Dairy products	Mining of metal ores	Skilled labor	Natural resources
Russia	Vegetables, and fruits	Sugar	Other extraction		Capital
Developed	Other grain crops	Beverages, and tobacco	Textiles, and clothing		
Developing	Live bovine animals	Other processed food	Light manufacturing		
Least developed	Other live animals	Fish	Heavy manufacturing		
	Raw milk		Utility, and construction		
	Raw animal products used in textiles		Transport, communication and trade		
	Meat of bovine animals		Other services		

Source: Author's aggregation based on GTAP 8 database

Trade liberalization is simulated through the removal of three types of distortions: domestic production subsidies/taxes, export subsidies/taxes, and import tariffs. Four scenarios (unilateral, bilateral with China, bilateral with Russia, and multilateral) are considered, each of which is subdivided into agricultural and non-agricultural policy reforms. Agricultural reforms are defined broadly to include agricultural raw materials and processed foods. For the unilateral and bilateral reform scenarios, removal of all three types of distortions is considered. For the multilateral reform scenario, we consider full removal of distortions in the developed and developing countries, and no changes for the least-developed countries. The closure rules follow the standard GTAP closure. For unilateral liberalization simulations, a small-country assumption, in which domestic policies do not affect the world prices, is applied.

The CGE model results produce changes in consumer, producer, and factor prices. These sets of price changes are then entered into the microsimulation model to measure welfare and poverty indicators at the household level. The microsimulation model uses highly disaggregated data on 11,172 households sampled nationwide in the 2007–2008 HSES.

This study's methodology closely follows that of Chen and Ravallion [2]. In this model, each household maximizes its utility by choosing consumption and work effort subject to its budget constraint. By solving the maximization problem and applying the Envelope theorem, we can calculate a first-order approximation to the welfare impact in a neighborhood of the household optimum. Then, the monetary value of the change in utility, g_i, for a household i is given by

$$g_i = \sum_{j=1}^{m}\left[p_{ij}^s q_{ij}^s \frac{dp_{ij}^s}{p_{ij}^s} - p_{ij}^d\left(q_{ij}^d + z_{ij}\right)\frac{dp_{ij}^d}{p_{ij}^d}\right] + \sum_{k=1}^{n}\left(w_k L_{ik}^s \frac{dw_k}{w_k}\right) \quad (1)$$

where p_{ij}^d and p_{ij}^s indicate consumer prices and supply prices, respectively, w_k represents wage rates, q_{ij}^s and q_{ij}^d indicate quantities supplied and consumption, respectively, z_{ij} represents production inputs, and L_{ik}^s represents the household labor supply of activity k outside its own business. The subscript j refers to sectors. Equation (1) yields the household-level welfare impacts for changes in prices and wages resulting from trade reforms.

The welfare gain/loss from trade reform in equation (1) depends on household consumption, labor supply, and production choices, which, in turn, depend on prices and household characteristics, that is, on x_{1i} and x_{2i}, respectively. Therefore, the welfare change can be written implicitly as

$$g_i = g\left(p_i^d, p_i^s, w_i, x_{1i}, x_{2i}\right) \quad (2)$$

Assuming that price differences are captured using a complete set of regional dummy variables, linearly transforming equation (2) with an additive error term yields the following regression model for the gains/losses:

$$g_i = \beta_1 x_{1i} + \beta_2 x_{2i} + \sum_k \gamma_k D_{ki} + \varepsilon_i \quad (3)$$

where $D_{ki} = 1$ if household i lives in region k and 0 otherwise and ε_i is the error term. The characteristics may include age of household head, education, demographic characteristics, and occupation.

Matching between the GTAP model and the household survey is the most crucial part of the macro–micro approach. The GTAP model sectors are matched with the closest category of the household survey. The detailed description of concordances of the GTAP sectors in the household survey categories is provided in the online appendix. Once we match the GTAP sectors and household survey categories, we can calculate changes in consumption and production for each household.

The GTAP model defines two types of labor: skilled and unskilled. In the household survey data, we use educational level to define individuals' skill levels. People who completed vocational education or higher are defined as skilled, whereas those with a qualification lower than vocational education are considered unskilled. Then, changes in the wage rates are used to calculate changes in wage income for each type of labor.

Land price changes from the GTAP model do not affect the household sector in our model. In Mongolia, the land privatization process is still ongoing. Currently, citizens can only own land for residential purposes. Pastoral land belongs to the government, and herders can use the land free of charge. Therefore, the household survey has no information on land ownership.

In assessing the impacts of trade reforms on poverty, we recalculate household consumption as a welfare measure for changes in prices. The poverty ratio is determined as the share of the population whose consumption is below the national poverty line (i.e., 62,494 MNT per month per person) estimated using the household survey.

4. Results

The GTAP model results show that the impact of trade liberalization in Mongolia varies depending on the reform type (Tables 5 and 6). In general, the impact of the unilateral trade reform is smaller compared to other types. Bilateral trade liberalization with China and Russia shows more positive effects, of which most gains are from non-agricultural reforms. By contrast, multilateral trade liberalization scenarios yield declines in GDP and welfare owing to several reasons, which are discussed later.

Generally, the welfare change from trade liberalization can be decomposed into allocative efficiency and the terms of trade effects. The allocative efficiency gained from trade is usually positive because productive factors are allocated more efficiently when trade policy barriers are removed during liberalization. Conversely, the terms of trade effects can be either positive or negative, depending on the trade structure. The net effect on welfare is the sum of the allocative efficiency gain and the changes in terms of trade. In the case of Mongolia, allocative efficiency is positive in all types of trade reforms. However, the adverse effects of the terms of trade dominate in the unilateral and multilateral reforms, resulting in welfare reduction.

Table 5. Changes in GDP in Mongolia, percentage change from the base

	Private consumption	Investment	Government expenditure	Exports	Imports	GDP
Base, million USD	1,984.0	1,474.8	518.2	2,391.9	-2,439.3	3,929.6
Unilateral	-0.8	-0.3	-0.5	0.2	0.2	-0.6
Agricultural	-0.1	-0.1	-0.1	0.1	0.1	-0.1
Non-agricultural	-0.5	-0.8	-0.5	2.3	2.3	-0.6
Bilateral with China	2.0	3.9	2.2	0.5	1.9	1.9
Agricultural	0.0	0.1	0.1	0.1	0.1	0.1
Non-agricultural	2.0	3.9	2.1	0.3	1.8	1.8
Bilateral with Russia	4.6	6.1	4.8	-0.1	1.6	4.2
Agricultural	0.4	0.7	0.4	0.2	0.4	0.4
Non-agricultural	4.3	5.4	4.4	-0.3	1.2	3.8
Multilateral	-10.3	-10.6	-10.2	-7.8	-8.3	-10.1
Agricultural	-0.5	0.1	-0.1	0.0	0.1	-0.3
Non-agricultural	-9.7	-10.7	-9.9	-7.7	-8.4	-9.7

Source: Author's simulations

Table 6. Welfare change in Mongolia, in millions of USD

	Total	Allocative efficiency	ToT in goods and services	ToT in savings-investment
Unilateral	-6.9	5.5	-11.8	-0.7
Agricultural	0.2	1.3	-1.0	0.0
Non-agricultural	-7.3	4.2	-10.8	-0.6
Bilateral with China	43.3	0.3	42.8	0.2
Agricultural	1.5	0.2	1.3	0.1
Non-agricultural	41.8	0.2	41.6	0.1
Bilateral with Russia	110.2	3.5	106.5	0.3
Agricultural	5.0	1.0	3.9	0.1
Non-agricultural	105.8	2.7	103.1	0.1
Multilateral	-83.2	4.8	-85.4	-2.7
Agricultural	10.0	2.6	7.3	0.1
Non-agricultural	-91.5	2.3	-91.0	-2.8

Source: Author's simulations
Notes: ToT—terms of trade

Although the negative welfare impact of trade liberalization, particularly the multilateral reform, seems odd, it is not uncommon. Trade reforms improve overall world welfare, but an individual country may suffer (Bouet [1]). This finding also holds for our multilateral simulation, because our result for the world welfare is positive (239 billion USD), whereas that for Mongolia is negative.

A number of reasons exist for the possible negative growth and welfare implications of trade liberalization. First, as the welfare decomposition suggests, the effects of adverse terms of trade outweigh the allocative efficiency gain because either import prices increase or export prices decrease owing to increased competition in the export markets. Because Mongolia mainly exports primary commodities and imports manufactured goods, it is subject to deterioration in terms of trade. Second, preferential access to certain developed countries' markets could be eroded. Currently, Mongolia is granted nonreciprocal preferential access under the United States Generalized System of Preferences (GSP) and the European Union's (EU's) GSP Plus. In particular, cashmere exporters have been benefiting from the EU GSP Plus scheme. If tariff cuts were to be granted to all WTO members under the multilateral liberalization scenario, the relative advantage of existing preferential access would be reduced. In some cases, costs associated with the erosion of preferences may exceed the benefits derived from multilateral trade liberalization, resulting in a net loss. Third, Mongolia may face short-run adjustment costs when government revenues from tariffs are reduced. This is particularly true for our simulations because we consider short-run impacts to match the GTAP model with the household survey. A dynamic CGE model that considers the increase in factors of production, technical progress, and factor productivity is required to evaluate the long-term impacts of trade liberalization. Finally, because of data limitations, our model does not consider several types of distortions such as rules of origin, technical barriers, and sanitary and phytosanitary regulations that may distort trade and reduce welfare. Therefore, the multilateral liberalization in our model does not refer to frictionless trade.

In contrast, Mongolia is likely to gain from bilateral trade agreements with China and Russia. The complementary trade structure between Mongolia and its two major trading partners may improve Mongolia's terms of trade by increasing the demand for its exports. Moreover, physical proximity positively affects trade relations with the two countries.

Table 7. Regression of per capita gains/losses from unilateral and multilateral reforms

	Unilateral			Multilateral		
	Total	Agricultural	Non-agricultural	Total	Agricultural	Non-agricultural
Characteristics of household						
Poor	-2,780.8 ***	-3,300.1 ***	1,968.1 ***	-31,242.4 ***	-2,906.5 ***	-27,556.6 ***
	-(9.12)	-(39.21)	(7.20)	-(53.32)	-(24.48)	-(50.91)
Household size	-578.9 ***	-785.2 ***	406.2 ***	-2,739.5 ***	-505.4 ***	-2,272.5 ***
	-(6.53)	-(32.13)	(5.12)	-(16.10)	-(14.66)	-(14.46)
Share of kids	10.2	-2.3	10.7 *	-81.9 ***	9.1 ***	-84.6 ***
	(1.41)	-(1.18)	(1.65)	-(5.90)	(3.22)	-(6.60)
Savings	3,031.7 ***	341.8 ***	2,159.3 ***	5,273.4 ***	705.9 ***	3,740.2 ***
	(9.88)	(4.04)	(7.85)	(8.95)	(5.91)	(6.87)
Characteristics of household head						
Age	-23.6 *	10.7 ***	-47.0 ***	12.2	-6.7	22.9
	-(1.80)	(2.96)	-(3.99)	(0.48)	-(1.30)	(0.98)
Male	1,891.3 ***	303.6 ***	1,691.6 ***	-1,608.6 *	797.0 ***	-2,236.1
	(4.32)	(2.51)	(4.31)	-(1.91)	(4.67)	-(2.88) **
Married	840.6 **	55.3	586.4 **	1,737.2 ***	214.9 *	1,257.1 **
	(2.54)	(0.61)	(1.98)	(2.73)	(1.67)	(2.14)
No education	-1,903.3 ***	-278.7 *	-1,174.6 **	-9,717.9 ***	-959.8 ***	-8,318.0 ***
	-(3.32)	-(1.76)	-(2.29)	-(8.83)	-(4.31)	-(8.19)
Primary education	-1,598.6 ***	-204.1 *	-941.8 **	-8,094.6 ***	-713.0 ***	-6,857.1 ***
	-(3.66)	-(1.70)	-(2.41)	-(9.66)	-(4.20)	-(8.86)
Secondary education	-827.6 ***	-70.4	-841.8 ***	-4,096.4 ***	-388.6 ***	-3,303.6 ***
	-(2.42)	-(0.75)	-(2.74)	-(6.23)	-(2.92)	-(5.44)
Vocational education	-1,677.5 ***	-332.8 ***	-1,531.0 ***	-4,312.4 ***	-669.1 ***	-3,222.1 ***
	-(3.98)	-(2.86)	-(4.06)	-(5.33)	-(4.08)	-(4.31)
College education	2,657.4 ***	311.4 ***	2,028.6 ***	3,010.3 ***	693.1 ***	3,072.5 ***
	(6.48)	(2.75)	(5.52)	(3.82)	(4.34)	(4.22)
Herder	1,128.7 ***	322.4 ***	614.9	-258.6	1,163.0 ***	-1,589.7 *
	(2.41)	(2.49)	(1.46)	-(0.29)	(6.38)	-(1.91)
Constant	8,042.0 ***	11,973.9 ***	-6,604.7 ***	78,379.7 ***	8,384.4 ***	68,513.6 ***
	(8.93)	(48.21)	-(8.19)	(45.33)	(23.93)	(42.89)
Observations	11,172	11,172	11,172	11,172	11,172	11,172
R-square	0.36	0.25	0.36	0.31	0.24	0.28

Source: Author's estimations

Notes: t-statistics are in parentheses. *, **, and *** represent the 1%, 5%, and 10% statistical significance level, respectively. The dependent variable is the per capita gains/losses in MNT.

Although the welfare change at the national level is a useful indicator, it conceals information on the trade reform winners and losers. We expect that household gains/losses from trade liberalization depend on household-specific characteristics. Tables 7 and 8 show highlights from our regression model estimation (3). The full series of independent variables estimated is reported in the online appendix. Equation (3) is estimated using a robust regression technique to remedy outliers that persist even after appropriate data cleaning procedures. By applying the robust regression technique, we are able to consider all valuable data collected and still get consistent and unbiased estimates.

The estimated coefficients on most variables are highly statistically significant; however, their signs vary for the different trade reforms. Because there are no *a priori* expected signs for the estimated coefficients, it indicates that various types of trade reforms have different impacts on household welfare. Our results demonstrate that poor households and those with many children are likely to lose in unilateral and multilateral reforms, with the exception of a unilateral non-agricultural reform.

Table 8. Regression of per capita gains/losses from bilateral reforms

	Bilateral with China			Bilateral with Russia		
	Total	Agricultural	Non-agricultural	Total	Agricultural	Non-agricultural
Characteristics of household						
Poor	7,000.9 ***	459.8 ***	7,074.5 ***	11,958.4 ***	2,817.4 ***	9,406.6 ***
	(24.01)	(14.63)	(26.76)	(20.97)	(18.57)	(20.57)
Household size	659.8 ***	79.0 ***	604.9 ***	2,424.3 ***	1,314.2 ***	1,012.9 ***
	(7.79)	(8.66)	(7.88)	(14.64)	(29.83)	(7.63)
Share of kids	23.7 ***	1.0	25.5 ***	77.0 ***	25.7 ***	51.4 ***
	(3.43)	(1.34)	(4.08)	(5.70)	(7.14)	(4.74)
Savings	520.6 *	101.6 ***	210.4	1,952.9 ***	54.2	1,370.3 ***
	(1.78)	(3.22)	(0.79)	(3.40)	(0.36)	(2.98)
Characteristics of household head						
Age	-40.8 ***	-5.0 ***	-35.1 ***	-134.1 ***	-40.1 ***	-82.0 ***
	-(3.25)	-(3.72)	-(3.08)	-(5.45)	-(6.12)	-(4.16)
Male	2,148.9 ***	265.8 ***	1,816.8 ***	3,088.8 ***	-77.3	3,229.2 ***
	(5.13)	(5.89)	(4.79)	(3.77)	-(0.36)	(4.92)
Married	274.2	-18.2	222.0	1,334.2 **	451.7 ***	574.0
	(0.87)	-(0.53)	(0.77)	(2.15)	(2.74)	(1.16)
No education	-323.8	249.9 ***	-362.3	-2,571.4 **	863.9 ***	-2,138.8 ***
	-(0.59)	(4.23)	-(0.73)	-(2.40)	(3.03)	-(2.49)
Primary education	-358.9	315.9 ***	-591.0	-2,454.6 ***	162.6	-2,201.5 ***
	-(0.86)	(7.03)	-(1.56)	-(3.01)	(0.75)	-(3.37)
Secondary education	-1,010.1 ***	300.6 ***	-1,271.5 ***	-3,914.5 ***	-395.1 **	-3,089.8 ***
	-(3.09)	(8.52)	-(4.29)	-(6.11)	-(2.32)	-(6.02)
Vocational education	-1,733.4 ***	-40.1	-1,660.8 ***	-3,569.3 ***	-549.3 ***	-3,219.1 ***
	-(4.31)	-(0.92)	-(4.55)	-(4.53)	-(2.62)	-(5.10)
College education	396.8	-292.3 ***	584.8 *	2,912.3 ***	-107.2	2,451.7 ***
	(1.01)	-(6.92)	(1.65)	(3.80)	-(0.53)	(3.99)
Herder	2,890.7 ***	968.2 ***	1,737.6 ***	4,809.4 ***	320.7	3,474.6 ***
	(6.46)	(20.06)	(4.28)	(5.49)	(1.38)	(4.95)
Constant	-15,631.6 ***	-1,145.0 ***	-15,698.9 ***	-38,374.2 ***	-17,141.7 ***	-22,111.3 ***
	-(18.17)	-(12.35)	-(20.13)	-(22.80)	-(38.29)	-(16.38)
Observations	11,172	11,172	11,172	11,172	11,172	11,172
R-squared	0.26	0.18	0.27	0.30	0.18	0.29

Source: Author's estimations

Notes: t-statistics are in parentheses. *, **, and *** represent the 1%, 5% and 10% statistical significance level, respectively. The dependent variable is the per capita gains/losses in MNT.

Table 9. Poverty incidence, change from the base in percentage points

	Urban	Rural	Total
Base	26.9	46.6	35.2
Unilateral	0.05	0.12	0.08
Agricultural	0.39	0.54	0.45
Non-agricultural	-0.51	-0.86	-0.66
Bilateral with China	-1.04	-1.27	-1.14
Agricultural	-0.16	-0.12	-0.15
Non-agricultural	-1.03	-1.27	-1.13
Bilateral with Russia	-1.71	-2.60	-2.09
Agricultural	-0.82	-1.17	-0.97
Non-agricultural	-1.38	-1.61	-1.48
Multilateral	3.63	3.36	3.52
Agricultural	0.26	0.25	0.25
Non-agricultural	3.21	3.11	3.16

Source: NSO [5] and author's computations

Notes: The baseline poverty rate is for 2008.

By contrast, the same households tend to gain in all bilateral reforms. Households with savings gain in all reforms, and those with young, male, and married household heads are likely to gain in most unilateral and bilateral reforms. Conversely, the age of household head is not an important factor affecting whether the household gains from multilateral reforms. The educational level of the household head is more important in non-agricultural reforms. Whereas the less educated are able to gain in bilateral agricultural reforms, the college-educated gain from most trade reforms. Herders are likely to gain in all bilateral and agricultural reforms, whereas they lose from multilateral non-agricultural reforms. In general, bilateral trade reforms are more poverty alleviating, whereas the poor tend to lose in unilateral and multilateral reforms.

Table 9 summarizes poverty impacts of different trade reform scenarios in Mongolia. Consistent with the regression results, bilateral reforms reduce poverty, whereas multilateral reforms likely increase poverty. The magnitude of the changes is larger in non-agricultural reforms. The poor tend to be engaged in activities that are adversely affected by increased competition from multilateral liberalization, whereas the complementary trade structures of China and Russia increase the demand for Mongolia's exports and reduce poverty.

5. Conclusion

This study attempted to analyze the effects of various trade reforms on economic growth and poverty in Mongolia using a macro–micro simulation approach. Our results prove that trade reform types matter for growth and poverty. In the case of Mongolia, bilateral trade liberalization with China and Russia positively affects both GDP and welfare. Bilateral reforms are also more poverty alleviating than unilateral and multilateral liberalization, particularly in rural herder households. In contrast, multilateral liberalization is likely to result in a decline in growth and an increase in poverty. Several reasons could explain why trade liberalization causes a negative outcome, including terms of trade deterioration, erosion of preferences, and short-run adjustment costs.

We find that household characteristics determine whether the household gains from trade liberalization. Poor households and those with many children are likely to lose in most unilateral and multilateral reforms, whereas they tend to gain in bilateral reforms. This may indicate that the poor are likely to be engaged in activities that are adversely affected by the increased competition from multilateral liberalization. Thus, complementary policies that help the poor overcome the adverse effects of multilateral liberalization should be implemented. For example, investment in human capital may alleviate poverty, as the low educated tend to lose from trade liberalization. Moreover, macroeconomic stability policies should be implemented to mitigate adverse short-term shocks of trade reforms.

Although the advantages of our model for evaluating welfare changes at the household level are evident, it is not free of limitations. First, dynamic gains resulting from technical progress and productivity growth may exist that are not being captured by our model. Such dynamic gains can be captured by applying a dynamic CGE model and household survey panel data. Second, owing to data limitations, several types of distortions are not considered in our model, such as rules of origin, technical barriers, and sanitary and phytosanitary regulations. These types of distortions have often been applied because the relative importance of tariffs and export subsidies has declined considerably owing to worldwide trade liberalization agreements. Although we acknowledge these limitations, we believe that our results provide evidence regarding the short-run distributional impact of trade liberalization.

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An Integrated Epidemiological-economic Analysis of HP-PRRS Control Strategies in Vietnam

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1. Introduction

Highly pathogenic porcine reproductive and respiratory syndrome (HP-PRRS) is a very contagious, economically devastating viral disease affecting swine. Since 2007, the Vietnamese pig-farming sector has been affected by this syndrome, which has caused more than 300,000 swine deaths and affected 26/60 provinces during 2008. Since pig production is the major source of income for most farmers in Vietnam, HP-PRRS severely damaged these farmers' livelihoods (Zhang and Kono [14]).

To control HP-PRRS, the Food and Agriculture Organization (FAO) recommended nine control measures, including surveillance, vaccination, cleaning, and disinfection. However, conducting all of the measures at pig farms in Vietnam was considered to be unrealistic due to budget limitations. According to Ministry of Agriculture and Rural Development (MARD) regulation No. 80/2008/QD-BNN, the stamping out (SO) control strategy was applied in Vietnam, and the government provided a subsidy (amounting to about 70% of the market value of all culled pigs) to encourage pig farms to cull infected pigs. In this regulation, the HP-PRRS vaccination is also recommended; however, only a few large commercial pig farms took this measure, due to the cost and unavailability of the vaccine.

Three types of HP-PRRS control strategies are available in Vietnam: ① SO, or culling of all infected pigs; ② strategic vaccination (SV), which implies culling all infected pigs and vaccinating susceptible pigs immediately after the first infection, aiming to achieve an optimal vaccination proportion[1)]; and ③ preventive vaccination (PV), which refers to vaccinating all pigs before an outbreak occurs.

Although the PV strategy is epidemiologically effective (Mengeling [8]), only a few large commercial pig farms applied this strategy due to the high price of the HP-PRRS vaccine (Field survey, 2012). Clearly, PV is not economically suitable for HP-PRRS control in Vietnam. For that reason, an integrated epidemiological and economic analysis of alternative HP-PRRS control strategies is needed. It can be hypothesized that a proper HP-PRRS control strategy, appropriate for the pig farms in Vietnam, would control the virus in an epidemiologically effective manner and also be economically efficient. Therefore, the purpose of this study was to investigate the most economically and epidemiologically efficient HP-PRRS control strategy for Vietnam.

2. Data and Methods

Epidemiological data were collected from Huong Tra District in Hue province, Vietnam, where a severe outbreak of HP-PRRS occurred in 2008. Field surveys were conducted in September 2012 and March 2013 in Hue province, Vietnam. In those surveys, research interviews were conducted with local veterinarians and experts on agricultural economics.

To determine the most economically effective HP-PRRS control strategy, several effects, epidemiological as well as economic, must be taken into account (Morris [9]). Therefore, this study uses the concepts described by Dijkhuizen *et al.* [3], who developed a framework for analyzing the efficiency of animal disease control strategies from economic and epidemiological standpoints. This framework includes two sub-models (the epidemiological and economic models). Because SV is not administered in Vietnam, an epidemiological model was applied to estimate its epidemiological effectiveness, and an economic model was designed to evaluate the economic efficiency of each control strategy.

It is accepted practice to apply epidemiological principles and economic analysis (also known as animal health economics) for evaluating animal disease control strategies in developed countries. However, this remains a novel approach for evaluating animal disease control strategies in developing countries (Zhang *et al.* [15]).

2.1 Epidemiological models

To estimate the epidemiological effectiveness of SV, we developed a variant of the classic infectious disease epidemic model, the Susceptible Infected Recovered (SIR) Model, for HP-PRRS transmission within individual pigs. This model is based on that of Lanzas *et al.* [7], with modifications specific to HP-PRRS outbreak in pig farms.

In an SIR model, we hypothesize a population which is composed of three groups of individuals: susceptible (S), infectious (I), and immune (R).[2] A latent state was not included in the models as the latent period in HP-PRRS infection is thought to be very short and therefore to have little impact on the infection dynamics (Anderson and May [1]).

The SIR model was applied to the situation of pig production in Huong Tra District. This model operated under the following assumption:

①The pig population size in Huong Tra District is constant, as the recruitment rate is equal to the exit rate.

② The pig population mixes homogeneously in terms of piglets, grower pigs, boars and sows.[3]

③The pig population consists of those immune and those susceptible, but they are mixed homogenously and not distinguished in the market.

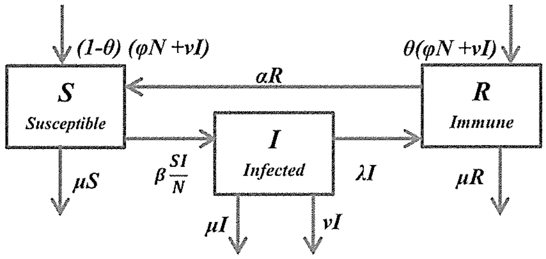

Figure 1. Flow diagram of the SIR model for HP-PRRS control (SV case)

④Vaccination is administered immediately after the first case of HP-PRRS infection.

⑤The infected animals will be identified and culled under the surveillance system ($\nu I(t)$), or be sold to the market ($\mu I(t)$), or will recover and gain natural immunity ($\lambda I(t)$).[4]

⑥The analysis period is one year.

The dynamics of state transitions are illustrated in Figure 1. All symbols are defined in Table 1. This model was defined by a set of three ordinary differential equations.[5]

$$\frac{dS(t)}{d(t)} = -\beta\frac{S(t)I(t)}{N} + (1-\theta)(\varphi N + \nu I(t)) + \alpha R(t) - \mu S(t) \qquad (1)$$

$$\frac{dI(t)}{d(t)} = \beta\frac{S(t)I(t)}{N} - \lambda I(t) - \nu I(t) - \mu I(t) \qquad (2)$$

$$\frac{dR(t)}{d(t)} = \theta(\varphi N + \nu I(t)) - \alpha R(t) - \mu R(t) + \lambda I(t) \qquad (3)$$

The basic reproduction number R_0 and the optimal vaccination proportion θ should be:[6)]

$$R_0 = \frac{\beta}{\mu + \lambda + \nu} \qquad (4)$$

$$\theta > \frac{1 - (1/R_0)}{h} \quad for \quad R_0(1 - h\theta) < 1 \qquad (5)$$

The "basic reproduction number, R_0" is defined as the average number of successful transmissions of the disease per infectious pig. The "optimal vaccination proportion, θ" is defined as the minimum proportion of animals required to be vaccinated for the incidence of an infection to decrease (Vynnycky and White [11]). If $R_0 > 1$, the number of infections will increase, and when $R_0 < 1$, the number of infections will decrease. However, if the vaccination proportion exceeds the optimal vaccination proportion, then R_0 will fall to less than one, and the number of infected pigs will decrease. Therefore, in the SV control strategy, the vaccination proportion should be at least the optimal vaccination proportion.

Table 1. Definitions of variables and initial parameter estimates in the SIR model

	Symbol	Unit	Definition	Estimate	Source
Variables	S	Head	Susceptible population	Initial = 28899	Field survey, 2012
	I	Head	Infectious population	Initial =1	---------
	R	Head	Recovered population	Initial =0	---------
	N	Head	Total population	Initial = 28900 (=S+I+R)	Field survey, 2012
Parameters	β	Day^{-1}	Transmission coefficient	0.192	MCMC[a)]
	φ	Day^{-1}	Recruitment rate	0.0089	Field survey, 2012[b)]
	θ	Day^{-1}	Vaccination proportion	0.134	Equation [5][c)]
	α	Day^{-1}	Immunization failure rate	0.001	Expert opinion[d)]
	λ	Day^{-1}	Recovery rate	0.017	Wills *et al.* [13][e)]
	ν	Day^{-1}	Daily culling rate	0.143	Field survey, 2012[f)]
	μ	Day^{-1}	Daily exit (sold) rate	0.0089	Field survey, 2012[g)]
	h	Day^{-1}	Vaccine efficacy	0.9	Field survey, 2012[h)]

Notes: a) The parameter was derived from data in a previous study (Zhang *et al.* [15]), and the Markov Chain Monte Carlo (MCMC) method was applied (See notes 7).
b) The daily recruitment rate is the reciprocal of the number of breeding days (112 days from the field survey data of Zhang *et al.* [15])
c) If the vaccination proportion is lower than this level, the outbreak would continue for more than 1 year, which would exceed the present analysis period.
d) Probability of HP-PRRS immunized pigs losing their immunity.
e) The recovery rate is the reciprocal of the disease onset period (60 days in previous research)
f) The culling rate is the reciprocal of the time period between the pigs being infected and being culled; we presume this time period is 1 week in this study.
g) The daily exit rate is same as the daily recruitment rate (see assumption ①)
h) ***h*** is the proportion vaccinated who are completely protected (gain immunity); *1*- ***h*** is the proportion of complete failures to vaccination (those with no immunity). (See notes 8)

2.2 Economic models

Cost-benefit analysis (CBA) is an economic model suitable for comparing the costs and benefits of an HP-PRRS vaccination program. It has been widely used for evaluating animal disease control programs. There are two perspectives for calculating the cost and benefit in the CBA: ①, the private perspective; and ②, the social perspective (Hitzhusen *et al.* [4]). The CBA in this study takes the point of view of the pig farm owner (*i.e.*, a private perspective).

Based on the results of the epidemiological model of disease losses in alternative HP-PRRS control strategies, the economic model calculates the costs and benefit of each control strategy. The major input values for economic analysis are summarized in Table 2. The CBA model is presented in Table 3.

The variables "⑥, number of culled pigs" and "⑦, number of vaccinated pigs" (Table 2) in SV were estimated from the SIR model, and based on this epidemiological estimation, we calculated the disease loss and the economic benefit of each control strategy (Table 3). The benefit of each control strategy (SO, SV, and PV) can be calculated by the disease loss in the baseline situation: No intervention (D_{NI}) minus the disease loss in each control strategy (D_{SO}, D_{SV} and D_{PV} respectively).

Table 2. Input values used for cost-benefit analysis

Items	Value	Source
①Vaccine cost (VND/head)	39,000	Field survey, 2012[1)]
②Total pig population (head)	28,900	Field survey, 2012[2)]
③Average body weight of culled pigs (kg)	50.1	Zhang *et al.* [15][3)]
④Market price of healthy pigs sold (VND/kg)	38,000	Zhang *et al.* [15][4)]
⑤Subsidy for culled pigs (VND/kg)	25,000	Zhang *et al.* [15][5)]
⑥Number of culled (dead) pigs (head)	Simulation results	SIR model[6)]
⑦Number of vaccinated pigs (head)	Simulation results	SIR model[7)]

Notes: VND=Vietnam Dong.
1) Cost per dose of HP-PRRS vaccine (33,000 VND for vaccine cost and 6,000 VND for veterinary service). The vaccination cost is paid by the pig farm owners. One dose of HP-PRRS vaccine is sufficient.
2) Total pig numbers in Huong Tra District, estimated by local veterinarians.
3) The average body weight of culled pigs was calculated from the epidemiological data collected in Huong Tra District in Hue province, Vietnam.
4) Average market price during 2008, Ministry of Agriculture and Rural Development in Vietnam.
5) The government provided a subsidy (approximately 70% of the market value of the culled pigs) to encourage pig farms to cull infected pigs.
6) The number of culled pigs was estimated accordingly. In the SV scenario it was estimated from the SIR model; in the no intervention (NI) scenario, it was estimated from a previous study by Zhang *et al.* [15]; in the SO scenario it is cited from actual epidemiological data collected from field research in 2013 in Hue province; and in the PV scenario we assumed it to be 0.
7) The number of vaccinated pigs was estimated accordingly. In the SV scenario it was estimated from the SIR model; in the NI and SO scenarios, it was 0; and in the PV scenario we assumed it to be 86,700 (=28,900*12/4; the estimated lifespan of pigs in this study was 4 months).

Table 3. Costs and benefit of alternative HP-PRRS control strategies

Cost item	No intervention (NI)		Stamping out (SO)		Strategic vaccination (SV)		Preventive vaccination (PV)	
Cost	0		③*⑥*(④-⑤)[1)]	$=C_{SO}$	①*⑦+③*⑥*(④-⑤)	$=C_{SV}$	①*⑦	$=C_{PV}$
Disease loss	③*④*⑥	$=D_{NI}$	③*④*⑥	$=D_{SO}$	③*④*⑥	$=D_{SV}$	③*④*⑥	$=D_{PV}$
Benefit	0		$D_{NI}-D_{SO}$	$=B_{SO}$	$D_{NI}-D_{SV}$	$=B_{SV}$	$D_{NI}-D_{PV}$	$=B_{PV}$
Benefit/cost (B/C) ratio=	0		B_{SO}/C_{SO}		B_{SV}/C_{SV}		B_{PV}/C_{PV}	

Notes: The number (①,②...⑦) in Table 3 correspond to the same number in Table 2.

3. Results

According to our SIR model, the R_0 of HP-PRRS outbreak in the study area was 1.14 and the optimal vaccination proportion was 13.4%.[9)]

The epidemiological analysis shows that PV had the largest economic benefit among the three strategies, but the highest cost. On the other hand, SV had the lowest cost (794 million VND compared to 3,381 million VND for PV) but a benefit only a little smaller than that of PV (32,218 million VND, compared to 33,012 million VND for PV), and this strategy had the largest benefit/cost (B/C) ratio (Table 4).

Table 4. Costs and benefits of alternative HP-PRRS control programs

Items	Unit	NI	SO	SV	PV
Number of culled (dead) pigs	(head)	17,340	2,441	417	0
Number of vaccinated pigs	(head)	0	0	12,006	86,700
Disease loss	(Million VND)	33,012	4,647	794	0
Cost	(Million VND)	----	1,590	990	3,381
Benefit	(Million VND)	----	28,356	32,218	33,012
B/C ratio		----	**17.8**	**32.5**	**9.8**

If the SV control strategy was to be conducted with the optimal vaccination proportion, the estimated number of infected and culled pigs would be 417, but 12,006 animals would need to be vaccinated during the 1-year period (Table 4). On the other hand, in the SO scenario, although the cost of vaccination was zero, 2,441 infected pigs would have to be culled, and in the PV scenario, although the disease loss of culling infected pigs was zero, 86,700 would have to be vaccinated.

However, in the case of SV, if the vaccination proportion was increased from the optimal vaccination proportion (13.4%) to around 20%, the B/C ratio would increase, in other words, the economic efficiency would increase. Although the optimal vaccination proportion of 13.4% is the most epidemiologically efficient HP-PRRS control strategy, a vaccination proportion of around 20% is the most economically efficient. On the other hand, for a vaccination proportion over 20%, the B/C ratio would decrease due to the high cost of vaccination, but even we increased the vaccination proportion to 100%, the benefit of the SV would still be about 10 times larger than its cost (Figure 2).

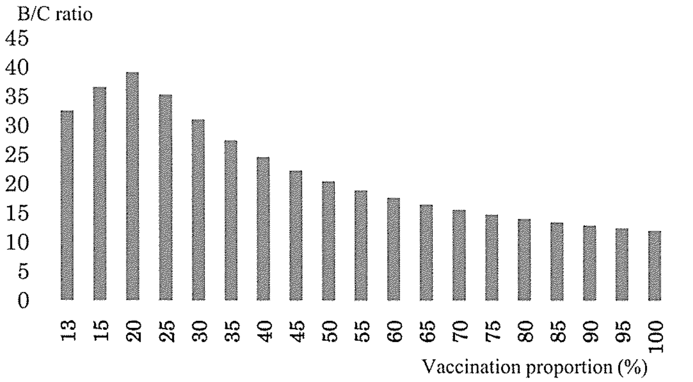

Figure 2. Relationship between HP-PRRS vaccination proportion and the B/C ratio

Conversely, if the vaccination proportion fell below to 13.4%, the B/C ratio would decrease and the outbreak would continue for more than 1 year. For example, if the proportion was 10%, the estimated number of infected pigs in the first year would be 1,518, but the infection would continue to occur and 10,838 animals would be newly infected in the second year.

4. Discussion

4.1 Major findings of this study

Our results suggest that a SV control strategy (with a vaccination proportion of 13.4%) is the most epidemiologically efficient HP-PRRS control strategy; moreover if the vaccination proportion increased to around 20%, it would also be the most economically effective. On the other hand, if the vaccination proportion fell below 13.4%, the outbreak would continue more than 1 year and B/C ratio would decrease; conversely, if the vaccination proportion exceeded 20%, the B/C ratio would also fall due to the high cost of vaccination.

From a pig farmer's point of view, although the benefit of PV is the largest, the B/C ratio of SV is the highest. Although PV enables perfect control of HP-PRRS, the cost of this strategy is more than three times that of SV (3,381/990=3.42; Table 4). The cost performance of PV is the lowest (as indicated by the lowest B/C ratio; Table 3) of the strategies. On the other hand, although SV cannot prevent an HP-PRRS outbreak completely (417 animals infected and culled (Table 4)), it can indeed control an outbreak effectively, with the lowest cost and highest cost performance of the three strategies (S/C ratio of 32.5; Table 4). Further, if the vaccination proportion in the SV strategy was increased from 13.4% to around 20%, the cost performance would increase further (Figure 2).

HP-PRRS vaccine is available but expensive. For HP-PRRS in developing countries where most pig farms are small, a PV control strategy is costly and therefore difficult to conduct. A SV strategy with a vaccination proportion of 20% had the most favorable economic results, and this is an appropriate strategy to pursue for developing countries, in terms of reducing the economic burden on small farms. The SV strategy can also decrease government spending on animal disease control, because fewer subsidies would be provided to pig farms to cull HP-PRRS infected pigs.

Overall, the SV control strategy is epidemiologically and economically efficient, and the vaccination proportion of 13.4% is much easier to achieve than complete vaccination (PV) in developing countries where most pig farms are small. However, one of the problems of administering SV in a developing country such as Vietnam is that the infrastructure is not fully developed. HP-PRRS vaccines have a short shelf life and must be kept cold to prevent loss of immunogenicity (Saitoh [10]). However, in Vietnam, it is very difficult to deliver the vaccine in a cold chain due to the poor road conditions, incomplete electricity supply, and the fact that many homes and farms do not have a refrigerator (Field survey, 2012).

4.2 Limitations of this study

Our findings are based on the assumption that all infected animals are identified and culled, under the surveillance system. In other words, an effective surveillance system is essential.

The epidemiological data were collected from Hue province where the animal disease surveillance system is well organized (Zhang *et al.* [15]). The epidemiological simulation results of the present study have also shown that if the surveillance system does not function efficiently, and the infectious period is more than 2 weeks, even a SV strategy with a vaccination proportion of 50% cannot control HP-PRRS outbreaks.[10] Therefore, to apply SV in a region with a poor surveillance system, the priority would be enhancing the surveillance system.

HP-PRRS occurs every year in Vietnam, so multiple years' CBA is desired. However, due to the data limitation, only one year epidemiological data was collected, and the analysis period was one year. The multiple years' analysis will be investigated in the next step.

4.3 Suggestions for further research

The present CBA takes a pig farm owner's point of view (private perspective), further research from the government's point of view and providing social perspective is also needed. Moreover, the HP-PRRS vaccination proportion is very low in Vietnam, and the vaccine price is very high (Field survey, 2012). Accordingly, it is not easy to increase the vaccination proportion. Therefore, further studies to design an appropriate HP-PRRS vaccination program, and to determine pig farm owners' willingness to pay for the vaccine, are also important. Such research might provide insights into how to encourage pig farm owners to administer the vaccination and increase the vaccination proportion, and into the social impact of the SV strategy on pig production in Vietnam.

5. Conclusion

A SV program with a vaccination proportion of 13.4% is the most epidemiologically efficient HP-PRRS control strategy; moreover, if the vaccination proportion increased to around 20%, it would also be the most economically effective control strategy. The economic effectiveness of the SV strategy is higher than that of the other control strategies examined (SO and PV). The estimated B/C ratio for investment in SV is 32.5, indicating the vaccination program to be economically viable. The findings of this study also imply that to control HP-PRRS outbreaks in Vietnam, government support for reinforcement of other animal disease control measures such as animal disease surveillance is necessary.

Notes

1) The "optimal vaccination proportion" is defined as the minimum proportion of animals required to be vaccinated for the incidence of an infection to decrease (Vynnycky and White [11]).

2) In regard to "R", originally, it represents the individuals who have an immune response by naturally "recovered" (Kermack and McKendrick [6]). The SIR model in this study is a modified version, and the "R" represents the pigs that have an "immune" response by both naturally "recovered" and "vaccinated". To emphasize this point, we used "immune" instead of "recovered" to describe the category "R".

3) According to the local veterinarian's estimation, the total number of pigs in the Huong Tra District in 2008 was around 28,900. It was impossible to classify the pigs in this area into categories, for example, piglets, fattening pigs, and sows, so we assumed the distribution of pigs to be homogeneous with an average body weight of 50.1 kg. Moreover, feed cost can be considered to differ in various situations according to the different control strategies; however, because detailed data regarding pig feeding are also not available, we did not consider the feed cost in this study, and focused only on the disease control cost. In Vietnam, both the HP-PRRS vaccinated and the non-vaccinated pigs are sold, but not distinguished in the market.

4) The detection ability of the surveillance system as applied in practice is likely to be less than 100%. It is also a rational assumption that some of immunized pigs might lose their immunity during the outbreak ($\alpha R_{(t)}$). According to expert opinion, 0.1% of the immunized pigs might be expected to lose their immunity per day ($\alpha = 0.001$).

5) We considered the frequency-dependent (true mass action) transmission in our SIR model. The HP-PRRS transmission rate ($\beta \frac{S(t)I(t)}{N}$) will depend on the pig population size. Therefore, following the methods of De Jong [2], assuming true mass action, the transmission rate will be $\beta \frac{S(t)I(t)}{N}$ in our SIR model.

6) R_0 is formally defined as the average number of secondary infectious pigs resulting from a typical infectious pig following its introduction to a totally susceptible population. For the purpose of predicting the threshold level of vaccination necessary for eradication, and based on Keeling and Rohani [5] (pp. 26-28), the calculation of R_0 is described in Equation (4)

Vaccination increases the proportion of immunized pigs and decreases the proportion of susceptible pigs, resulting in fewer transmissions from each infected pig. In such circumstances, with the proportion of susceptible pigs decreasing, the number of actual disease transmissions will fall to less than R_0, and is defined as the net or effective reproduction number, often given the symbol R_n. In simplest terms,

$$R_n = R_0 * s \qquad \text{(a)}$$

where s is defined as the proportion of the population that is susceptible. Equation (a) shows a fundamental relationship that when the proportion susceptible, s, is equal to $1/R_0$, then each infectious person should lead to just a single transmission, i.e., $R_0 = 1$. If the proportion susceptible is less than this proportion, incidence will decrease; if it is greater, incidence will increase. This critical threshold of susceptibility is typically described in terms of its converse, or the proportion immune (=1 − s). Therefore, the critical threshold of immunity, defined as the optimal vaccination proportion, is then given by Equation (5). A detailed explanation is presented in Vynnycky and White [11] (pp. 5-8)

7) Survey data were collected in a previous study (Zhang *et al.* [15]). Parameter β was derived from those data by the Markov Chain Monte Carlo (MCMC) methodology (Wakui [12]) with 2,000 iterations of Gibbs sampling using a Microsoft Excel spreadsheet.

8) According to an interview with the director of the Animal Health Department of Hue province, the HP-PRRS

vaccines used by the farms studied are made by Guangdong Dahuanong Animal Health Product Co., Ltd. in China. This is the only government permitted HP-PRRS vaccine available in Vietnam. Although the vaccine efficacy is reported to be 95% (Zhuyiwang [16]), in consideration of the differences in pig farming between China and Vietnam, we conservatively postulated the vaccine efficacy ***h*** as 90%.

9) From the field survey, 2,441 pigs were culled; on the other hand, in the modeled SO strategy, the total number of culled pigs was estimated at 2,882. The simulated culled number is very close to the actual number; therefore, we consider this epidemiological model to be appropriate. As indicated in Figure 1, our SIR model considered that time is required to administer the vaccination, in line with the actual situation in developing countries, and it also considered the time required for spread of the virus (Zhang *et al.* [15]). However, this model still differs from the real situation, in which there is a time lag between vaccine administration and acquirement of immunity. This time lag varies according to pig breed, age, and HP-PRRS pathogen strain. Further research is required to evaluate this time lag in the SIR model.

10) The infectious period is the time period between the pig being infected and culled. We assumed the surveillance was adequately functional and the infectious period was 1 week (parameter $\nu = 0.143$) in the epidemiological simulation. However, if the surveillance system is not functionally efficient, and the infectious period increases to more than 2 weeks (parameter $\nu = 0.071$), the outbreak will continue for more than 1 year, which is outside our period of analysis.

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Technical Inefficiency Effects among National Cereal Grain Balance Producers and Need for Implementation of Land Reform in Nepal

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1. Introduction

Nepalese economy is predominantly an agricultural economy. Thirty-seven percent share of gross domestic product (GDP) comes from agriculture (GON [8]). Based on food and non-food poverty line, 25.16 percent of population is still below poverty (CBS [4]) and food security is an issue of national concern. Since; cereal crop production is an important contributor to national food security, National Cereal Grain Balance (NCGB) is a crucial component of agricultural output constituting more than 60 percent share in total agricultural production. NCGB is calculated by the Ministry of Agricultural Development of Nepal and includes: paddy, maize, wheat, millet, barley and buckwheat. Table 1 shows the latest situation of NCGB in Nepal for the crop year 2010/11 and further illustrates broadly by cereal crop type, acreage, output and productivity. Paddy is the most important cereal crop contributing about 52 percent in the production of NCGB, and it is cultivated in about 43 percent of acreage. Moreover, its productivity is the highest of 2.98 metric tons per hectares (mt/ha) among other cereals. We see that buckwheat has the lowest productivity of 0.87 mt/ha. Average productivity of NCGB is 2.48 mt/ha in Nepal. Data show that productivity of cereals in neighboring countries is higher than in Nepal. India has cereal productivity of 2.54 mt/ha, Pakistan 2.59 mt/ha, Srilanka 3.97 mt/ha, Bangladesh 4.14 mt/ha and China 5.52 mt/ha (The World Bank [17]).

Since; more than seventy percent of population is dependent on agricultural sector for livelihood (GON [8]), without improving the productivity of this sector, it is almost impossible to lift the living standard of people and reduce the absolute poverty level. Investment in new technology, availability of extension services, market accessibility and farmers' knowledge of proper farming technique are very important for commercialization of agriculture, which can raise the productivity of this sector. We neither can create nor destroy the physical land, because it is the natural gift with limited supply. Therefore, the only alternative measure we have is the use of land in most productive way by trained farmers. Finding the sources of technical inefficiencies if any and reducing those barriers to enhance efficiency is very crucial during production process in utilizing land resource. Proper size of agricultural land and management of it by maximum possible efficient way is an important issue for Nepalese agriculture. This paper, thus studies about land size, technical efficiency and inefficiency effects of NCGB producers in Nepal.

Table 1: Area and Production of Cereal Crop in 2010/11

	Acreage		Production		Productivity
Cereal type	'000 ha*	Percent	'000 mt**	Percent	(mt/ha)
Paddy	1496	43.02	4460	51.77	2.98
Maize	906	26.05	2067	23.99	2.28
Wheat	767	22.05	1746	20.27	2.28
Millet	270	7.76	303	3.52	1.12
Barley	29	0.82	30	0.35	1.05
Buckwheat	10	0.30	9	0.10	0.87
Total	3478	100.00	8615	100.00	2.48

Source: Authors' calculation based on CBS[5]

Note: * in thousand hectares, ** in thousand metric tons

Nepal is a land scarce country. Since, the Northern part (Mountains) is covered by snow with high range mountains, middle part (Hills) is affluent with steep slopes and in comparison only the Southern part (Terai) has much productive land. To meet the need of growing population, the agricultural land needs to be managed in productive way. For this, the Government makes land reform laws and implements them time to time. In case of Nepal, The comprehensive land legislation of 1964 (GON [9]) is the milestone law for land reform. The Fifth Amendment to the 1964 Land

Related Act in 2002 (FALRA 2002) drastically reduced land ceiling aiming to use land in most productive way. Table 2 shows land ceiling policy before and after FALRA 2002. According to this, each household could hold 7.45 hectares (ha) of land in Terai, 1.52 ha of land in Kathmandu Valley and 3.81 ha of land in other regions (Hills and Mountains). There are about 3 percent of households, which have large sized lands beyond legal ceiling with more than 15 percent share in total acreage of households land and 25 percent of landless/marginal households have less than 4 percent share in total acreage of household land (GON[10]). This shows that there is huge inequality of land distribution, hence immediate needful implementation of land reform in Nepal. Land reform in Nepal has always been criticized for lack of will power to implement it. Even FALRA 2002 was not properly implemented, which indicates a failed reform on land. The scenario of land distribution would be different if the land ceilings of FALRA 2002 were properly implemented (Paudel & Saito [14]).

Table 2: Per Household Land Ceiling Policy of Government (in ha)

	Before Fifth Amendment			After Fifth Amendment		
Region	Agricultural	Homestead	Total	Agricultural	Homestead	Total
Terai	16.40	2.00	18.40	6.77	0.68	7.45
Kathmandu Valley	2.70	0.40	3.10	1.27	0.25	1.52
All other regions	4.10	0.80	4.90	3.56	0.25	3.81

Source: Authors' calculation based on(GON[9])

In the above-mentioned context, we in this paper, study the relationship between household land size (marginal/landless, medium-within limit and large-beyond limit) and technical efficiency of NCGB producers. Household land size category used in this paper is based on the land ceiling provisions of land reform law. The farmers who have less than 0.15 hectares of land in Terai, less than 0.04 hectares of land in Kathmandu valley and less than 0.08 hectares of land in other regions (Hills and Mountains) are identified as marginal/landless farmers. This criteria for the land less and marginal farmers who are eligible to get land is based on the proportion of land ceiling defined by FALRA 2002. Large farmers are those who have land beyond ceiling but medium farmers are in between marginal/landless and large farmers. Moreover, medium farmers are not affected by implementation of FALRA 2002.

The main objective of this study is to identify the efficiency gap and analyze the sources of technical inefficiencies for NCGB production in Nepal. Is there any inefficiency in NCGB production? If any what are the sources of inefficiencies? How land reform implementation can reduce inefficiencies? These are the main research questions, we plan to answer in this paper. To search for answers, our null hypotheses are: NCGB producers exhibit constant return to scale production technology; they produce on frontier; they do not have any technical inefficiency; farmers in all regions are equally efficient and there is no difference in efficiencies based on household land size. To check the validity (acceptance or rejection) of these null hypotheses, we estimate NCGB production behavior by using stochastic production frontier (SPF) methods and find mean efficiencies based on regions and size of lands.

The findings of this paper suggest that NCGB producers are operating less than their frontier and the gap is 28 percent. Moreover, there are many sources of inefficiencies such as less irrigation facilities, lack of extension services, lack of farmers' education and lack of use of modern equipments. Land is found to be the most important input for NCGB production and proper land size matters for raising efficiency of farmers. More importantly, there are still some households that have land holding beyond legal ceiling proposed by FALRA 2002, and they are technically less efficient, land reform implementation can enhance technical efficiency of NCGB producers in Nepal.

2. Literatures

Going through relevant literatures, we found many studies estimating efficiency or inefficiency effects of different grain producers based on different countries, regions, farms, crops etc. using cross section, time series or panel data. For example, using cross-section data and frontier function, Taylor and Shonkwiler [16]; Squires and Tabor [15] estimated technical efficiency of about 70 percent in average. More importantly, Bravo-Ureta et al [2] used a meta-regression analysis including 167 farm level technical efficiency studies of developing and developed countries and found the overall efficiency of 76.6 percent. The study of Tian and Wan [18], Kaur et al [12], Hasan and Islam [11], Dağistan [7], Kurkalova and Jenson [13] etc. studied technical efficiency of cereal grain (rice, wheat or corn) farmers and they found mean efficiency between 70 to 80 percent. All the studies mentioned here noticed that there are different factors that have some level of impact on technical efficiency of agricultural production. Their finding suggests the inefficiency effects such as lower level of farmers' education and experience, lack of market access, lack of irrigation etc. which are almost common in most of the existing literatures.

In Nepalese context, Adhikari and Bjorndal [1] studied the technical efficiencies of Nepalese agriculture using household survey data of 2003/04 and using stochastic distance function and data envelopment analysis methods. They could measure technical efficiency effects of 73 percent in Nepalese agriculture but their study did not mention about the existing land reform provisions and they also lack identifying the large household lands in their sample that are beyond legal ceiling in size and less efficient in production.

To the best of our knowledge, there are many papers which measure technical efficiency and estimate inefficiency effects, but there is no any paper that has linked technical inefficiency effects of NCGB producers to household land size category and identified the beyond legal ceiling lands which are subject to entail land reform implementation immediately. This study using latest household survey data, i.e., Nepal Living Standard Survey 2010/11 dataset, estimates technical efficiencies based on regional categories of land proposed by FALRA 2002, and clearly identifies the need of land reform implementation in Nepal. In this context, this study may draw some attention of researchers and policy makers, hence the relevance of this study.

3. Research Methods

3.1 Data

The data source used in this paper is Nepal Living Standard Survey III dataset (CBS [3]). This is a household survey conducted by the Government of Nepal in 2010/2011. This survey follows Living Standard Measurement Survey (LSMS) methodology developed and promoted by the World Bank and covers the whole country, five-development regions-eastern, central, western, mid-western and far western region and 75 administrative districts. The survey enumerated 5,988 sample households from 499 primary sampling units (PSUs) such as wards or sub-wards over 3 ecological zones, 5 development regions, 75 districts, 58 municipalities and 3,914 Village Development Committees. This cross section sample covers information from 34,344 individuals living in 5,988 households of the country. This was done in two stages using probability proportional to size (PPS) sampling method.

In this study, the households, which produce cereal crops, are taken for analysis. Among 5,988 households, the households whose share of cereal production in total agricultural production is more than 80 percent are taken as NCGB producers, which give adjusted sample of 1,133 as total observations. Those who produce less than 80 percent are excluded because the input used in production are same for a household and only households with at least 80 percent share in total household agricultural production could represent the NCGB producers in Nepal and this would rather give more realistic estimations. The data set has information of total harvested output of each crop in different ten units such as gram, kilogram, ton, muri, pathi, mounds etc. and their price according to respective units. Multiplying total harvested quantity by its price, we calculated the output of cereal grains. There is information in the data set about the inputs used- land, labor, capital, seed, fertilizer and other inputs in a household level but no information for inputs used in each crops. Therefore, calculation of elasticities for each crop is not possible. Moreover, other inputs include expenditure on irrigation, storage, transportation etc.

Table 3 shows the production composition of types of cereal crop according to our sample data. Out of total cereal crop production, early paddy constitutes 2.04 percent. Early paddy is cultivated in April-July. Main paddy is the main crop of NCGB in Nepal. The share of it is 57.57 percent. The cultivation time is July-December. Main paddy needs intensive water supply. Similarly, share of upland paddy is 1.23 percent. The cultivation time is June-November. Similarly, share of wheat is 16.76 percent, share of spring/winter maize is 2.68 percent, share of summer maize is 14.95 percent, share of millet is 4.13 percent, share of barley is 0.47 percent, share of buckwheat is 0.12 percent and share of other cereals such as oats, rye etc. is 0.06 percent respectively. Wheat needs a little water supply but for maize, millet, barley and buckwheat rain water supply is enough.

Table 3: Share of Cereal Crops

Cereal Crop Type	Share (%)
Early Paddy	2.04
Main Paddy	57.57
Upland Paddy	1.23
Wheat	16.76
Spring/ Winter Maize	2.68
Summer Maize	14.95
Millet	4.13
Barley	0.47
Buckwheat	0.12
Other Cereals	0.06
Total	100.00

Source: Authors' calculation

3.2 Stochastic Production Frontier (SPF) Model

In this paper, SPF method is applied to measure technical efficiency of NCGB producers in Nepalese agriculture. As given in Coelli et al. [6], a Cobb-Douglas stochastic frontier model for cross section data takes the form:

$$\ln(y_i) = \beta_0 + \beta_1 \ln x_i + v_i - u_i \quad (1)$$

$$y_i = \exp\ (\beta_0 + \beta_1 \ln x_i + v_i - u_i) \quad (2)$$

$$y_i = \exp\ (\beta_0 + \beta_1 \ln x_i) \times \exp(v_i) \times \exp(-u_i) \quad (3)$$

where,

$\exp\ (\beta_0 + \beta_1 \ln x_i)$: deterministic term

$\exp(v_i)$: disturbance term

$\exp(-u_i)$: inefficiency term

The observed output can be written as:

$$y_i = f(x_i\beta) \times \exp(v_i - u_i),\ \ u_i \geq 0 \quad (4)$$

Assuming that observed output lies below the stochastic frontier,

$$y_i \leq f(x_i\beta) \times \exp(v_i) \quad (5)$$

Consequently, we have:

$$\mathrm{TE}_i = \frac{\text{observed output}}{\text{potential maximum output}} = \frac{f(x_i\beta) \times \exp(v_i) \times \exp(-u_i)}{f(x_i\beta) \times \exp(v_i)} = \exp(-u_i), 0 \leq TE_i \leq 1 \quad (6)$$

3.3 Inefficiency Effects Model

The inefficiency effects model is used to estimate inefficiency of NCGB producers in Nepalese agriculture. The empirical model is as follows:

$$\eta_i = \delta + \xi z_i + e_i \quad (7)$$

Where η_i a technical inefficiency score (1-TE_i) used as a dependent variable, z_i is a vector of independent variables related to farm household specific characteristics, δ is constant and ξ is the unknown parameter and e_i an error term.

4. Estimation Results

4.1 Descriptive statistics

Table 4 shows the summary statistics. Mean output of NCGB is 55,220.65 Nepalese Rupees (NPR). Average labor used is 1,559.52 hours with average household operated land input of 0.74 hectares (ha). The minimum value of land is 0.002 ha and maximum is 32.77 ha. This shows that household cultivated land varies between almost landless to large landlords. The maximum land limit permitted by land act is 7.45 ha in Terai regions but sample data set shows there are still large size of household land beyond limit. The size of land dummy shows that there are 10 percent households with marginal land, which are almost landless being eligible to acquire land if land reform laws were implemented properly. Majority (89 percent) households have medium land (up to legally permitted limit) and 1 percent household have large land (beyond the limit). In the land reform implementation process, large landowners lose their land beyond limit and landless and marginal farmers are eligible to acquire those lands.

Table 4: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Dependent Variable				
(y) Output (NPR)	55,220.65	96,648.36	586.00	1,707,191.00
In dependent Variables				
(x1) Labor (hours)	1,559.52	2,079.16	12.23	43,404.25
(x2) Land (hectares)	0.74	1.48	0.00	32.77
(x3) Capital (NPR)	3,491.35	8,001.29	45.00	178,800.00
(x4) Seed (NPR)	1,070.15	6,677.54	15.00	208,000.00
(x5) Fertilizer (NPR)	1,768.12	11,101.22	15.00	348,825.00
(x6) Other inputs (NPR)	228.87	265.79	10.00	2,500.00
Inefficiency effects				
(z1) Unused land dummy	0.12	0.33	0.00	1.00
(z2) Age of head (years)	31.62	18.42	16.00	85.00
(z3) Schooling of head (years)	3.69	2.07	3.00	17.00
(z4) Extension service dummy	0.26	0.44	0.00	1.00
(z5) Year round irrigation dummy	0.12	0.33	0.00	1.00
(z6) Use of modern equipment dummy	0.22	0.41	0.00	1.00
Regions (dummy)				
(z7) Kathmandu Valley (reference)	0.05	0.22	0.00	1.00
(z8) Terai	0.50	0.50	0.00	1.00
(z9) All other regions	0.45	0.50	0.00	1.00
(z9-1) Hills	0.39	0.49	0.00	1.00
(z9-2) Mountains	0.06	0.23	0.00	1.00
Size of land (dummy)				
(z10) Marginal (reference)	0.10	0.30	0.00	1.00
(z11) Median	0.89	0.31	0.00	1.00
(z12) Large	0.01	0.07	0.00	1.00
Number of observations		1,133		

Source: Authors' calculation

Average values of inputs such as capital, seed, fertilizer and other inputs are 3,491.35 NPR, 1,070.15 NPR, 1,768.12 NPR and 228.87 NPR respectively. About 12 percent households have at least some unused or fallow land. This unused land is the land left unproductive. Average age and schooling of household head farmers are 31.62 and 3.69 years respectively. Additionally, only 26 percent household have access to extension services, 12 percent have year round irrigation system, 22 percent are using modern equipment for farming such as tractor, thresher etc.

While looking to the regional distribution of sample households, we see that 5 percent households are from Kathmandu valley. Kathmandu valley is the region where the capital of Nepal Kathmandu is situated. 50 percent households are from Terai region. This region lies in the Southern part of the country bordering with India and have very productive land for cereal crops. Rest 45 percent households are from all other regions, which further divided as 39 percent households from Hills, the middle hilly part of the country followed by 6 percent households from Northern Mountainous region boarding to China.

4.2 SPF Estimation Results

Table 5 shows the estimation results of SPF model. Here, we estimated the Cobb-Douglas Production Frontier with one output and six inputs. All of the coefficients of inputs are significant. Land has the highest coefficient of 0.32 followed by other inputs (expenditures on irrigation, transportation, draft animals, storage, management etc.). Labor, capital and fertilizer have same coefficient of 0.07 and seed has 0.06 coefficients. Since, production of NCGB is highly labor-intensive task; the coefficient of labor is low. The sum of all the coefficients of inputs is 0.87 (0.07+0.32+0.07+0.06+0.07+0.26)<1.00 and statistically significant. This shows that there is decreasing returns to scale production technology, rejecting our null hypothesis of constant return to scale.

Since the coefficient of sigma squared u is statistically significant, this shows that the model shows there are some technical inefficiencies present in the model. This also reveals that due to inefficiencies present in the production process, the observed output is less than the maximum possible output, which rejects our null hypotheses of farmers produce on frontier and there are no technical inefficiencies.

Table 5: Estimation of SPF Model

Variables	Coefficient	z-value
Dependent variable: ln(Output)		
ln(Labor)	0.07 ***	3.71
ln(Land)	0.32 ***	13.63
ln(Capital)	0.07 ***	5.04
ln(Seed)	0.06 ***	3.66
ln(Fertilizer)	0.07 ***	4.47
ln(Other inputs)	0.26 ***	11.33
Constant	8.18 ***	42.59
ln (sigma squared v)	-0.88 ***	-14.42
ln (sigma squared u)	-1.81 ***	-11.08
lambda	0.63 ***	
Wald chi squared (6)	956.17***	
Log likelihood value	-1,295.74	
No. of observations	1,133	

*** Significant at 1 %, ** at 5% and * at 10%

Source: Authors' estimation

4.3 Efficiency Scores

Table 6 shows the mean efficiency scores in NCGB production. Scores are presented by household land size across regions. In overall, the mean technical efficiency of NCGB producers is found to be 0.72, which is consistent with the findings of Adhikari and Bjorndal [1] as they found mean technical efficiency of 0.73 in Nepalese agriculture. Technical inefficiency in average is 0.28 (1-technical efficiency). This shows that there is possibility of increasing NCGB production by 28 percent if the farmers could achieve the maximum efficiency using the same resources they have.

Medium sized households lands are the most efficient among three sizes of lands. The average efficiency score of medium lands is 0.72. Marginal lands (efficiency score 0.67) are less efficient than medium and statistically significant in mean difference test and large lands have slightly smaller efficiency scores (0.70) than medium but they are not stastically significant. While going through regions, Terai exhibits highest efficiency with score 0.74 followed by all other regions with efficiency score 0.70 (Hills-0.69 and Mountains 0.71). Kathmandu valley has the lowest efficiency score (0.69) among the regions. Comparing land sizes among three regions, results show that medium household farms in Terai region are the most efficient among all (efficiency score 0.74). In contrary, marginal household farms in Hills are the most inefficient (efficiency score 0.59). The sample shows that among large sized household farms which are subject to imply land reform, four are in Terai and two are in Hills region. The results presented above reject our null hypotheses - farmers in all regions are equally efficient and there is no difference in efficiencies based on household land size.

Table 6: Technical Efficiency Scores by Holding Size and Regions

Region	Marginal		Medium		Large		Total	
	obs.	score	obs.	score	obs.	score	obs.	score
Kathmandu Valley	11	0.66	45	0.70	-	-	56	0.69
Terai	70	0.71	497	0.74	4	0.73	571	0.74
All other regions	33	0.60	471	0.70	2	0.63	506	0.70
Hills	25	0.59	418	0.70	2	0.63	445	0.69
Mountains	8	0.63	53	0.72	-	-	61	0.71
Total	114	0.67	1,013	0.72	6	0.70	1,133	0.72

Source: Authors' calculation

Terai is the plain area with productive quality of land. Compared to other areas, NCGB producing farmers in Terai have more access to irrigation, transportation, seeds, fertilizer, storage etc. They produce more paddy than other cereals, which is water intensive crop with more value in market. Therefore, they are more efficient. On the contrary, in Mountains, most of the cereal farming consists of maize, millet, barley and buckwheat and almost no paddy and wheat. So, the cereal crops produced in Mountains region are less intensive to water. In Hills, farmers produce all types of cereal crops but due to lack of irrigation system, productivity of paddy is less than in Terai. Hills have the least efficiency because they have both water intensive and non-intensive cereal farming. For water non-intensive cereals such as maize and barley, Mountains is better than Hills and for water intensive cereals such as paddy, Terai is better than Hills. This gets expressed by the efficiency results in table 6.

4.4 Inefficiency Effects

Table 7 shows the sources of inefficiencies among NCGB producers. The significant positive source of inefficiency is found to be unused land but significant negative sources are schooling of head, extension service, year round irrigation, use of modern equipment etc. The NCGB producers from Terai have less inefficiency effects than those from Kathmandu valley. In the same way, producers with medium sized household land have less inefficiency effects than marginal. Large lands have positive effects of inefficiency but they are not significant.

Table 7: Estimation of Inefficiency Effects Model

Variable	Coefficient	t-value
Dependent variable: Technical inefficiency score		
Unused land dummy	0.02 *	1.80
Age of head	0.01	0.98
Schooling of head	-0.01 **	-2.36
Extension service dummy	-0.03 ***	-4.09
Year round irrigation dummy	-0.04 ***	-3.84
Use of modern equipment dummy	-0.03 ***	-3.32
Regions (dummy)		
Kathmandu Valley (reference)	_	_
Terai	-0.03 **	-2.09
All other regions	0.01	0.32
Size of land (dummy)		
Marginal (reference)	_	_
Median	-0.04 ***	-4.32
Large	0.01	0.31
Constant	0.35 ***	20.64
F (11,1121)	11.93 ***	
R-squared	0.09	
No. of observations	1,133	

*** Significant at 1 %, ** at 5% and * at 10% level

Source: Authors' estimation

The households which left some of their land as fallow, and do not cultivate it or do not use it in production is unused land, and if the households have unused land, they have higher technical inefficiency by 2 percent than those who use all of their land in cultivation. Regarding the size of household land, results suggest that medium sized lands have less inefficiency effects by 4 percent than marginal lands. Though; results are insignificant because the size of sample is very small (only 6 households with large sized lands in sample data set), the relationship with inefficiency effects is positive. Among the farmers, which are liable to land reform by implementing FALRA 2002 (marginal-receiving and large-losing), marginal are technically less efficient than medium sized farmers.

Schooling of head has negative correlation on inefficiency effects suggesting that knowledge of farmer is very important to increase their efficiency. Similarly, availability of extension service reduces inefficiency effects. Availability of year round irrigation and use of modern equipments also reduce inefficiency of NCGB producers. Moreover, the producers from Terai region have less inefficiency effects than those of Kathmandu valley. This is because Terai is a region with more productive land than Kathmandu valley. Moreover, the major crop cultivated in Terai region is paddy, its productivity is higher than other crops in Nepal (see table 1) and market value of paddy is also higher than other crops.

5. Concluding Remarks

This study estimates technical efficiencies of national cereal grain balance producers in Nepal using stochastic production frontier (SPF) methods. The empirical application uses household level Nepal Living Standard Survey III, 2010/2011 data.

The average technical efficiency scores vary widely between household land sizes and regions. Efficiency scores range between 0.59 and 0.74 showing an overall mean technical efficiency of 0.72. Based on these results, sample NCGB producers could increase about 28 percent of their output through better use of available resources. Additionally, estimated results reveal that improper size of household land (marginal and large) is an important source of technical inefficiency. Other sources of inefficiencies are found to be lower level schooling of head, lack of extension services, lack of irrigation facilities, lacking use of modern equipments etc. Producers from Terai region are more efficient than those of other regions.

If the government enforces redistribution of land from large to marginal, the size of both marginal and large farm will be driven to be medium farm whose efficiency is significantly higher than marginal, though the mean efficiency between medium and large is not stastistically significant. This means that, in the process of land redistribution, size of large land will decrease and size of marginal land will increase while size of medium farms remains unaffected. Moreover, the unused land converted to cultivation by means of land reform will also raise the total efficiency and productivity of farmers. Therefore, we insist on that land reform laws need to be implemented urgently for increasing technical efficiency of NCGB producers in Nepal.

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Characteristics and Significance of the Indigenous Rice Farming Technology in Sri Lanka

A Case Study of Indigenous and Modern Rice Farmers in the Padaviya Irrigation System

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1. Introduction

In Sri Lanka, rice is a historically and culturally important crop grown in all regions of the country.[1)] Rice production in the country began in the dry zone area in 900 B.C. (Deraniyagala [3]) and has developed in an organized way since 300 B.C. (Mahawansa, Trans. by Geiger [9]). Until the early 1960s, this major crop was grown entirely based on the indigenous rice farming technology (IRFT). The IRFT is a set of time-tested agricultural and natural resource management practices, which were developed solely based on the extensive experience and knowledge of the local people (Venkatratnam [11]). This technology makes use of traditional rice varieties, which were developed and cultivated by the local people over centuries, in association with a set of practices, including the application of organic fertilizers, the management of weeds through pre-planting techniques, water management and hand weeding, and the management of pests and diseases by maintaining biodiversity using homemade biopesticides and by practicing agricultural rituals (Dharmasena [4]). The IRFT also takes into consideration the lunar cycle and is based on the natural conditions of the region, including field conditions, recycling of organic materials, and biological control mechanisms that correspond to the natural features of the region, including rainfall patterns, soil conditions, temperature, and humidity.[2)]

As emphasized in agricultural history, the IRFT was replaced by the modern rice farming technology (MRFT) during the Green Revolution (Farmer [5]; Wilson [12]). The MRFT used modern varieties (high yielding varieties (HYVs), in association with imported inorganic fertilizers and other agro-chemicals and with pre-scheduled irrigation and new methods of farming (Andersen and Hazell [1]; Farmer [5]; Kikuchi et al. [7]). Sri Lanka first attempted to improve seeds by selecting traditional varieties that had been used since the 1940s (Jayathilaka [6]). Those improved varieties were referred to as "old improved varieties—H series" (see Figure 2) (Kikuchi et al. [7]). Similar to other countries in Asia, the key elements of the Green Revolution were first introduced to Sri Lanka in the mid-1960s, with the release of IR8 from the International Rice Research Institute (IRRI), following establishment of the IRRI in the Philippines in 1962 (Farmer [5]; Jayathilaka [6]; Kikuchi et al. [7]). Specifically, the major initiative of the technology package of the Green Revolution was addressed by the "Food Drive" program of 1967 (Jayathilaka [6]). As stated in agricultural history in the 20th century, the main reasons for this technological transformation were the future challenges predicted to be associated with our food supply due to the rapidly increasing population.

Forty years after the Green Revolution, there was a contentious discussion in the academic literature about the adverse effects of abandoning the IRFT in the technological transformation. First, according to the World Health Organization (WHO), the chronic kidney, cancer, and diabetes issues in the main rice-growing areas of Sri Lanka are likely due to the long-term use of agrochemicals by the farmers (WHO [13]). Second, the MRFT has resulted in significant environmental problems, including the pollution of ground water, the decline in natural soil fertility, the imbalance of biodiversity, and the disappearance of essential flora and fauna. These issues endanger the lives of all people in the country, in terms of food safety and health. The relationship of the MRFT to these problems is demonstrated by the drastic increase in chemical fertilizer application per hectare (ha), by 190%, from 76.5 kg in 1967 to 222 kg in 2004 (DCS [2]) and 2006; pesticide application per ha also increased by 1,350%, from 0.2 liters in 1968 to 2.9 liters in 1995 (Kikuchi et al. [7]). Third, the MRFT has resulted in a severe farm management problem. Although the MRFT led to a doubling in rice production, from 2,127 kg to 4,337 kg per ha during the last 40 years (see Figure 1), the actual income for farmers has declined by 16% (DCS [2]). This decline has resulted in persistent poverty among the rice farmers in the country. Therefore, the government has to provide a significant amount of fertilizer subsidies to modern farmers. In 2009, the cost of fertilizer subsidies was Rupee (Rs.) 24,705 million, which represented 3% and 0.6% of government expenditures and gross domestic product (GDP), respectively (DCS [2]). In addition, health problems related to the use of agrochemicals have also added to the unaccounted costs of the rice farmers. Fourth, the indigenous rice varieties (heterogeneous varieties), which were developed and grown over thousands of years by the local people, disappeared in the rice land due to the technological transformation (see Figure 2).

Based on these observations, the hypothesis of this study is that the indigenous rice cultivation techniques are most adaptable to the soil, climate, and living conditions in Sri Lanka. Therefore, this study attempts to identify the characteristics and significance of the IRFT by comparing it with the MRFT. The study examines the characteristics of the IRFT, the impact of the IRFT on production costs, income, and yield, and the main constraints to the IRFT in Sri Lanka.

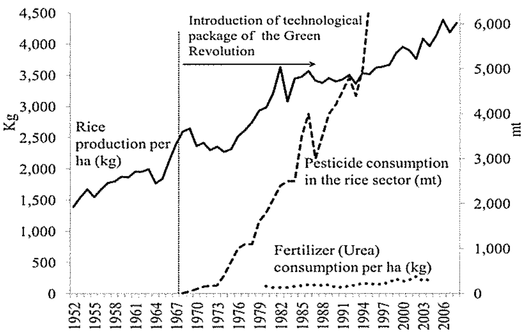

Figure 1: Trends of rice farm productivity, fertilizer and pesticide consumption during the pre- and post-Green Revolution era
Source: DCS [2]

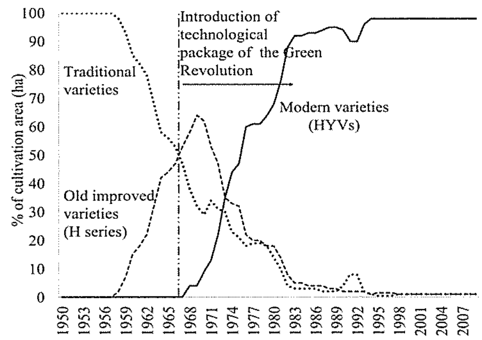

Figure 2: Historical trend of cultivated rice varieties in Sri Lanka (1950–2009)
Source: DCS [2]

2. Research methodology

1) Selection of the study area

The study was conducted in the Padaviya Irrigation System (PIS) area in the Anuradhapura district of Sri Lanka during the months of August and September in 2012. The reasons for selecting this study area were as follows. First, the PIS area is located in the historically significant rice-growing region of the country. This irrigation system is centered on the Padaviya reservoir, which was built by King Moggallana during the 6th century A.D (Paranawithana [10]). Specifically, the reservoir was built to store rainwater harvested from the northeast monsoons. During the 1950s, the area was rehabilitated under the government colonization scheme. The reservoir, which has a gross water capacity of 85,000 acre feet, is the second largest reservoir in the Anuradhapura district. Second, among the 8,000 indigenous rice farmers in Sri Lanka, approximately 3,000 are scattered in the Anuradhapura district. The density of indigenous rice farmers in the PIS area is relatively higher than that of other areas because there are 10 well-organized indigenous rice farmer organizations in the area. These farmer organizations have been mobilized by a local organization that has provided technical support to the indigenous farmers since the 1970s. Third, the majority of the farmers in the PIS area settled there in the 1950s. Thus, these farmers have experience with both the IRFT and MRFT. Fourth, the WHO has recognized this area as one of the most hazardous as it reports high rates of chronic kidney, cancer, and diabetes issues due to the farmers' use of agrochemicals in the rice land (WHO [13]).

2) Method of data collection

The primary data for the study was collected from the field survey. Three villages within the PIS area were selected based on the high density of indigenous rice farmers in each village. The total number of rice farmers in the selected villages was 165, including 60 and 105 indigenous and modern rice farmers, respectively. Two thirds (66%) of the farmers included in the sample, including 40 indigenous rice farmers and 70 modern rice farmers, were selected using a stratified random sampling method. The method used to distinguish between data provided by the farmers who applied the IRFT and those who applied the MRFT was identification of the types of rice varieties, namely, indigenous and modern rice varieties. The types of rice varieties were identified with the help of both a local organization, called the Movement for Protection of Indigenous Seeds (MPIS), and several government agricultural extension officers. Eight rice millers and 12 rice collectors in the area were also selected to collect data on the rice marketing system. The survey included the collection of data on the adopted rice farming technology at different stages of rice cultivation, production costs, rice production, income, the rice marketing system, and farmers' attitudes with regard to adoption of the IRFT. The data were collected by conducting personal interviews with farmers via the administration of a semi-structured questionnaire.

3. Results and discussion

1) Techniques of indigenous and modern rice farming and major characteristics of the IRFT

Table 1 presents the techniques adopted by indigenous and modern rice farmers in the survey area. The study identified eight major characteristics of the IRFT based on the farmers' responses; these are noted in Table 1, which also describes the relevant techniques associated with each technological step. Characteristic (A) describes the decision making process based on the environment and the lunar calendar. Specifically, the seed variety is

Table 1: Techniques of indigenous and modern rice farming in the survey area and their characteristics

Technological step	Indigenous rice farmers			Modern rice farmers	
	Indigenous rice farming techniques	Rank	Characteristics	Modern rice farming techniques	Rank
1.Primary land preparation	Slashing with addition of debris to paddy field	1	(B), (D), (G)	Use of weedicide	1
	Cattle feeding	2	(B), (D), (G)	Slashing with burning of debris	2
	Watering for retting weeds	3	(C), (E), (F), (G)		
2.Soil fertility management (before planting)	Release cattle to the field	1	(B), (D), (G)	Chemical fertilizer application	1
	Straw mulching	2	(B), (D), (G)	Straw mulching	2
	Green manure	3	(B), (D), (G)		
	Organic fertilization	4	(B), (D), (G)		
	Mid-season farming (leguminous plants)	5	(D), (G), (I)		
	Use of charred rice husk	6	(B), (D), (G)		
3. Water management	Select varieties based on the water level of the tank	1	(A), (E), (F)	Depend on the irrigation department data	
	Water management based on rainy calendar	2	(A), (C), (F), (G)		
4.Seed selection and pre-planting techniques	1. Seed procuring method			1. Seed procuring method	
	Borrow from indigenous research center	1	(F)	Buy from the agricultural research institute	1
	Self-produced seed in the previous season	2	(F)	Private traders	2
	Borrow from the contiguous farmers	3		Self-produced seed in the last season	3
	2. Separation of high viability seeds			2. Separate high-viability seeds	
	Seed pre-test method	1	(F)	Immerse in the water	1
	Immersion in the salt-mixed water	2	(F), (G)		
	Immersion in the salt-mixed water and follow the egg method	3	(F), (G)		
	Immersion in the water	4	(F), (G)		
	3. Improve the viability of the seeds			3. Improve the viability of the seeds	
	Put the seed bag inside the water for 20 or 25 hours	1	(B), (F), (G)	Not practice	0
	Mix the cow dung liquid with the soaked seed	2	(B), (D), (E), (F), (G)		
	Mix the wild-plantain liquid with the geminated seed	3	(B), (D), (E), (F), (G)		
5.Rice planting method	Direct seeding	1		Direct seeding	1
	Rice nursery method	2			
6. Soil fertility method after rice planting	Use of charred rice husk	1	(B), (D), (G)	Apply the chemical fertilizer	1
	Cultivation of legumes on ridges or selected places in the field	2	(D), (F), (G), (H)		
	Use of recycled rice straw	3	(B), (D), (G)		
	Add compost to the field	4	(B), (D), (G)		
	Hormone treatment for improving nitrogen in the soil and breeding slow-worm	5	(B), (D), (F), (G)		
	Apply dried cow dung	6	(B), (D), (G)		
7.Weed control method	Apply land preparation methods with appropriate time duration	1	(F), (G)	Weedicide application	1
	Water control method at the right time	2	(C), (F), (G)		
	Hand weeding	3	(B), (D)		
	Trailing of plantain trunk on the field	4	(B), (C), (D), (G)		
	Spread common salt on the field	5	(B), (C), (D), (F), (G)		
8.Pest & disease control method	Cultivation based on rainy calendar	1	(A),(F), (G)	Pesticide application	1
	Use of spiritual powers: Chanting pirith, rituals, Yantras and Mantras, making offerings to local deities	2	(F)		
	Use the cosmic power (astrology: Nekath and Karana methods)	3	(E), (F)		
	Use of botanical resources & biological resources	4	(B), (D), (G)		
	Use the cattle waste and product-based treatment	5	(B), (D), (E), (G)		
	Follow seed treatment before sowing for disease prevention	6	(B), (D), (E), (F), (G)		
	Dust the ash on the rice leaves early in the morning	7	(B), (D), (E), (G)		
	Put the light lamp in the paddy at the identified time period	8	(D), (G)		
	Grate fruits (citronella) immersion in the mud	9	(B), (D), (F), (G)		

Source: Field survey, 2012

Note: (1) The characteristics were identified based on surveyed farmers' responses.

(2) Main characteristics: A (decision making based on environment and lunar calendar), B (dependency on local resources), C (water management strategies to control weeds and diseases), D (environmental friendliness), E (tolerance for weeds, pests, and diseases), F (focus on risk reduction), G (effectiveness—low level of inputs and high degree of self-sufficiency), and H (household food safety and food security).

(3) We ranked the techniques based on the number of farmers who adopted each technology.

selected based on the predicted weather conditions as well as the water level in the tank. Generally, the farmers predict the natural rainfall patterns for the subsequent season based on the following environmental changes: natural symbolism related to wind speed and direction; color and height of clouds and lightning; humidity in the air and behavior of plants, such as leaf abscission or the appearance of new leaves and hardening of the bark; and abnormally high or low rates of flowering and fruiting in certain trees. The farmers also reported that the adoption of the IRFT at different stages of rice cultivation is associated with the lunar calendar. They select the rice varieties (either four- or three-month rice varieties) based on the lunar cycle (see Table 2) and natural rainfall patterns. The sowing period usually occurs before the onset of the northeast monsoon season in the country. The farmers expect to observe energetic growth of the rice plant with the monsoon. The seed germination date is determined according to the panicle initiation time of the rice. The panicle initiation time occurs during the waning half of the lunar month (January to mid-February) in terms of the concerned season. Using this technique, farmers achieve a high level of productivity by creating a favorable environment (temperature) for pollination, ensuring fewer pests and diseases (as the techniques employed avoid the dry months, particularly during panicle initiation time) and by maximizing the storage time capacity of harvested rice. In terms of land preparation, farmers determine the ideal period, using the lunar calendar, to increase the contribution of micro-organisms to the development of soil fertility. These farmers firmly believe that the waning half of the lunar month would be a better period for land preparation (see Table 2). The calendar is also used to make water management decisions to increase soil moisture levels.

Table 2: Relationship of indigenous techniques with the lunar calendar

Position	Period of lunar month	Applicable techniques
🌒	Waxing crescent moon	Continuing field preparation Weed sprouting period after the first plowing
🌓	First quarter of half moon	Continuing field preparation and seed germination activities
🌔	Waxing gibbous moon	Sowing and planting Seed sprouting and plant growth
🌕	Full moon	
🌖	Waning gibbous moon	Beginning field preparation Watering, fertilizing, controlling pests and weeds, tillering, pruning, and harvesting
🌗	Last quarter of half moon	
🌘	Waning crescent moon	Controlling pests and weeds, Pruning and harvesting
🌑	New moon	Not practicing any field work on New moon day

Source: Field survey, 2012

Second, characteristic (B) demonstrates that IRFT depends entirely on the local resources (see Table 1) and does not use external inputs. In particular, the required nutrients are supplied to the soil by applying cattle waste, rice straw, green manure, and charred rice husk as well as by practicing intercropping and mid-season farming. To control the spread of pests and diseases, farmers use cattle waste and dairy product-based treatments, botanical resources (plant components are used for the preparation of medicines), biological resources (predation on pests, such as vertebrates, reptiles, birds, and mammals), and ash, in addition to applying mixed planting techniques. All of these techniques are based on the availability of local resources. Characteristic (C) describes the water management techniques used to control pests, diseases, and weeds, as well as to increase the levels of relevant nutrients in the soil. Characteristic (D) shows that all of the techniques adopted by the indigenous farmers are environmentally friendly as they use locally available resources. These techniques improve the biodiversity in the field by maintaining the long-term potential of the rice land (see Table 1). Characteristic (E) shows several relevant techniques for improving the tolerance of seed to weeds, pests, and diseases. Specifically, the farmers select highly viable seeds using seed selection and separation techniques and avoid possible diseases, such as "rice blight," using traditional pre-treatment methods. For these methods, the farmers only use locally available resources. The farmers reported that these techniques improve the seed fertility rate as well as the tolerance of the rice plant to weeds, pests, and diseases (see Table 1). Characteristic (F) shows that most of the techniques are related to risk reduction in terms of drought, flood, pests, and diseases. Specifically, the techniques used for seed selection and seed treatment, as well as for sowing based on rainfall patterns and the lunar calendar, were highly noted by the farmers as methods of eliminating possible risks. Characteristic (G) reports the effectiveness of the techniques. Specifically, the farmers reported that most of the techniques are effective as they were able to generate the expected outcome using available and affordable resources by contributing to long-term production sustainability. Characteristic (H) shows the effectiveness of the techniques in assuring both the safety of the food produced by indigenous farmers and the security of household food in various ways. In contrast to the IRFT, the MRFT do not show these characteristics as they depend heavily on external inputs and hybrid varieties to achieve the outcome mentioned above with regard to the indigenous farmers in the survey area.

2) Analysis of yield, production cost, and income of rice farming under the IRFT

1. Yield comparison between the IRFT and the MRFT

Table 3 shows that the average yield recorded under the MRFT was 2,249 kilograms per acre (kg/acre), which is statistically significantly higher than the 1,431 kg/acre yield recorded under the IRFT; however, our results provide important evidence that explains the observed rice yields under the IRFT. First, the rice farm yield data show that some farmers were able to achieve high yields per acre. According to Table 3, the maximum yield recorded by the indigenous farmers is 1,799 kg/ acre. This is a considerably significant yield per acre for several reasons. Firstly, this yield was recorded under conditions involving low inputs and environmentally friendly techniques, as discussed in the previous section. Secondly, the indigenous rice lands are located in an area in which many modern rice farmers practice their techniques. Therefore, the influence of the MRFT on the indigenous rice lands is still critical, particularly with regard to the management of water, pests, diseases, and weed control, among others. Thirdly, the farm management conditions faced by indigenous rice farmers are rather different from those faced by modern farmers as modern rice farmers receive considerable support from the government in terms of agricultural extension services, subsidy programs, and marketing. Thus, the comparison of yields between the two farmer groups is not rational as both groups are not facing similar farm management conditions.

Second, the correlation analysis between farmer experience, measured as the number of seasons each technology was applied in rice farming, and yield suggests that the per acre rice yield can be further increased with more experience using the IRFT. Table 4 indicates the positive relationship between farmer experience in the IRFT and per acre rice yield, which is statistically significant. The farmer survey revealed that with the adoption of the IRFT for several seasons, rice farming could improve soil conditions, including organic matter and several other physical properties (i.e., improved drought tolerance, decreased soil salinity, etc.). The reason such improvements could occur is that those rice lands had previously been farmed using the MRFT. The analysis also shows that there is no statistically significant relationship between the farmer experience in the MRFT and the rice yield. This result indicates that the MRFT will not further support an increase in rice production as the farmers record optimal yields under high external input usage.

Table 3: Actual yield per acre for rice farming under the IRFT and MRFT

Type of technology	Yield (kg/acre)	Standard deviation	Min. (kg/acre)	Max. (kg/acre)
IRFT	1,431	245.5	735	1,799
MRFT	2,249	246.7	1,766	2,600
Difference	818*** (4.28)			

Source: Field survey, 2012

Note: (1) *** $p < 0.01$ significance level. (2) Parenthesis is t value.

Table 4: Correlation analysis between numbers of seasons each technology was applied and yield performance

Type of Technology	Pearson correlation	p-value	N
IRFT	0.705***	0.001	40
MRFT	0.033	0.874	70

Source: Field survey, 2012

Note: *** $p < 0.01$ significance level.

2. Production costs of rice farming under the IRFT and MRFT

As presented in Table 5, production costs of all particulars were lower for rice farming under the IRFT compared to the MRFT. Among the particular variables, the costs of land preparation, seed and pre-planting techniques, soil fertility management, and controls for weeds, pests, and diseases all showed statistically significant differences between the two groups. These results suggest that input cost is a major cause of the difference in production costs per acre between the two farming technologies. As shown in Table 5, the per acre input cost of rice production under the IRFT was Rs. 2,459, which accounted for 6.8% of total production costs. By contrast, the per acre input cost of rice production under the MRFT was Rs. 28,263, which accounted for 43.9% of the total production costs. This difference indicates that the Green Revolution in Sri Lanka has resulted in an increase in input costs by over six-fold in the MRFT compared with the IRFT. The low-input cost of rice farming under the IRFT is associated with several characteristics of the IRFT, particularly the decision making based on the lunar calendar, the dependency on local resources, the adoption of risk reduction techniques, and the adoption of techniques for improving seed fertility rate and rice plant resistance to diseases, pests, and drought at the stage of seed selection, in addition to the pre-planting techniques employed by the farmers.

The modern rice farmers are entirely dependent on external inputs, which are mainly imported from the world market. The farmer survey revealed that the modern farmers apply 67 kg of chemical fertilizer (Urea—5 kg, TSP—45 kg, MOP—15 kg, and Sulfate—2 kg) per acre in the land preparation stage and 120 kg of chemical fertilizer (Urea—100 kg and MOP—20 kg) per acre after planting for soil fertility management in the rice land. In both stages, the average cost of chemical fertilizer application was Rs. 18,840 per acre; however, farmers paid only 5.8% (Rs. 1,085) of the total chemical fertilizer cost. The remainder of the cost (94.2%) (Rs. 17,755) was paid for by the government as a result of the subsidy provided for chemical fertilizer. Moreover, modern farmers have spent Rs. 1,280 on weed control, Rs. 660 on pest control, and Rs. 1,033 on disease control (see Table 4). The indigenous farmers did not face such high costs. These results indicate that modern rice farmers have to depend on the external input market due to the characteristics of the MRFT, while indigenous rice farmers do not, a result of the characteristics of the IRFT regarding input usage. As shown in Table 5, the results of the t-test indicated the statistically significant difference in total production costs ($t = 9.26$, $p < 0.01$).

Table 5: Paddy production costs—Rs. per acre under the IRFT and MRFT

Particular	Indigenous Technology				Modern Technology				t value
	Labor cost	Machinery cost	Input cost	Total cost	Labor cost	Machinery cost	Input cost	Total cost	
1. Land preparation	8,800	7,467	0	16,267	8,167	7,442	3,573	19,182	2.99**
2. Seed, seed selection, and pre-planting techniques	580	0	1,990	2,570	483	0	2,877	3,360	8.13***
3. Rice planting (seeding/nursery)	3,883	0	0	3,883	3,933	0	0	3,933	0.69
4. Soil fertility management	707	0	347	1,054	1,390	0	18,840	20,230	6.05***
5. Weed control	1,000	0	0	1,000	1,200	0	1,280	2,480	6.35***
6. Pest control	383	0	122	505	800	0	660	1,460	1.98**
7. Disease control	267	0	0	267	903	0	1,033	1,936	3.89***
8. Harvesting, threshing, and winnowing	0	8,687	0	8,687	0	8,933	0	8,933	0.02
9. Drying, transportation, and storage	433	1,437	0	1,870	1,503	1,310	0	2,813	0.00
Total cost, including the cost of fertilizer subsidy	16,053	17,591	2,459	36,103	18,379	17,685	28,263	64,327	9.26***

Source: Field survey, 2012

Notes: (1) Detailed items of each cost component under each technology are mentioned in Table 1. (2) Sri Lankan government provides all types of chemical fertilizer at Rs. 350 per 50 kg bag. On behalf of this fertilizer subsidy, the government had spent Rs. 4,950, Rs. 6,850, and Rs. 5,950 per 50 kg bag of Urea, Muriate of Potash (MOP), and Triple Supper Phosphate (TSP), respectively, in 2012, based on the world market price. Therefore, we took into account the cost of this fertilizer subsidy in our determination of the total cost of chemical fertilizers in the MRFT. (3) *** $P < 0.01$ significance level

3. Differences in net income of rice farming between the IRFT and MRFT

In this study, we assumed the same price for rice produced by both farmer groups as there is no segmented market for indigenous rice due to the non-existence of a wholesale market for indigenous rice in the area and country at large. For this reason, although there is an increasing demand for rice produced under the IRFT due to the lack of chemical inputs and the health and food safety relevance of indigenous rice varieties (Maddumabandara [8]), traders in the area purchase both types of rice at the same price. Table 6 shows the unit price of rice as Rs. 25.8; however, a small quantity of indigenous rice has been purchased by the MPIS at a relatively high price for the purpose of seed preservation. Table 6 shows that although the net income of indigenous rice farming is low, this type of farming records a surplus in net income, in contrast to the MRFT, which records a deficit in net income. The deficit in net income recorded by the MRFT, however, is not visible to the modern rice farmers due to the large fertilizer subsidies that they receive. Finally, the results show a Rs. 8,730 difference in net income per acre of rice production under the IRFT and the MRFT.

Table 6: Differences in the income of rice farming between the IRFT and MRFT (Rs. per acre)

Variable	IRFT (A)	MRFT (B)	Difference (A-B)
Unit price (Rs./kg) (1)	25.8	25.8	0
Unit cost (including the cost of fertilizer subsidy (Rs./kg)) (2)	24.1	28.6	-4.5
Net unit price (Rs./kg) (1) – (2) = (3)	1.7	-2.8	4.5
Average yield (kg/acre) (4)	1,431	2,249	-818
Net income per acre (including the cost of fertilizer subsidy) (Rs.) (3)*(4)	2,433	-6,297	8,730

Source: Field survey, 2012

3) Constraints to the IRFT from the perspective of modern rice farmers

Table 7 presents the main justifications for not adopting the IRFT by the modern rice farmers in the area. One hundred percent of the farmers reported that the lack of a segmented market for the indigenous rice was their main reason for not adopting the IRFT. The field survey revealed that there is no established market for rice produced under the IRFT in the survey area. Although the MPIS purchases the rice produced under the IRFT at a significantly high price, their collection capacity is not sufficient to address the farmers' rice marketing problem in this area. Thus, the farmers must rely on local traders who purchase the rice at the same price. The second reason for not adopting the IRFT, which accounted for 89% of the total modern farmers, was the lack of technical information and training. Particularly, the MPIS is the only organization promoting this technology in the area, and they have a training and experimental station in the district. Interviews with the officers at the MPIS revealed that promotion of the IRFT among farmers is difficult due to the scant attention it has received from the government and researchers. Eighty-one percent of the modern farmers reported that the IRFT provides low yields compared to the MRFT; however, those farmers are not aware of the high production costs involved in growing rice under the MRFT due to the government subsidy policy, and thus, they are not aware of the deficit in the net income of rice farming under the MRFT. Another issue raised by the modern farmers is the existing debt problem associated with the high production costs in the MRFT. This study revealed that these farmers usually borrow agricultural inputs from local agents of the input companies and local rice traders in the area. Eighty percent of the farmers reported that the support of the government agricultural extension officers is not sufficient to practice this technology. The farmers claimed that those officers do not have adequate technical knowledge about the IRFT, and thus, they neglect the IRFT, instructing farmers to follow the MRFT. Likewise, the lack of quality seeds and problems with diseases and pests due to the high density of the modern rice fields in the area were also reported by 60% and 37% of the farmers, respectively.

Table 7: Main reasons for not practicing the IRFT by the modern rice farmers

Problems mentioned by the surveyed modern farmers	No. of farmers	%
1. Lack of segmented market for indigenous rice in the area	70	100
2. Lack of technical information and training on the IRFT	62	89
3. Low productivity compared to the MRFT	57	81
4. The existing debt trap created by the MRFT	57	81
5. Lack of support from agricultural extension officers	56	80
6. Lack of quality seeds	42	60
7. Problems of diseases and pests due to the high existence of modern rice fields	26	37

Source: Field survey, 2012

4. Conclusions and considerations

This study presents the results of a survey designed to identify the characteristics and significance of the IRFT, which was developed based on the extensive experience of the local people in Sri Lanka and which has been tested over long periods of time. The study findings indicate the potential of the IRFT to address problems that originated from the technology package of the Green Revolution.

Characteristics of the IRFT revealed that the techniques it employs are adaptable to the natural features of the region as many of these techniques are specifically related to local resources. Based on the farmers' experience and information related to the environment, as well as decision making based on the lunar cycle and dependency on rainfall patterns in the region, the farmers can establish the conditions necessary for improved rice plant growth. These techniques also have the ability to improve the seed fertility rate and rice plant tolerance to potential diseases. The study further showed that these techniques do not have adverse environmental effects and that they generate the expected outcome. The empirical results indicated the significance of the IRFT in terms of farm management. The analyses of production costs and income provide further support for the IRFT. The results indicated a significantly low input cost per acre for rice farming under the IRFT, the main reason being that the IRFT is not dependent on external inputs. This study further emphasized that the Green Revolution has resulted in a six-fold increase in the input cost of rice farming under the MRFT compared to the IRFT. Income analysis indicated a surplus in the net income of rice farmers using the IRFT, whereas a deficit in net income was recorded for farmers using the MRFT. Moreover, the analysis of rice yields supported the existing potential for further enhancing rice yields under the IRFT. Although the rice yields recorded by the indigenous farmers were low, they can be regarded as considerably high for several reasons. First, the indigenous farmers do not rely on external inputs but instead use only locally available resources in an environmentally friendly manner. Second, the reported yields were recorded by indigenous farmers who face the existing influence of the MRFT on their indigenous rice land due to the high density of modern rice land. Additionally, the indigenous rice farmers face different farm management conditions in rice farming as modern rice farmers receive significant support from the government, while indigenous rice farmers do not. The survey results also indicated the positive correlation between farmers' experience using the IRFT and rice yield. This correlation suggested that the rice yield under the IRFT can be further increased through proper training and the implementation of a guidance program in the long term. Marketing issues due to the non-existence of a segmented market for indigenous rice, lack of extension facilities with regard to the IRFT, low productivity discourse, debt problem among the modern farmers, lack of government support with regard to the IRFT, and lack of quality seeds are the main limitations in the dissemination of this technology among the farmers in Sri Lanka.

This study recommends further research on the special conditions and technology adopted by progressive farmers who have recorded high yields for the purpose of identifying yield-enhancing techniques in different regions. Further research will address the low-yield argument for the IRFT, which will eventually be associated with the country's food security. Moreover, if every farmer adopts the IRFT, the country's rice supply will decline, and rice prices will increase, causing adverse effects on the impoverished population; however, the adoption of IRFT by every farmer will cause the elimination of subsidy costs (fertilizer subsidies) to the MRFT. Thus, the government should replace the current fertilizer subsidy with the market price stabilization of rice to protect the indigenous technology. This policy will eventually contribute to the elimination of environmental problems associated with agrochemical usage in the rice land, ensure food safety and food security for all of the country's people, and eliminate health risks for all rice producers and consumers. Particularly, the elimination of health risks will greatly reduce the health costs currently incurred to both parties, as cited by the WHO [13]. Moreover, indigenous farmers will receive benefits in terms of household consumption and additional income from naturally grown vegetables, ridge cultivation, and mid-season farming in the rice land. An economic assessment of the aforementioned benefits, as well as an evaluation of the unaccounted costs of environmental degradation and health problems caused by the MRFT, remain an issue to be addressed in the future. This study concludes that the IRFT provides the most appropriate solutions to overcome the problems that originated from the Green Revolution in Sri Lanka. These findings are novel in regard to the existing body of knowledge in the field. Thus, this study suggests that technological development in the rice sector should be undertaken based on the historical evaluation of the characteristics of the IRFT in the region and the indigenous knowledge of the local people.

End notes:

1) The rice sector in Sri Lanka occupies approximately 45% of the total agricultural land (DCS [2]). This sector provides livelihood for more than 1.8 million farmers and employment for more than 30% of the total labor force (DCS [2]). Rice plays the biggest role in household dietary intake, accounting for 48% of daily calorie intake as a staple food of Sri Lanka (DCS [2]). The sector is predominantly in the hands of smallholders whose land of area is measured at less than 1 ha (DCS [2]).
2) The IRFT differs from techniques applied in organic farming since the IRFT extends more to a lunar cycle, rainfall patterns and other agro-climatic conditions in the region, and agricultural rituals in rice farming.

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Milk Production Determinants and Technical Efficiency among Dairy Farms in Different Agro-climatic Zones, Sri Lanka

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1. Introduction

Dairying is an important source of supplementary income, especially for the marginal farmers in the mixed crop livestock system in Sri Lanka. Total milk production in 2010 was 247 million liters, meeting 33% of the annual national requirement. Sri Lanka's milk imports make up the difference at a cost of 21.5 million US dollars annually (Department of Census and Statistics [6]). According to the national policy for agriculture and livestock, the sector is supposed to achieve a self-sufficiency rate of at least 50% in milk and milk products by 2015. Nevertheless, almost 90% of the farmers are small-scale and poor. Thus, government needs to wake-up and support these farmers to become self-sufficient.

The type of dairy farming management system used in Sri Lanka is highly dependent on the agro- climatic zone where the farm is located. Each dairy farm and agro-climatic zone has its own unique ability to make decisions to produce a certain output given a set of inputs and technology. "Technical efficiency" is the ability of farms to produce the maximum possible output with a given set of inputs" (Farrell [8], Coelli [4]). Thus, understanding technical efficiency, its measurement and determining factors, is of crucial importance in dairy production economics.

Numerous studies have assessed dairy production efficiency in both developed and developing countries (Coelli [3], Fraser [9], Mbaga [13], Demircan [5]). In addition, some studies have examined the characteristics and profitability of dairy farms in Sri Lanka (Navaratne [14], Jayaweera [11]). However, no study to date has examined the technical efficiency of dairy farms in different agro-climatic zones in Sri Lanka. Studying of the factors that determine milk production and farm efficiency in each agro-climatic zone are important from a farmer's, as well as, from a policy point of view. Policy makers can use this knowledge to identify and target public interventions to improve farm productivity and income, while farmers can use this information to improve their performance, which ultimately leads towards self-sufficiency in milk production. Therefore, the objectives of this study were to identify and determine the effect of socio-economic factors on milk production and to measure the technical efficiency level in different agro-climatic zones of the country.

2. Study Area and Data Source

The study was conducted in three different agro-climatic zones in Sri Lanka. The different agro-climatic zones were selected for study because of the significant variations in temperature, cattle breeds and dairy management systems. The common topographic and climatic features, type of animals and husbandry practices in the three agro-climatic zones are given in Table 1. The Up-country is situated 1,200m above sea level and the ambient temperature range is between 10°C – 24°C. Farmers feed their cattle with weeds and fodder from the estate lands. They are mainly tea plantation workers, especially in the tea estates. The elevation of the Mid-country varies from 450m – 1200m above sea level and the ambient temperature ranges between 21°C – 32°C. The animals feed on grass along the roadsides and home grass plots, crop residues, and tree fodder. The Coconut Triangle goes from sea level – 450m and the average temperature is between 24°C – 29°C. Also, the Coconut Triangle has more than 70% of the nation's coconut plants and cattle are reared under tethered or free grazing conditions and fed mainly coconut processing by-products.

The selected study districts were Nuwara-eliya, Kandy, and Kurunegala representing the Up-country, the Mid-country and the Coconut Triangle, respectively. The second highest cattle population (132.6 thousand numbers, 2011) is in the Kurunegala district and the monthly average milk production in Nuwara-eliya is the highest (2749.8 thousand liters, 2009) (Department of Census and Statistics [6]. In addition, the Kandy district has the highest (75%) proportion of dairy cattle, mainly Jersey, Ayrshire and Friesian crosses, and the highest proportion of purebreds (25%). Average number of female animals are in the Nuwara-eliya, Kandy and the Kurunegala are 2.7 (least), 3.1 and 5.6, respectively.

A cross-sectional survey was conducted using a multistage random stratified sample design. A total of 522 dairy farmers were interviewed and data were collected using a pre-tested structured questionnaire on socio-economic characteristics of households, dairy management practices, herd characteristics, feeding practices and expenditures, animal health and veterinary services, land utilization, and labor utilization.

Table 1: Main characteristics in different agro-climatic zones

Characteristic	Agro-climatic zone		
	Up-country	Mid-country	Coconut Triangle
Elevation (m)	>1200	450-1200	0-450
Temperature(°C)	10 to 24	21 to 32	24 to 39
Rainfall (mm)	>2,000	1,675-5,000	1,500-2,500
Typical fodder bas	Roadside and railway lines	Roadside and home plots	Under coconut and home plots
Type of cattle	European crosses	European crosses	Local and cross breeds

Source: Ibrahim [10]

3. Methodology and Data

1) Multiple regression analysis

The linear, Cobb-Douglass and semi-log functional forms were used to determine the effect of socio-economic variables on milk production in the different agro-climatic zones. The semi-log form was selected on the basis of the number of significant variables, magnitude of R^2, F-statistics, standard error and the sign of coefficients.

The production function is estimated by;

$$\ln Q_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \beta_6 X_{6i} + \beta_7 X_{7i} + \beta_8 X_{8i} + \beta_9 X_{9i} + \beta_{10} X_{10i} + \beta_{11} X_{11i} + \beta_{12} X_{12i} + e_i$$

Where Q_i is total milk yield in the i^{th} farm; Based on the literature and data available, the characteristics and related variables assumed to be affecting the milk production were included. X_{1i} is land area including both highland and lowland in the i^{th} farm. It is very difficult to measure the pasture intake of cattle. Hence, the land variable is included as an indicator of pasture source. Increased land area may tend to increase pasture intake by cattle and therefore increase animal performance. In addition, this variable is important because the system of management and crop residuals available for the animals totally depends on the land availability; X_{2i} is labor hours per month used by the i^{th} farm and represents family and hired labor ; X_{3i} is total purchased feed quantity per month used by the i^{th} farm including formulated feed, broken rice and coconut poonac ; X_{4i} is number of cows in milk in the i^{th} farm; X_{5i} is experience of the i^{th} farmer; X_{6i} is age of i^{th} farmer; X_{7i} is cost of veterinary services (artificial insemination cost, disease treatment cost, transport cost, etc.) per month by the i^{th} farm including.; X_{8i} is a dummy variable equal to one if farmers received government subsidy (shed construction, animal purchasing, pasture cultivation, bio-gas, etc.) and zero otherwise; X_{9i} is a dummy variable equal to one if the farmers received any kind of training related to feed management, pasture cultivation, use of paddy straw, prevention of diseases etc. and zero otherwise. The training variable is included to capture directly the impact of the level of adaptation of dairy management practices on milk production; X_{10i} is a dummy variable equal to one if the farmers milked twice per day and zero otherwise; X_{11i} is a dummy variable equal to one if the farmers used natural service and equal to zero if the farmers used artificial insemination; X_{12i} is a dummy variable equal to one if the farmers practiced intensive system and equal to zero for extensive system; β_i are parameters to be estimated (i= 0,.....,12); and e is an error term.

2) Data Envelopment Analysis

The Data Envelopment Analysis (DEA) was used to analyze the technical efficiency of each agro-climatic zone in Sri Lanka. DEA builds an equi-efficiency frontier and an efficiency envelope for each Decision Making Unit (DMU). A number of studies have suggested that for an estimate of technical efficiency at the provincial level, a non-parametric approach appears to outperform a parametric approach such as the stochastic frontier approach (Fare [7], Chaves [2]). If agro-climatic zone k consists of data on L_k it forms a convex metafrontier that can be identified using the DEA on the inputs and outputs of all $L=\sum_{k=1} L_k$ dairy farms in all studied agro-climatic zones. Assuming all DMUs or farms are operating at an optimal scale, the input-oriented constant return to scale (CRS) DEA model is as follows:

$$Min_{\sigma,\lambda}\sigma$$

$$\text{s.t.} \quad -y_i+Y\lambda\geq 0; \quad \sigma x_i - X\lambda\geq 0; \quad \lambda\geq 0$$

Where, y_i: Milk quantity for i^{th} farm; x_i: Nx1vector of input quantities for i^{th} farm; Y: 1xL vector of milk quantities for all L farms; X: NxL matrix of input quantities for all L farms; λ : Lx1 vector of weight. $1\leq\sigma<\infty$ is a scaler and $\sigma-1$ is the proportional increase in output achieved by i^{th} farm, with input quantities held constant. The inverse of σ defines a technical efficiency score that varies between zero and one. To derive a set of N technical efficiency scores, the problem should be solved N times, one for each farm.

The specification of CRS is only suitable when the farms are working at optimum scale, otherwise, the measure of technical efficiency can be mistaken for scale efficiency, which considers all types of returns to production, i.e., increasing, constant and decreasing. The efficiency measure obtained on the variable return to scale (VRS) DEA is referred to as 'pure technical efficiency' as it is free of scale effects, and it can be obtained by the following model:

$$Min_{\sigma,\lambda}\sigma$$

$$\text{s.t.} \quad -y_i+Y\lambda\geq 0; \quad \sigma x_i - X\lambda\geq 0; \; N_1\lambda=1; \quad \lambda\geq 0$$

Where N_1 is a vector of one. When there are differences between the values of the technical scores in the models CRS and VRS, scale inefficiency is confirmed, indicating that the return to scale is a variable. In this paper, both the constant return to scale model (CRS)[1] and the variable return to scale (VRS) were estimated using input-oriented[2] specification (Farrell [8], Coelli, [4]). Estimates were made using linear programming in the software LIMDEP 7.0. In this study four important input variables were identified: land, labor, feed and cow number. The output variable is the total milk quantity.

4. Results and Discussion

1) Multiple Regression Analysis

Descriptive statistics and explanation of variables used in the analysis are given in Table 2. The milk production depends on breed type, climatic condition, management practices and other related factors. The total milk yield per farm is highest in the Coconut Triangle and least in the Mid-country.

Table 2: Descriptive statistics of dairy farms in different agro-climatic zones

Variables	Up-country	Mid-country	Coconut Triangle
		Mean	
Total milk yield per month (000, liters)	0.532 (0.568)	0.387 (0.322)	0.647 (0.638)
Average milk production per cow per day (liter)	9.917 (4.419)	7.395 (3.399)	6.083 (2.383)
[1]Land area; Highland and lowland (acre)	0.484 (1.214)	1.050 (2.015)	3.172 (2.735)
Labor hours used per month (000, hours)	0.176 (0.079)	0.291 (0.138)	0.243 (0.109)
Total purchased feed per month (000, kilograms)	0.181 (0.263)	0.107 (0.129)	0.265 (0.533)
Cow number (head)	1.808 (1.524)	1.729 (0.984)	3.327 (2.187)
Farming experience (years)	16.745 (11.920)	17.545 (14.600)	12.001 (10.252)
Age of farm head	45.403 (11.050)	51.083 (10.478)	47.138 (11.886)
[2]Veterinary cost per month (000, rupees)	0.300 (0.425)	0.195 (0.296)	0.374 (0.723)
		Rate	
Government subsidy dummy	0.324 (0.469)	0.375 (0.486)	0.260 (0.423)
Training programs dummy	0.231 (0.422)	0.340 (0.475)	0.440 (0.495)
Milking time dummy	0.851 (0.357)	0.746 (0.437)	0.240 (0.428)
Breeding method dummy	0.040 (0.195)	0.042 (0.201)	0.153 (0.361)
Management system dummy			
Intensive system	0.654 (0.477)	0.493 (0.502)	0.082 (0.275)
Extensive system	0.033 (0.179)	0.014 (0.117)	0.378 (0.486)

Note: Standard deviations in parentheses

[1]Highland includes pasture land, crop land and housing area; Lowland used for paddy cultivation.

[2]Deflated value is used, because, the study was conducted in three different time periods

Source: Survey cross-sectional data.

Table 3 presents the results of multiple regression analysis. The variance inflation factor (VIF) was used to check for multicollinearity and employed a Ramsey reset test to diagnose omitted variable bias. The coefficients of total land area were found to be significant with a positive effect in the Mid-country and the Coconut-Triangle, but not in the Up-country. The average land area per farm in the Up-country, the Mid-country and the Coconut Triangle are 0.48, 1.05 and 3.17 acres, respectively. Increased land area may tend to increase pasture intake by cattle and therefore increase animal performance and total milk production. In addition, this variable is important because the system of management and crop residuals available for the animals is totally dependent on land availability. The average land area per farm in the Up-country is very small and they are heavily dependent on purchased feed such as formulated feed, broken rice and coconut poonac (a by-product of coconut oil production).

The management of the dairy farming system can be classified into three groups: extensive, intensive, and semi-intensive. Extensive management system is low cost and has low productivity based on free grazing. The intensive system is characterized by the heavy use of efficient methods such as cut and fed in a shed, zero grazing, utilization of high yielding cows, fed compound feeds etc. The semi-intensive management system is a combination of intensive and extensive systems and it is less expensive compared with the intensive system and technically more advanced than the extensive system. The semi-intensive system is characterized by a medium level of input usage, where pregnant and lactating animals are housed indoors; others are allowed to graze in a paddock during the day and housed indoors at night.

The intensive management system was found to be positive and significant in the Up-country and the Mid-country. A majority of the farmers in the Up-country (65%) and the Mid-country (49%) practice intensive management system due to land limitation and some characteristics associated with the breeds raised. This implies that milk production in these zones tends to increase as percentage of intensively managed farms increases. In the Coconut Triangle, a majority of the farmers were practicing semi-intensive (54%) and extensive (38%) management systems due to the greater availability of land and low cost breeds. The same coefficient had a positive relationship with milk production, although it was not significant. The reason is fewer farmers operate intensively in this area.

Table 3: Socio-economic correlates of dairy farms in different agro-climatic zones

Variables	Up-country	Mid-country	Coconut Triangle
	Coefficients		
Constant	3.075 (0.087)***	3.069 (0.124)***	3.143 (0.075)***
Land area	0.002 (0.013)	0.023 (0.009)**	0.010 (0.005)***
Labor hours used	0.368 (0.076)*	0.006 (0.141)	0.380 (0.003)***
Total purchased feed	0.312 (0.090)***	0.301 (0.151)**	0.047 (0.035)
Cow number	0.067 (0.012)***	0.169 (0.021)***	0.122 (0.006)***
Farming experience	0.002 (0.001)	- 0.001 (0.002)	0.002 (0.001)
Age of farm head	- 0.003 (0.002)*	0.001 (0.002)	- 0.002 (0.001)
Veterinary cost	0.007 (0.038)	- 0.092 (0.061)	0.023 (0.018)
Subsidy dummy	0.042 (0.034)	0.109 (0.042)**	0.004 (0.032)
Training programs dummy	0.104 (0.039)***	0.055 (0.039)	0.025 (0.028)
Milking time dummy	0.335 (0.051)***	0.073 (0.043)*	0.120 (0.033)***
Breeding method dummy	- 0.005 (0.081)	- 0.083 (0.088)	- 0.143 (0.039)***
Management dummy			
Intensive system	0.065 (0.074)*	0.113 (0.039)***	0.044 (0.048)
Extensive system	0.009 (0.122)	0.047 (0.151)	- 0.033 (0.031)
R-squared	0.68	0.60	0.80
Adjusted R-squared	0.65	0.56	0.78
F - statistic	26.60***	14.59***	55.12***
Sample size	182	144	196

Note: Standard errors in parentheses, *,**,and *** are statistically significant at 10%, 5% and 1% level respectively.

Dependent variable - Log milk production per month per farm.

Source: Survey cross-sectional data.

The average amount of purchased feed fed per milking cow per day in the Up-country, the Mid-country and the Coconut Triangle are 3.22, 2.28 and 2.06 kilograms, respectively. The coefficients of total purchased feed quantity were found significantly positive in the Up-country and the Mid-country, while it was insignificant in the Coconut Triangle. This happens because of the potential cattle-grazing area(number of animals per unit of land area) is comparatively high in the Coconut Triangle compared with the other two agro-climatic zones. Therefore, animals are either graze or tethered in the paddy fields along roadside or in the backyard.

Government subsidies have played a key role in the Mid-country and more than 37% of the farmers in the Mid-country have received money for cattle shed construction, while dairy extension and training plays a main role in milk production in the Up-country. These findings indicate that subsidy and training are important factors in milk production. Additionally, the Up-country farmers use high tech, expensive and efficient methods (in feeding and breeding) in dairy farming. Interestingly, "Age" of the farmers in the Up-country has a negative relationship with milk production, which suggests that older farmers tend to be less efficient. This agrees with the findings of Omonona *et al.*[12]. It could be that older farmers have a less access to technology than younger farmers. In the case of new technology, for example feed management, older farmers may be less adaptable than younger ones. This suggests that dairy farm training may improve the use of new technology making the production process efficient.

As expected, the coefficients of the milking time dummy were found highly significant with a positive impact on average milk production in all agro-climatic zones. The coefficient of natural service breeding method was found significantly negative in the Coconut Triangle while, it was insignificant in the Up-country and the Mid-country. In the Coconut Triangle, some dairy farmers (10%) tend to use natural service over artificial insemination for many reasons such as, availability of bulls, having enough land for mating, problems in getting timely artificial insemination and difficulties with heat detection. This suggests that a dairy farmer who uses artificial insemination, will see milk production of the farm increase.

2) Data Envelopment Analysis

Table 4 shows the average technical efficiency in different agro-climatic zones under the assumption of CRS and VRS. The overall mean average technical efficiencies are 0.629 and 0.879 for TE_{CRS} and TE_{VRS}, respectively. The difference between CRS and VRS measures indicates that some farmers do not operate at an efficient scale and improvement in the overall efficiencies can be achieved if the farmers adjust their scale of operation. Results show that the superiority, in terms of average technical efficiencies (assuming VRS) is 0.922, 0.888 and 0.828 in the Up-country, Mid-country and Coconut Triangle, respectively. This suggests that, assuming there is a common technology between the Up-country, the Mid-country and the Coconut Triangle dairy farms, the Up-country farmers make more efficient use of this technology in the dairy sector.

Table 4: TE_{VRS}, TE_{CRS} and Scale efficiencies in different agro-climatic zones

Agro-climatic zones	TE_{VRS}	TE_{CRS}	SE
Up-country	0.922(0.151)	0.627(0.228)	0.680
Mid-country	0.888(0.178)	0.613(0.217)	0.690
Coconut Triangle	0.828(0.174)	0.646(0.228)	0.780

Note: Standard deviations in parentheses

TE_{VRS} = technical efficiency from DEA variable return to scale;

TE_{CRS} = technical efficiency from DEA constant return to scale;

SE = scale efficiency = TE_{CRS}/TE_{VRS}

Source: Surevey cross-sectional data.

The highest mean technical efficiency (assuming CRS) is in the Coconut Triangle, while the

Mid-country has the lowest mean technical efficiency. The average technical efficiency (TE_{CRS}) is 0.646, indicating that the mean gap between the best farmers and other farmers is about 35% in the Coconut Triangle, but the mean technical efficiency (TE_{VRS}) is 0.828 of this agro-climatic zone. Moreover, the scale efficiency of 0.780 indicates that the average farm is 22% scale inefficient. The distribution of technical efficiency (TE_{CRS} and TE_{VRS}) levels for the different agro-climatic zones are shown in Figure 1.

These technical estimates (TE_{VRS}) show that majority of the dairy farmers in the Up-country (83%) and the Mid-country (75%) are operating at near or fully efficiency. Meanwhile, in the Coconut Triangle, 55% of the farmers are operating at a 80-100 percent technical efficiency level.

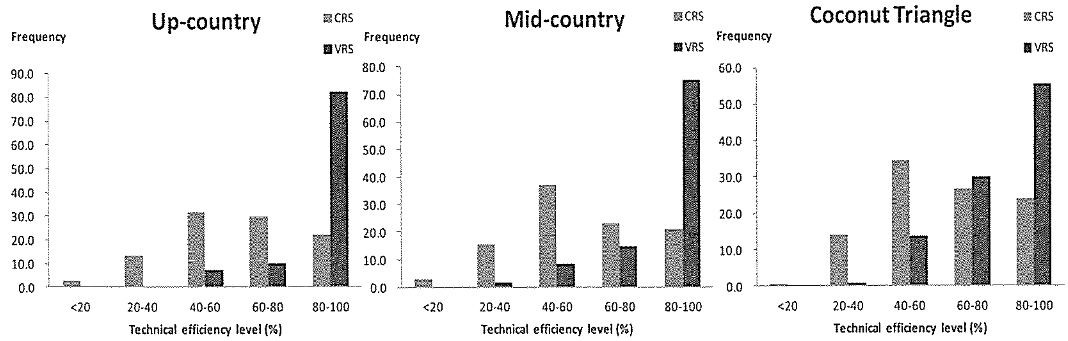

Figure 1: Distribution pattern of technical efficiency estimates of dairy farms in different agro-climatic zones

5. Conclusion

The study examined the effect of socio-economic factors on milk production and distribution of technical efficiency levels in different agro-climatic zones in Sri Lanka. A DEA was used to measure input-oriented efficiency scores, assuming both VRS and CRS. The intensive system of farm management has a significantly positive impact on milk production in the Up-country and the Mid-country. Thus, the government should promote dairy farm intensification, taking into consideration resource availability, in each agro-climatic zone. However, because of land limitations due to population pressure, land segmentation and a small quantity of compound and coarse feed in the distribution system in Sri Lanka more than 90% of the farm herds in the Up-country and the Mid-country are less than five cattle. Thus, common pastures will be important in providing a continuous supply of milk production in the future. In order to have a long-term commitment to pasture management farmer management societies will need to be established.

The government training and extension service play an important role in the Up-country, while, in the Mid-country, government subsidies have had a significant influence on milk production. Therefore, the development of human capital is important through training and extension. Furthermore, as milking twice a day has been found to be more productive than once a day, it is important that efforts be made to increase milking frequencies through credit or subsidies for the purchase of milk storage and cooling facilities and to solve the major problem of insufficient capacity of the milk collection centers. In the Coconut Triangle farmers have enough pasture and they mainly used local and cross breeds. The negative impact of natural service breeding suggests that artificial insemination leads to higher average milk production in the Coconut Triangle. This finding has important implications and the progeny test could be used to select high yielding, heat tolerant and more feed efficient breeds. There are some constraints, however, since introducing exotic breeds from a temperate zone can reduce production and to complete a set of progeny tests will take at least seven years.

In the Up-country and Mid-country farmers are operating at near efficiency level, but in the Coconut Triangle only 55% of the farmers are operating at a 80-100% technical efficiency level. As discussed before, the results indicate that there are ample opportunities to improve production efficiency by using inputs more efficiently in different agro-climatic zones. Based on the findings of this study, subsequent research is required to identify the relationship between each of the farm efficiencies and their main productive characteristics (cluster analysis and discriminant analysis) in different agro-climatic zones.

Note:

1. Total technical efficiency (CRS model) can be decomposed in to pure technical efficiency (VRS model developed by Banker [1]) and scale efficiency (SE) for management factors and scale factors, respectively. Moreover, SE measures the difference in efficiency levels between CRS and VRS.
2. Input-oriented model is utilized because, a farmer is able to take control of inputs more easily than outputs.

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Smallholding Rubber Farming In Indonesia: Is it Efficient?

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1. Introduction

Rubber is one of Indonesia's leading agriculture export commodities besides palm oil, coffee, and cocoa. Its export value is the second largest among agricultural commodities after palm oil, and followed by coffee and cocoa (Board of Statistical Center, [12]). Also, at least 7 million people rely on this sector (Paramune and Budiman [10]). That implies that the rubber sector plays an important role in Indonesian economic development. In the last decade, the price of natural rubber in the world has dramatically increased from US$ 1/kg in 2000 to US$ 3/kg in 2009. This price increase is caused by increasing demand, which in turn is triggered by rising of oil price and environmental issues.

Indonesia has the largest rubber planted area by 3.4 million hectare, followed by Thailand and Malaysia, but total production is lower than Thailand (Association of Natural Rubber Producing Countries-ANRPC[3]). That is due to the fact that the rubber productivity in Indonesia is still low. Even though productivity has been increasing from 765kg/ha/year in 2003 to 901 kg/ha/year in 2009, but it is still lower Thailand's and Malaysia's productivity,1704kg/ha/year and 1,450kg/ha/year, respectively.

Domestically, 83% of the land area for rubber is cultivated by smallholder rubber farmers, while 17% is cultivated by private and public estates (Board of Statistical Center, [12]). Smallholder rubber farmers cultivate rubber individually, and are supported by their household member, whereas private and public estate manage rubber plantation very well. Therefore, productivity of smaalholder rubber farmer is lower than government and private estate.

Paramune and Budiman [10] stated that smallholder rubber farming is still weak both in *on-farm* and *off-farm* points of view. From the *on-farm* side, around 60% of smallholder rubber farms are said to be in a rubber agro-forest or "rubber jungle"; in a rubber jungle, rubber is grown alongside other annual crops like fruits and timber. In rubber jungle cultivation, the farmers' inputs are low and the farms are not managed well. Furthermore, Roger, Sinaga and Budidarsono [11] showed that regardless the environmental adaptation the smallholder rubber monoculture system yielded higher profits than smallholder rubber agroforestry traditional systems (i.e., the "rubber jungles"). Another reason is that the age of rubber cultivation is very old.

Based on the background this study hypothesizes that smallholder rubber farmer is not efficient. So far, however, there has been little discussion about the efficiency of smallholding rubber farming and farmer behavior given the conditions. Hence, this paper will focus on production efficiency of smallholding rubber farming in Indonesia. This paper will contribute in improvement of smallholder rubber farmer in Indonesia.

2. Literature Review

1) Related Research

A considerable amount of literature related to rubber production efficiency has been conducted in several countries. In Malaysia, one of the top three rubber producers in the world, rubber production efficiency research in Terengganu was conducted by Nik Hashim Nik Mustofa in[9]; Terengganu is part of the Rubber Industrial Smallholders Development Authority (RISDA) project. The results show that average technical efficiency for both Cobb-Douglass and Translog models are 0.832 and 0.817, respectively. Cultivated area and tapping intensity have positive significant effect on rubber productivity. Number of rubber tree per land area is positively associated with inefficiency, while yield per tapping is negatively associated with inefficiency.

In Nigeria, Stochastic production function by maximum likelihood approach was utilized to estimate the inefficiency (Giroh and Adebayo [7]). The results demonstrated that wage variation has positive significant effect on increasing production variation. On the contrary, plantation or rubber age has a negative significant effect. Furthermore, socio-economic factors including education, training, and gender have a significant effect to tapper efficiency. Another research by Tran et. al. [13] focused on the technical efficiency of a rubber farm in Vietnam. A time-varying stochastic frontier production function model was utilized for 33 farms. The result showed that mature trees were more productive than young and very old trees. Furthermore, the average of technical efficiency was 0.59. This means that many farmers operated rubber management away from the frontier. Farmers who applied technology for latex transportation were more efficient than the farmers who did not.

It is apparent that land area and the age of tree play an important role on rubber output. The age of trees affects many variables such as the amount of fertilizer the farmers put in, the number of employed workers, and the number of trees in each hectare. Indonesian Rubber Research Centre – Sembawa Division [2], mentions that the recommendation fertilizer to put in the rubber plantation depend on ages of rubber plantation, that are 392kg/ha/year; 492kg/ha/year; 407kg/ha/year and 175kg/ha/year for 1-5 year; 6-15 year; 16-25 year; and more than 25 year, respectively.

2) The Stochastic Frontier Production Function

Stochastic Frontier Production (SFP) has been applied in many research fields because it can simultaneously predict the usefulness of the production function and find an inefficiency model. Originally, the function was introduced by Meeusun and Broeck [8] and Aigner, Lovell and Schmidt [1] and has been developed using various approaches. In a cross-section data by N-firms, the stochastic frontier production function can be defined as follows:

$$y_i = f(x_i, \beta) + v_i - u_i, \text{ where } i = 1, 2, \ldots, N, \quad \ldots(1)$$

where y_i is production for firm-i, x_i is a vector of input quantities used by the i-th firm; β is a (kx1) vector of unknown parameters to be estimated; v_i refers to random error effects which are independently and identically distributed (*i.i.d.*); normal random variables with mean zero and constant variance, σv^2, independent of the u_is. The latter are non-negative random variables and are assumed to be *i.i.d* exponential or half normal random variables. The term technical efficiency is defined as maximum attainable output via the production input. Mathematically, it is the ratio between the observed output for the i-firm and the potential output as described below (Coelli, Rao and Battese, [4]):

$$TE = \frac{y_i}{\exp(x_i\beta)} = \frac{\exp(x_i\beta - u_i)}{\exp(x_i\beta)} = \exp(-u_i) \quad \ldots(2)$$

Furthermore, because u_is are assumed to be exponential variables, two methods are used to estimate the function, *maximum likelihood* (ML) and *corrected ordinary least square* (COLS). Because the ML estimator is asymptotically more efficient than the COLS estimator, the ML estimator is more widely used than the COLS estimator.

3. Data and Methods

The study was carried out in North Sumatera Province, one of the centers of rubber in Indonesia. North Sumatera's smallholder rubber farming is a common type of smallholder rubber farming in Indonesia. To figure out the comprehensive conditions of smallholding rubber farmers, two different research areas were purposively selected, Labuhan Batu District to represent areas where the farmers' average field areas are large; and Deli Serdang Disrict to represent areas where farmers' average field areas are small. Primary data were obtained by random sampling method by using a structured questionnaire to 32 farmers in Labuhan Batu and 30 farmers in Deli Serdang.

Following Nik Hasyim Nik Mustafa [9] and Giroh and Adebayo [7], this research also adopts Cobb-Douglas production frontier function. The Cobb-Douglas production frontier can be expressed as follows:

$$\ln y_i = b_0 + b_1 \ln F_i + b_2 \ln L_i + b_3 lnNoT_i + (v_i - u_i) \quad \ldots(3)$$

Where crop output Y is measured in kg, fertilizer F is measured in kg, labor L is measured in work day, and number of tree NoT is measured in tree; v_i represents random error which are *i.i.d*, u_i :

non-negative and half normal counted as inefficiency. In this model, since the two different research areas represent the scale of land ownership, we do not put the variable "land area" in production function, instead recognized it in two different estimations.

In rubber cultivation, variables such as fertilizer, labor, and number of tree are important variables that directly affect the return to scale as mentioned in equation 3. On the other hand, other variables such as farm management practice are assumed to be inefficient variables (Forsund, Lovell and Schmidt, [6]). In this research, the reasons behind farmer behavior in rubber production can be traced to farm management practices. Therefore, our hypothesis states that rubber clones, rubber age, tapping share system, farmer training, tapping job, and final product have a significant relation to rubber farm inefficiency:

$$u_i = d_0 + d_1C_i + d_2RA_i + d_3TSS_i + d_4T_i + d_5TJ_i \quad (4)$$

where u_i is inefficiency effect in ratio; C is dummy clone with a value of 1 for certified clone and 0 for otherwise; *RA* is rubber age measured by year, *TSS* is dummy tapping share system with a value of 1 for tapping by the owner, 0 for otherwise; *T* is dummy training with a value of 1 for having work or even worked at rubber company or project and 0 for otherwise. Furthermore, *TJ* is dummy tapping job with a value of 1 for farmers who do right tapping and 0 for otherwise. For the model, the null hypothesis is no technical inefficiency effects in the model; statistically, this is expressed as H_0: γ=0 and is tested by a one-sided generalized likelihood-ratio test (Coelli, [5]).

4. Results and Discussion

1) Smallholding Rubber Farming Characteristics

In the research area, the rubber farms were introduced to farmers since the colonial era. The farms were then continuously hereditarily cultivated. A farmer acquires knowledge of rubber farming from his/her parent and transfers this knowledge to the succeeding generations. Table 1 shows that on average, land ownership in the research area is 2.00 hectares, in Labuhan Batu is 3.72 hectares, while in Deli Serdang is 0.47 hectare. We observed that because of time allowance to do a tapping job, the optimum land area for one farmer to manage is two hectares and share its remains to tapper worker. Henceforth, in order to get more yield, tapper workers tend to consume more bark. In the short term, this could produce more yield, but long term effects include damage of rubber tree. This is a terrible condition for farmers who have a large cultivation area and for those who do not have any ability to do tapping by themselves. However, when the owners share their cultivation to skillful and responsible tapper worker, the cultivation will be managed well.

In Labuhan Batu, rubber farmers spend 87 man days/ha/year; this is less than what is spent in Deli Serdang, where farmers spend 221 man days/ha/year. Labor is both family and hired labor. In addition, tapping job is most of the time a consuming job, 90% of total labor time. Labor in Labuhan Batu is higher than in Deli Serdang because in Labuhan Batu time to tap per rubber tree is 40 second, lower than in Deli Serdang, 60 second.

Number of tree/land area represents the farmers' effort to increase productivity by cultivating rubber tree more dense-off. Since the number of tree/land in Labuhan Batu area (423 trees/ha) is lower than in Deli Serdang (615 trees/ha), the effort of farmers to increase the number of tree/land area in Labuhan Batu is less than in Deli Serdang. The age of rubber cultivation and the kind of clone may be key factors that affect the number of tree/land area.

In Labuhan Batu, 84.38% of farmers applied certified clones, whereas 15.63% applied seedlings. Farmers who applied seedlings are not engaged in the P3RSU Project. In the project, farmers received any production inputs, received any salary during gestation period and learn how to manage rubber plantation. Also, the project initiated establishing of agriculture cooperative by which rubber yield sells. The farmer had to return the money they borrowed from the project after their rubber plantation can be harvested. Furthermore, In Deli Serdang, as many as 70% of the farmers applied certified clones and the clones' remains, while 30% of the farmers applied seedlings. Farmers who used seedlings are those who never worked in a rubber company. Furthermore, the average number of fertilizer/hectare in Labuhan Batu (128 kg/hectare) is lower than in Deli Serdang (330.2 kg/ha). Besides, by looking at fertilizer/number of tree as proxy to farmers' effort to increase production by increasing fertilizer, we see that farmers in Labuhan Batu applied less fertilizer/number of tree (32.0 gram/tree) compared to those in Deli Serdang (57.2 gram/tree).

In Labuhan Batu, the age of rubber is 31 years, i.e., very old and is beyond economic life. Sixty percent of the rubber plantations was cultivated in 1977 during the project, Smallholding Plantation Development Project (hereafter called the P3RSU project) that was implemented by the Indonesian government and the World Bank. In Deli Serdang, rubber plantations were cultivated in 1990 (19 years old), twelve years younger than those in Labuhan Batu.

Table 1 Description of Smallholding Farmers' Characteristics within the Research Area

Descriptive	Labuhan Batu	Deli Serdang	t-statistic
Land ownership (ha)	3.72	0.47	6.30***
Fertilizer (kg/ha/year)	128.2	330.2	5.17***
Workdays (day/ha/year)	87	221	7.54***
Number of trees (tree/ha)	423.0	615.0	5.01***
Clone [certified clone / seedling] (%)	[84.4 / 15.6]	[70 / 30]	NA
Age of rubber (year)	31	19.0	5.24***
Tapping share system [by oneself / share with tapper worker] (%)	[56.3/43.7]	[93.3/6.7]	NA
Training [engaged / not engaged] (%)	[65.6 / 34.4]	[83.3 / 16.7]	NA
Tapping job [do right tapping/do mistaken tapping] (%)	[21.9/78.1]	[40/60]	NA
Production in wet rubber (kg/ha/year)	1,777	2,577	5.86***
Price [slab / cup lump] (IDR/kg)	[-/9,811]	[7,050]	-19.15***
Income from rubber crop (IDR/ha/year)	11,106,207	14,384,675	2.69***

Source: Based on the household survey data, 2012

Notes:

1) Fertilizer: Urea, TSP/SP36, KCl, and Kieserite
2) One workday: 8 hours
3) Certified clones: Prang Besar 260, Gondang Tapen1, Proefstation voor Rubber 300, Balai Penelitian Medan-24
4) *** : significant at level 1%; NA: not available

Moreover, nearly 75% of farmers do tapping by themselves: 56.3% in Labuhan Batu and 93.3% in Deli Serdang. They do not need to pay tapper workers. However, farmers who share the tapping activity with the tapper workers pay these workers after the yields have been sold. The share systems vary from one farmer to another. Generally, the share system for farmers with a close relationship with their tapper workers (such as family) or for those whose rubber estate is very old (estates beyond economic life, i.e., those that are 25 years or more) is 50:50. To make sure that yield is continuous, farmers who do tapping by themselves must correctly do the tapping. Unfortunately, farmers are only able to tap two hectares of rubber trees by themselves; the rest they share with hired tapper.

Farmers learn rubber cultivation management from their engagement with private rubber companies (where they presumably work or ever worked), in a rubber development project, from their parents, and even from other farmers. Because of the apparent control mechanism, with the first two means, the farmers are designated as "*engaged in training*", and in the last two, farmers are designated as "*not engaged in training*". In Labuhan Batu, as many as 65.6% of the farmer s is engaged in training, while in Deli Serdang, as many as 83.3% of the farmers is engaged in training. This condition could affect the skills of the farmers.

Furthermore, in Labuhan Batu, the productivity of wet rubber is 1,777 kg/ha/year, which is lower than in Deli Serdang, which is 2,577kg/ha/year. However, the average of production/tree in Labuhan Batu is 4.6 kg/tree/year, while production/tree in Deli Serdang is 4.5 kg/tree/year. This means that farmers in Deli Serdang cultivate more trees than the farmers in Labuhan Batu. In detail, in productivity of certified clone is 2,636/ha/year, which is higher than seedling, 2458kg/ha/year.

Finally, as the main purpose of rubber farms is to reach the profit maximization, in Deli Serdang average income is 14,384,675 IDR/ha/year higher than Labuhan Batu, 11,106,207 IDRha/year lower. This is due to the fact that total production in Deli Serdang is higher than Labuhan Batu. Also, farmer in Deli Serdang produces nursery transplant by oneself, whereas farmer in Labuhan Batu buys it from rubber nursery which is more costly.

2) Production Efficiency of Smallholding Rubber Farming in Indonesia

For detail result, we analyzed the production function of two research areas separately. The results were gained by using the Cobb Douglas production frontier analysis and the software, FRONTIER 4.1 [5]. The variance parameters of the stochastic production frontier are represented by one-sided generalized likelihood-ratio test by 27.448 in Labuhan Batu's model and 27.540 in deli Serdang's model; that are statistically different from zero. This implies that we reject the null hypothesis and obtain an alternative hypothesis, i.e., that there is inefficiency in production function.

As stated in Table 2, both in Labuhan Batu and Deli Serdang labor and number of trees have positive significant effect on rubber output; whereas fertilizer does not have any effect on rubber output. Labor, with an elasticity of 0.296 and 0.933 in Labuhan Batu and Deli Serdang, has a positive significant effect on rubber output. This elasticity value means that increasing labor by one percent would increase rubber output by 0.296 and 0.933. Labor elasticity in Deli Serdang is higher than in Labuhan Batu due to the fact that farmer spends more time to manage their rubber cultivation than in Labuhan Batu. Especially for tapping job, the most time consuming job, farmer in Deli Serdang spends 60 second/tree, longer than in Labuhan Batu, 40 second/tree.

The number of trees has a positive significant effect on rubber output both in Labuhan Batu and Deli Serdang by elasticity 0.596 and 0.514. This is due to the fact that the number of trees per hectare In Labuhan Batu is 423 trees/ha; this is less than in Deli Serdang, which has 615 trees/ha. According to the Indonesian Rubber Research Institute, the suitable number of trees per hectare is 500. It seems to make sense that output increase is proportional to the number of trees. In Deli Serdang case, the number of tree is denser that recommended one. This means that marginal production is getting lower.

Table 2 Maximum Likelihood Estimation of Cobb-Douglas Stochastic Frontier Production Function

Variable	Parameter	Coefficient (t-value)	
		Labuhan Batu	Deli Serdang
Stochastic frontier			
Intercept	b_0	1.365***(6.166)	0.235^{ns}(0.558)
Ln fertilizer	b_1	-0.009^{ns}(-0.229)	-0.034^{ns}(-0.889)
Ln labor	b_2	0.296***(8.558)	0.933***(3.199)
Ln number of tree	b_3	0.596***(4.939)	0.514***(4.131)
Inefficiency model			
Intercept	d_0	-0.229*(-0.776)	-0.049^{ns}(0.214)
Dummy clone	d_1	-0.131**(-1.838)	-0.094**(-1.709)
Ln rubber age	d_2	0.429***(2.184)	0.107^{ns}(1.043)
Dummy tapping share system	d_3	0.041^{ns}(0.915)	0.198**(1.614)
Dummy training	d_4	-0.159***(-3.374)	-0.154**(-1.970)
Dummy tapping job	d_5	-0.153***(-2.530)	-0.096***(-2.053)
Variance parameter			
Sigma squared	σ^2	3.331***	3.569***
Gamma	γ	0.193^{ns}	0.048^{ns}
Log likelihood ratio of the one-sided error		27.448***	27.540***
Number of observations		32	30

Source: Based on the household survey data

Notes: *** : Significant at 1%, ** : Significant at 5%, *: significant at 10%, ^{ns}: not significant

In the inefficiency model, an important part of this research, a positive direction on estimated parameter implies that the particular variable is negatively associated with efficiency and vice versa.

From the five independent variables, four variables are significantly associated with efficiency in the Deli Serdang's inefficiency in Labuhan Batu's efficiency model.

A dummy clone is positively associated with efficiency both in Labuhan Batu's and Deli Serdang's inefficiency model. This implies that certified clones such as PB260, GT1, PR 300, and BPM 24 can be more efficient than seedlings. Farmers who applied certified clones tend to maintain their plantation better than farmers who applied seedlings. In order to cultivate rubber by certified clone, farmers either spend much more money or spend more time. At the least, farmers spend IDR 4.000/piece to purchase a certified clone. These clones take six months to grow and family labor is needed in making the nursery. Furthermore, during the gestation period, these farmers have to maintain the plantation more frequently than farmers who applied seedlings. On the other hand, farmers who applied seedlings cultivated a denser number of trees than farmers who applied certified clones. Even though the number of trees via seedling cultivation is higher than the number of trees via certified clone cultivation, applying seedlings could not improve efficiency. This was resulted from the way of farmers cultivate rubber by seedling is the cultivation grows up from seed which is from previous cultivation. Ordinary, mature rubber trees produce ovules that fall on the ground and grow to become mature rubber trees. Because of this, rubber cultivation via seedling is irregular and denser. Also, farmer tend to not maintain well during gestation period, instead they comes when their rubber cultivations are ready to tap.

The rubber age is negatively associated with efficiency in Labuhan Batu's inefficiency model but not Deli Serdang's inefficiency model. This indicates that rubber farms tend to be inversely proportional to the age of rubber. As mentioned above, age of rubber cultivation in Labuhan Batu generally exceeds economic life. Interestingly, when rubber age is old, more than economic life, bark of rubber tree is getting hard and not much latex anymore. Also, age of cultivation is closely related to the number of trees/land area. The number of trees/land area decreases when cultivation becomes older due to diseases such as *rigidoporus lignosus* and *mouldy rot*. Actually, farmers in Labuhan Batu understand that old rubber cultivation could decrease rubber output. However, due to high replanting costs, plus farmers worry about the survival of trees during the gestation period, farmers have not replanted yet. In Deli Serdang, rubber age is not statistically associated with efficiency. This is due to the fact that the rubber age is still young, that is in economic lifa age.

Dummy tapping share system is negatively associated with efficiency in Deli Serdang's inefficiency model but not in Labuhan Batu's inefficiency model. In other words, farmers who do share their cultivation are efficient. It is difficult to understand due to, as we mentioned in descriptive statistic above, hired tapper tend to consume more bark in order to get more yield. But in Deli Serdang case, farmers who share their rubber cultivation to hired tapper hand over their rubber cultivation start from initial planting time. Hence, hired tapper has full responsibility to maintain the rubber tree and rubber cultivation as well. These hired tappers manage the shared rubber plantation like they manage on their own rubber plantation.

Furthermore, dummy training is positively associated with efficiency in Labuhan Batu's and Deli Serdang inefficiency model. Rubber farmers who work in rubber companies or farmers who ever engaged in the P3RSU project are more skillful than farmers who have not engaged in either. Conceivably, smallholder rubber farmers could learn cultivation management from the companies where they work. In turn, they apply their experiences to their plantation. In rubber companies and in the P3RSU project, farmers learn cultivation management such as how much fertilizer farmers should put in the tree on every stage, how to maintain the tree, how to do tapping correctly and so on.

Finally, tapping job is positively associated with efficiency both in Labuhan Batu's and Deli Serdang's inefficiency model. This means that farmers who correctly do the tapping procedures more efficiently than farmers who do not do tapping correctly. Right tapping includes doing tapping in the right slope, consuming the right bark thickness, and doing tapping at the right depth of the bark. When tapping correctly, latex flows into cup easily and regularly. Based on the in-depth interview, farmers tend to wrongly do the tapping when they are tired and when farm cultivation is more than merely an economic life.

3) Technical Efficiency of Smallholding Rubber Farmer

The technical efficiency of smallholding rubber farming was obtained from equation 2. The arithmetical average of technical efficiency achieved by smallholding rubber farmers are 0.846 and 0.874 in Labuhan Batu and Deli Serdang, respectively. This average is statistically significant from zero by t-test 1.390. This means that rubber farming in Deli Serdang is more efficient than in Labuhan Batu. This makes sense because in Deli Serdang farmers manage rubber cultivation better than in Labuhan Batu. Farmers whose efficiency is low are farmers who apply seedlings, are not engaged in any training, farmers who do wrong tapping and farmers whose rubber age are very old, Briefly, those farmers applied good agricultural practices to a lesser extent in their cultivation.

Training farmers spend more time to manage their cultivation than not training farmers. Managing rubber cultivation includes planting, maintaining and tapping job. Training farmers spend 2.70 hours/week/tree to manage their rubber cultivation whereas not training farmers spend 2.52 hours/week/tree. Furthermore, training farmers tend to do right tapping. In detail, time allowance for farmer who does right tapping is 55 second/tree, higher than mistaken tapping, 48 second/tree.

Farmers who have large land area do not have enough time to manage their plantation well. In Deli Serdang, representative large area, farmers spend 219day/ha/year to manage their cultivation, whereas in Labuhan Batu farmer spend 86day/hectare/year.

Especially for training, the appearance of field supervisor is necessary. In Labuhan Batu, especially in the P3RSU project the supervisor taught and monitored what farmer did in every stage starting from transplanting, putting fertilizer, maintaining the plantation and doing right tapping. After fifteen years since starting project, 1992, and farmers already returned the money they borrowed back to the project, the supervising activity was stopped. Somehow, farmers already understood how to manage their rubber cultivation well. In Deli Serdang, field supervisor, belong to rubber plantation company, regularly teach and controls what the employee's (farmer's) job such as transplanting, maintaining and tapping. Indirectly farmers could learn how to manage the cultivation well.

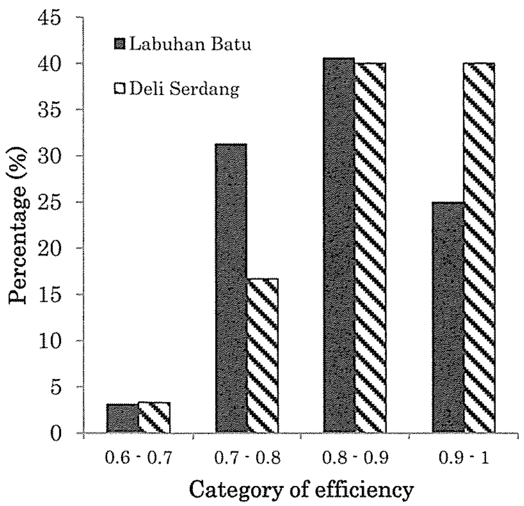

Figure 1. Frequency distribution of technical efficiency of smallholder rubber farmers in Indonesia
Source: Analysis results based on farm survey data, 2012

5. Conclusion and Policy Implications

This study dealt with the production efficiency of smallholding rubber farming in Indonesia. We conclude that certified clone, training farmer, and tapping job are positively associated with efficiency. In rubber area where the cultivation is very old the rubber cultivation is not efficient. Furthermore, tapping share system that the owner hand over their cultivation starting from initial planting is efficient. Hence, the average technical efficiency of smallholding rubber farmers are 0.846 and 0.874 in large area and small area, respectively, which means smallholder rubber farmer in Indonesia is still not efficient. Therefore there are 14.4% and 12.6% ample rooms to increase the efficiency.

These findings suggest that in order to achieve efficiency, applying certified clones, engaged in training and doing right tapping are recommendable. Because some farmers perceive that certified clones are expensive, they can make a nursery to produce certified clones by themselves.

Furthermore, farmer capabilities can be attained by engaging farmer in training either involving farmers in a replanting project, or having some experience from rubber companies. To support this suggestion, related government institution should supervise the farmers including planting job, maintaining job, and tapping job.

Since doing right tapping is positively associated to efficiency, it recommends to farmer to do right tapping by tapping carefully and patiently to keep the bark save and to maintain the tree can be tapped for long term. Do right tapping is also can be attained by engaging farmer in training.

Furthermore, for area where the cultivation is very old, replanting cultivation is urgently recommended. Replanting program as government did on 1977 can be applied as solution the replant the old rubber tree.

In smaller rubber area, tapping share system is negatively associated with efficiency, which means that sharing the rubber plantation to tapper worker is efficient. It happened when the owner share to skillful and responsible hired tapper. Furthermore this finding recommends to farmer who shares their cultivation to find skillful and responsible hired tapper.

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Mode of Matching Buyers and Sellers as a Determinant of Efficiency in Madagascar Rice Markets

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1. Introduction

Rice is the single most important staple food in Madagascar: it is produced, traded, and consumed in all the regions of the country. According to FAOSTAT [5], Malagasy rice production was stagnating in the 1990s at about 2.5 million tons per year, but it has been increasing since the year 2000, reaching 5 million tons by 2011. Between 2007 and 2011, for the first time in several decades, rice production, growing at a rate of 9% per year, outpaced the annual population growth rate of 3%. These production growth figures were recorded against a low growth rate trend of less than 1% per year from the 1980s until the early 2000s.

Current rice production should be sufficient to feed the population, assuming approximately 100 kg of milled rice is consumed per capita per year. Nevertheless, there appears to be strong seasonality in the consumer price of milled rice, causing rice to be imported every year to stabilize rising prices. This price volatility is a key indicator of an inefficient market, which negatively affects both farmers and consumers in many ways. For example, farmers do not have an incentive to produce more rice, as the high market price is not transmitted to them. Price volatility is also likely to impact the food security of consumer households, especially those that are sensitive to price rises. Therefore, it is important to address such inefficiencies and improve the rice markets in Madagascar.

Chahal and Gill [1] note prices as being related in the following manner in a market that operates efficiently: price in a particular region of a country should not exceed price in another region by more than the transportation cost; price at one point in time should not exceed the price level of a previous period by more than the cost of storage, plus normal profit; and the price of processed products should only exceed the price of unprocessed products by an amount equivalent to the cost of processing, plus normal profit. However, owing to data constraints, instead of the aforementioned indicators, this paper uses price volatility measured by the coefficient of variation of retail price as an indicator of inefficiency.

Weekly retail price data collected by the Observatory of Rice (a governmental agency in Madagascar) from January 2011 to December 2012 indicate a 40% price rise between June 2011 (when price was the lowest) and January 2012 (when price was the highest)[1)]. The data also reveal that the degree of price volatility varies across markets. The coefficient of variation of retail price varies within a range of 8% to 19% during the year 2011 across 31 major markets of the country. This demonstrates that some markets in Madagascar are more efficient than others, which raises the following question: what makes one market more efficient than another?

The literature indicates that rice markets in Madagascar are inefficient because of high transaction costs. Fafchamps *et al.* [2], [3], [4] note that the high transaction costs result from contract enforcement and the risk of thefts, and they observe that trader networks play an important role in reducing these costs. Miyake and Sakurai [6] underline the importance of transportation infrastructure in improving market efficiency. The present paper, on the other hand, focuses primarily on the mode of matching buyers and sellers as a source of inefficiency. First, the relationship between the mode of matching and the coefficient of variation of price is examined, and in instances where a significant relationship is detected, the mode of matching is considered a determinant factor of efficiency. Second, given its variability, we look at the determinants of mode of matching across various markets.

2. Data

The data used in this paper are based on the "Rice Trader Census," which covers all the major markets of Madagascar. The Census consists of cross-sectional data collected in September 2011 from 31 district capital cities out of 111 district capitals in Madagascar, including 22 region capital cities and 9 district capital cities in Diana, Sava, Sofia, and Boeny regions, located in the eastern and northern parts of the island.[2)] The district capitals have been included because of the significance of rice production and trading in these locations.

Four different types of surveys were conducted as part of the census: market, retailer, wholesaler, and inter-district trader. The market survey collected general information pertaining to the main rice market in each city.[3)] The retailer survey collected information from rice retailers/wholesalers in the main rice market.[4)] The wholesaler survey collected information from large wholesalers that were independently located outside the main rice market. The inter-district trader survey collected information from traders who purchased and trucked rice from rice producing districts and subsequently sold it to wholesalers and retailers directly from trucks parked near the main rice market.

One supervisor and three enumerators constituted a survey team. After arriving in an assigned city, the survey team was tasked with identifying the main rice market of the city, the location of rice retailer/wholesaler clusters in the market, the location of wholesalers outside the market, and the parking space for trucks from where inter-district traders sold rice. After identifying these elements, the team interviewed as many rice retailers, wholesalers, and inter-district traders as possible within a period of three days. As a result, we collected information from 1,142 retailers/wholesalers in the market and 102 wholesalers outside the market, across 31 cities. We also interviewed 54 inter-district traders from 23 different districts across 15 cities.

3. Results

1) Relationship between matching mode and coefficient of variation

a. Sources of rice supplied to retailers

The retailers were first questioned on the sources of their purchase for the past year. The result is represented in Table 1. For retailers, the major suppliers of rice were the wholesalers that are based in the same city, and 47% of the respondents reported to having purchased rice from such sellers in the past 12 months. Two other sources of supply were the farmers (42%) and inter-district traders (30%). For making rice purchases from farmers, retailers usually travelled to rural areas within the district or in neighboring districts on market days. In case of purchases from inter-district traders, retailers usually bought rice from trucks coming in from other districts, parked in the parking lot of the consumer market place. Retailers purchased milled rice from wholesalers and inter-district traders and often bought paddy from farmers.

Table 1: Source of rice purchases made by retailers in the past 12 months

	Observation	Frequency	Percentage
Purchases from wholesalers in the same city	1,142	532	47%
Purchases from farmers in rural areas	1,142	471	42%
Purchases from inter-district traders in the marketplace of the city	1,142	338	30%

Source: Authors' calculations based on Rice Trader Census in Madagascar (September 2011)
Note: Sum total of percentages exceeds 100 because each retailer had the option of purchasing from several sources

Figure 1 shows the change in rice suppliers over the past 12 months. During the lean months (December to March), the percentage of retailers who purchased from farmers in rural areas decreased significantly. However, the percentage of retailers who purchased from wholesalers and inter-district traders was stable throughout the year. This could be explained by the fact that fewer products were available in the rural areas during the lean months, as farmers ran out of stock. Moreover, only wholesalers in the cities who stocked rice and/or inter-district traders who purchased rice in rice-abundant districts had rice for sale.

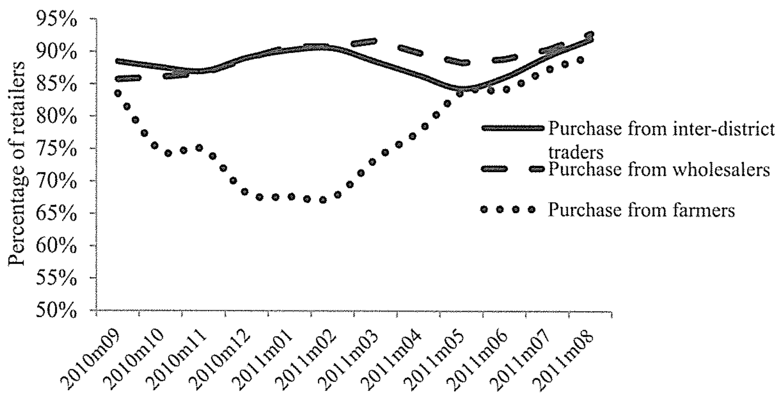

Figure 1: Rice Suppliers by month (Sep 2010 to Aug 2011)

Source: Authors' calculations based on Rice Trader Census in Madagascar (September 2011)

Note: The percentage is relative to the frequency given in Table 1: that is, 338, 532, and 471, respectively for "purchase from inter-district traders," "purchase from wholesalers," and "purchase from farmers."

b. Mode of matching buyers and sellers

Although some retailers depend on several sources for making rice purchases, as indicated in Table 1, the survey revealed that each market has a main source of rice supply, and hence, markets can be classified into three types as shown in Table 1. Moreover, the market type identified above largely determines how a retailer (i.e., buyer) finds a rice supplier (i.e., seller) or how a rice supplier finds a retailer. In other words, in terms of the mode of matching buyers and sellers in the retail market, a particular mode is dominant over other modes depending on the source of rice supply.

The first matching mode is "centralized matching." It is found in markets where the proportion of retailers purchasing from wholesalers in the city is high. In such markets, matching is centralized at a few core wholesalers, and foreign sellers such as inter-district traders and retailers could build a long-term relationship with the wholesalers. The next matching mode is called "random matching," taking place between retailers and inter-district traders at the parking space. In markets where random matching is dominant, retailers purchase rice from any random inter-district trader, rather than from fixed wholesalers. In most cases, intermediaries facilitate the matching of sellers and buyers since they are not known to each.[5)] "Spread matching" is the third mode. In markets where neither wholesalers nor inter-district traders are operating, retailers have to search for sellers (usually farmers) in neighboring rural villages. Spread matching derives its name from the wide area over which potential sellers are spread across in this case.

This paper advances the hypothesis that retail prices are more volatile in markets where spread matching is dominant, primarily as a result of market supply being dependent solely on neighboring rice-producing rural villages. In such cases, when the farmers run out of stock during the lean months, prices rise as a result of significant decrease in supply.

Figure 2 presents the result of the test of correlation between matching mode and coefficient of variation of retail price. We observe that the coefficient of variation decreases when the proportion of random matching increases and the coefficient of variation increases when the proportion of spread matching increases. There was no significant correlation in markets with a high proportion of centralized matching. This may be explained by the importance of markup or commission paid to wholesalers, data relating to which have not been captured through the survey.

We can conclude that markets with a high proportion of random matching have lower price volatility. This means that markets that attract traders from other districts have stable supply, resulting in stabilized prices. So the question is, why do only certain markets attract inter-district traders, or in other words, on what basis do inter-district traders select markets?

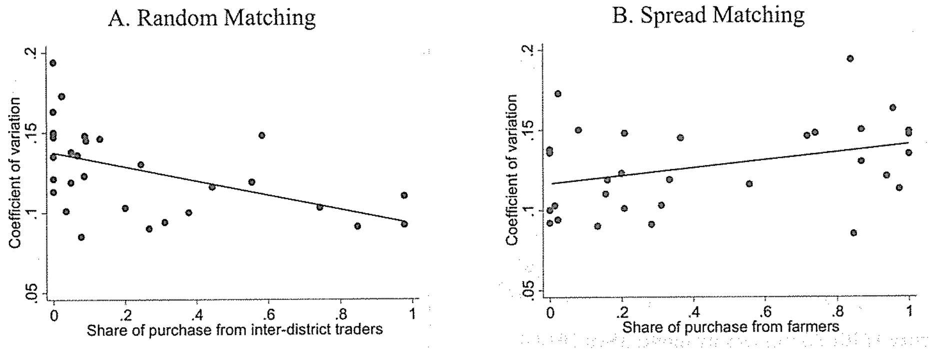

Figure 2: Correlation between matching mode and coefficient of variation of rice price
Source: Authors' calculations based on 2011 weekly price data from Madagascar Rice Observatory and 2011 Rice Trader Census in Madagascar.

2) Factors affecting market selection by inter-district traders

In order to develop "random matching" markets in Madagascar, it is essential to understand the behavior of inter-district traders. Since inter-district traders select a market (either known or unknown to them) to visit and sell rice to buyers (either known or unknown to them), information about the market and buyers is very important. Assuming that inter-district traders aim at maximizing their profit, our hypotheses concerning their behavior are (a) their decision depends on market price information; (b) they use intermediaries to reduce transaction costs; and (c) they use intermediaries to reduce risks, particularly those associated with credit transactions.

a. Use of price information

Comparing prices across markets in order to find the highest price is considered to be important for inter-district traders to maximize their profits. However, out of the respondents interviewed, only 50% checked the price in the market before visiting the market to sell rice, and only 20% checked prices in other markets when they select the market to visit. Figure 3 summarizes the reasons why some inter-district traders did not check the price. The main reasons cited for not checking the price in the market before visiting the market in are as follows: "I sell only in this market" (50%), "I know the price in this market from experience" (46%), and "There was no one to ask the price" (4%). A similar pattern of answering is replicated for not checking the price in other markets when they select the market to visit: "I sell only in this market" (62%), "I know the price from experience" (21%), and "There was no one to ask the price" (10%). It must be noted that all the inter-district traders had cellular phones and could have obtained price information with ease had they known anyone in the potential markets.

We asked the inter-district traders to provide two reasons for choosing the selling destination. The results are reported in Figure 4. For the first reason, 31% reported that they are "used to the market," followed by "good price/low transportation costs" (26%), "quick sales" (19%), and "have regular customers" (13%).

These were some of the second reasons cited: "used to this market" (26%), "have regular customers" (21%), "stable price" (19%), "quick sales" (15%), and "good price/low transportation cost" (6%).

Therefore, it can be observed that although price matters, for inter-district traders, their decision to choose a particular market does not primarily depend on this consideration. Rather, they invest more in searching and matching, since "being used to the market" would mean they have potentially greater chances of meeting reliable buyers. Their concerns about the risk of contract enforcement must also be noted. It may so happen that inter-district traders enter markets where credit transactions are considered to be the norm and consequently, buyers demand credit sales. Hence, "collecting payment quickly" becomes an important reason for choosing a market destination.

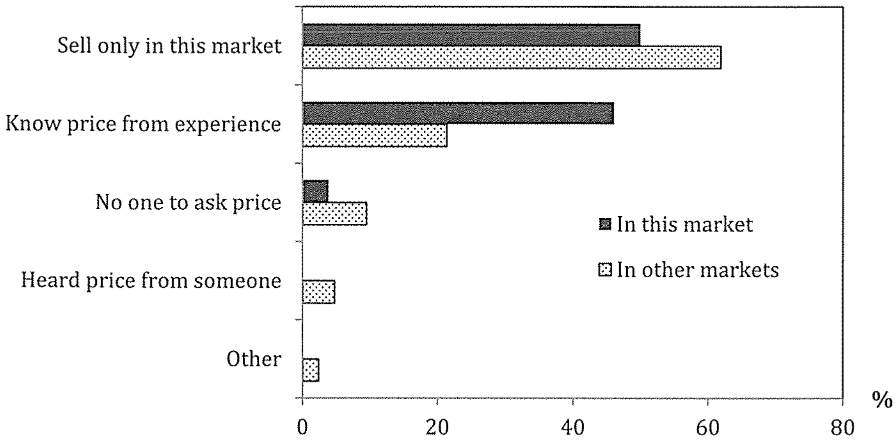

Figure 3: Reasons cited by inter-district traders for not checking the price in selecting market
Source: Authors' calculations based on Rice Trader Census in Madagascar (September 2011)
Note: "This market" refers to the market they were physically present in at the time of being interviewed, specifically, the parking area of the market.

b. Role of intermediaries in reducing transaction cost and contract risk

As we saw in the previous section, it is important for inter-district traders to identify buyers efficiently in their destination market. Sales by inter-district traders in the destination city can be made in a random matching manner in the market parking area or by direct sales to regular customers. Given that almost half of the respondents do not have regular customers who directly visit their truck, random-matching trade at the parking space is an important mode of sales. In such a market, the place for matching is highly concentrated, so the cost to search for trading partners is minimized. However, since trade might take place with new trading partners, there is a risk of contract enforcement.

We found that intermediaries played an important role in matching inter-district traders with retailers and in lowering the risk of contract enforcement. Figure 5 summarizes the role played by the intermediaries for inter-district traders. Since they are attached to a particular market and have been match-making for many years, they know most of retailers and wholesalers in the market and are able to do the jobs listed in Figure 5 for inter-district traders.

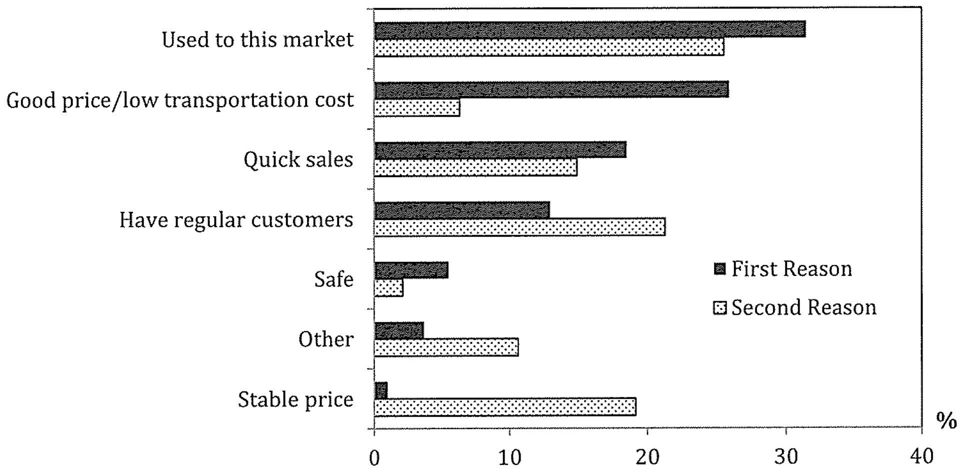

Figure 4: Reasons cited by inter-district traders for choosing their selling destination
Source: Authors' calculations based on Rice Trader Census in Madagascar (September 2011)

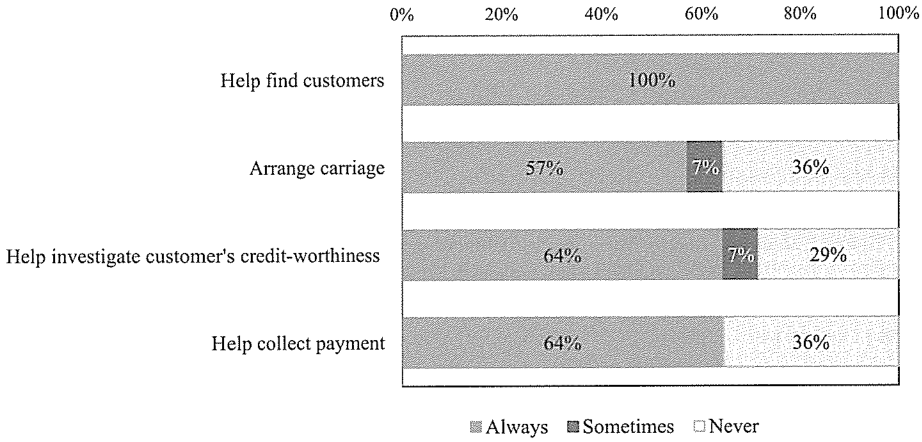

Figure 5: Roles intermediaries play for inter-district traders
Source: Authors' calculations based on Rice Trader Census in Madagascar (September 2011)

All traders reported that the intermediaries have always been helpful to them in finding customers, and 64% of the traders reported that intermediaries always helped in investigating the credit-worthiness of customers and in collecting payments. In addition, 57% said that intermediaries always helped arrange carriage, referring to the process of carrying bags of rice from trucks to retailer shops.

Figure 6 reports the impact of the intermediaries on credit sales. Credit sales are a common occurrence when trading with regular customers but not so common in case of non-regular customers: 82% of the respondents reported to sell on credit basis "always" or "sometimes" to regular customers, and the same figure dropped to 13% for non-regular customers that do not use an intermediary. On intermediary mediation, the percentage of traders who "always" or "sometimes" sold on credit to regular customers increased to 85%.

More significantly, the percentage of traders who "always" or "sometimes" sold on credit to non-regular customers rose to 57%.

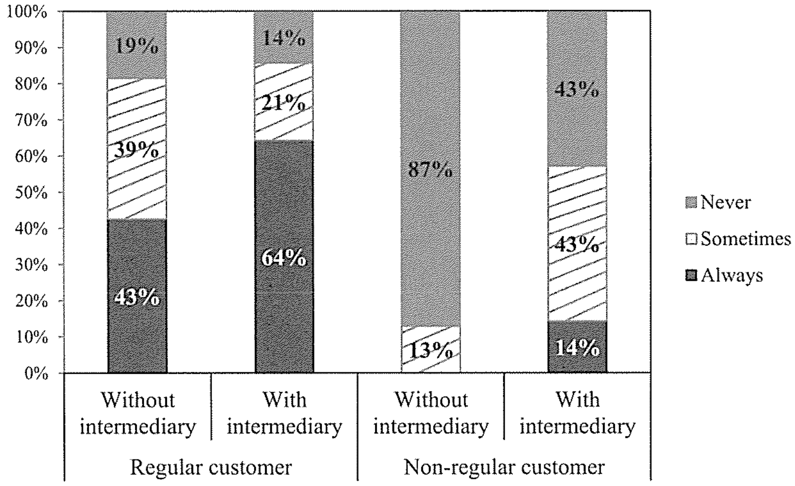

Figure 6: Possibility of sales on credit

Source: Authors' calculations based on Rice Trader Census in Madagascar (September 2011)

4. Conclusion

We identified three modes of matching sellers and buyers in rice markets in Madagascar: centralized matching, random matching, and spread matching. We further found that each market can be characterized by its dominant mode of matching and that the dominant matching mode affects rice price stability in the market.

Among the three modes of matching, random matching takes place in the parking area between inter-district traders (sellers) and retailers/wholesalers (buyers), often mediated by intermediaries. Our analysis indicates that the coefficient of variation of rice price is smaller in random-matching markets than in markets with other matching modes.

Inter-district traders are more sensitive to transaction costs, such as the cost for search and matching and cost of contract enforcement, than to rice prices. The majority of them visit only one market and do not check or compare prices in other markets as they tend to select such markets for sale where they have regular customers, since regular customers ensure reduced transaction costs. With respect to the mode of payment, in some markets, buyers always request for sales on credit, which may prohibit new outside sellers from entering such markets. Our survey reveals that in some markets, there are intermediaries between foreign sellers and local buyers, who assist sellers to find buyers, investigate their credit-worthiness, and collect payments. By offering these mediation facilities for a commission, intermediaries can help sellers visit an unfamiliar market. Even though intermediaries play an important role in making a market attractive for inter-district traders, not all markets have such intermediaries.

Random-matching concentrated in a parking space and mediated by intermediaries seems to be the most advanced form of wholesale market in Madagascar. At this moment, all of them have been informally developed, but we consider that it will be possible to establish regional wholesale markets that have functions similar to intermediaries such as matching sellers and buyers and facilitating credit transactions as a potential solution for improving market efficiency in Madagascar. In order to investigate the feasibility of establishing such markets, future studies on the determinants of informal market institutions and the analyses of market efficiency depending on the institutions will be necessary.

Notes

The surveys conducted as part of this study were mostly financed by the Japan International Cooperation Agency (JICA), which is now implementing the Project for Rice Productivity Improvement in Central Highland (PAPRiz) in Madagascar. Partial funding was provided by Hitotsubashi University.

1) In Madagascar, price is low during the harvest months, that is, April through August. Price is usually the lowest in May and June, and the highest in January and February.

2) This region is the highest administrative unit in Madagascar. There are 22 regions divided into 111 districts. Each region and district has a capital city. Please refer to the map in the Appendix.

3) The number of markets varies from 1 to 8 among the 31 cities, with an average of 2 per city. In each city, we selected only one market that is considered to be the "main rice market of the city" according to the commune staff, local INSTAT (National Institute of Statistics) staff, and rice traders.

4) At the time of interview, we did not distinguish between retailers and wholesalers because very often, a trader carried out both the functions.

5) As mentioned in the previous section, we interviewed 54 inter-district traders in 15 markets. It is difficult to identify markets that have no intermediaries, but our record shows that in 9 markets out of the 15, the inter-district traders we interviewed employed intermediaries and that the 9 markets tend to be larger than the other 6 markets: average number of inter-district traders is 5.1 and 1.3 respectively and the difference is statistically significant.

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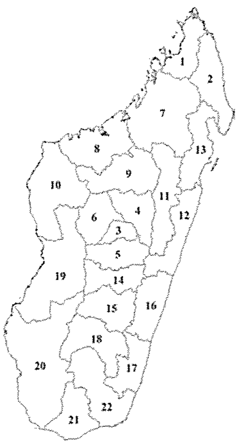
Appendix: Regions of Madagascar



Number	Region Name	Region Capital
1	Diana	Antsiranana
2	Sava	Sambava
3	Itasy	Miarinarivo
4	Analamanga	Antananarivo-Renivohitra
5	Vakinankaratra	Antsirabe I
6	Bongolava	Tsiroanomandidy
7	Sofia	Antsohihy
8	Boeny	Mahajanga I
9	Betsiboka	Maevatanana
10	Melaky	Maintirano
11	Alaotra-Mangoro	Ambatondrazaka
12	Atsinanana	Toamasina I
13	Analanjirofo	Fenerive Est
14	Amoron'i Mania	Ambositra
15	Haute Matsiatra	Fianarantsoa I
16	Vatovavy-	Manakara
17	Atsimo-Atsinanana	Farafangana
18	Ihorombe	Ihosy
19	Menabe	Morondava
20	Atsimo-Andrefana	Toliara I
21	Androy	Ambovombe Androy
22	Anosy	Taolagnaro

Note: In addition to the capital cities of 22 regions shown in the map, 9 district capitals from the regions of Diana, Sava, Sofia, and Boeny were included in the survey.

Agricultural Cooperatives' Contributions to Farming Practices in An Giang Province, Mekong Delta, Vietnam

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1. Introduction

1) Background

Vietnam's agricultural cooperatives (ACs), in general, and the Mekong Delta's agricultural cooperative, in particular, have been developing since 1958. However, these ACs have not significantly contributed to the national economy. The contribution of the collective economy[1] as the core AC to gross domestic product (GDP) has continuously decreased since 1996. For example, the contribution of the collective economy to GDP was 10.0% in 1996, 8.6% in 2000 and only 5.2% in 2010. In addition, the fact that fewer farmers have been enrolling in ACs also indicates the weakness of ACs. For example, in 2010, only 28.5% and 21.9% farmers in Vietnam and Mekong Delta, respectively, enrolled in ACs [1]

However, we found that ACs offer certain positive contributions to farming practices in An Giang province, Mekong Delta, Vietnam. Therefore, our major interest is in identifying ACs' positive contributions to farming practices and determining how to expand these. We also explore how ACs in An Giang province could be further developed in the future.

2) Definitions

Agricultural Cooperative: We define an agricultural cooperative as an organization of farmers similar to a Japan Agricultural Cooperative (JA)[2] but simpler and smaller.

Cooperative member or 'member': A farmer, who buys at least one share in ACs and receives dividends (share profits) from the cooperative at the end of year.

Non-member: A farmer who buys no share from an AC and receives no dividend but uses its services and pays service fees as a customer.

3) Objectives

This study attempts to

- Identify AC contributions to farming practices in An Giang province, Mekong Delta.
- Analyze reasons for different AC contributions between members and non-members and different farming practices before and after farmers receive AC services.
- Suggest actions for improving AC contributions to farming practices and methods for improving the AC in An Giang province, Mekong Delta, Vietnam.

2. Research Methodology

We used a case study of an AC in An Giang province to demonstrate the contributions of an AC to farming practices. The primary data were collected at seven ACs at five out of 11 districts in An Giang province. Table 1 reports the name of each

Table 1:Serveyed Agricultural Cooperative, Rating and Services

#	Name of AC	Rank of AC (2011)	No. of services	Irriga tion	Agr. training	Market info	Har vest	Good seed	Land prep	Fertilizer, pesticide	Cre dit	Oth ers
1	Phu Thanh	Excellent	9	1	1	1	1	1	1	1	1	1
2	Vinh Trach	Good	8	1	1	1	1	1	1	1	1	0
3	Long Binh	Good	8	1	1	1	1	1	1	1	0	1
4	Thanh Loi	Average	5	1	1	1	0	1	0	1	0	0
5	Hoa A	Average	5	1	1	1	1	1	0	0	0	0
6	Long Thanh	Weak	4	1	1	1	1	0	0	0	0	0
7	Hoa An	Weak	2	1	1	0	0	0	0	0	0	0
Provide service to		Members		yes	yes	yes	yes	yes	yes	yes	yes	yes
		Non-Members		yes	few	few	few	few	yes	few	no	no

Source: Field survey, Jan. 2012 *Note: 1 - Service; 0 - Non-service*

AC, their quality ratings as of 2011 and their services.

We selected 123 rice farmers by random sampling and surveyed using a questionnaire in seven ACs in An Giang (Table 1). Sixty-two of those interviewed were members of ACs, which we called Group A (GA), and the other 61 were non-members, called Group B (GB). Non-members had farmland in the same area as members and used some of the same AC services used by members.

P0 denotes the period before GA and GB began receiving AC services and PT indicates the period after GA and GB began receiving AC services. We measured the AC's contributions to farming practices by comparing PT and P0 services. The limited data did not contain P0 values for several indicators. Therefore, we measured those cooperative contribution indicators by comparing the difference between GA and GB. This method cannot exactly measure the contributions of only the AC to farming practices; however, a relatively accurate contribution amount and trend can be measured because ACs provide many priority services to members and discount their service fees for members.

Secondary data were collected from the reports of the Department of Agriculture and Rural Development (DARD) in An Giang province, the An Giang Cooperative Alliance and our previous studies.

3. Results

1) Descriptive statistics of research results

Table 2 reports the gap in farming characteristics, such as age, farming experience, educational level, and farm size, between members and non-members.

Table 2: Descriptive Statistics Characterictics of Group A and B

Farmers' background	*Age (year)*		*Experience (year)*		*Education (grade)*		*Agricultural land (ha)*		*Attend training courses (times)*	
	Mem	*N-mem*	*Mem*	*N-mem*	*Mem*	*N-mem*	*Mem*	*N-mem*	*Mem*	*N-mem*
Mean	*54*	*49*	*28*	*23*	*8.1*	*6.7*	*2.34*	*1.85*	*4.0*	*1.4*
Standard Error	*1.17*	*1.04*	*1.17*	*1.15*	*0.39*	*0.34*	*0.27*	*0.19*	*0.13*	*0.13*
Minimum	*34*	*32*	*6*	*5*	*1*	*1*	*0.2*	*0.2*	*2*	*0*
Maximum	*78*	*70*	*44*	*48*	*12*	*12*	*10*	*8*	*6*	*4*
Count	*62*	*61*	*62*	*61*	*62*	*61*	*62*	*61*	*62*	*61*
Confidence(95%)	*2.35*	*2.08*	*2.34*	*2.30*	*0.78*	*0.68*	*0.53*	*0.38*	*0.26*	*0.25*

Source: Field survey, Jan. 2012

As Table 1 reported, most ACs in the survey provides services to members and few provide services to both members and non-members. Figure 1 depicts the percentages of members and non-members using cooperative services among the 123 farmers sampled in the survey.

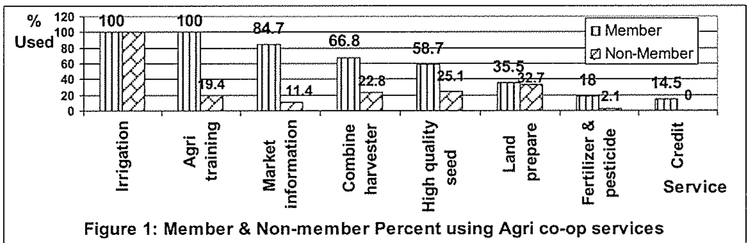

Figure 1: Member & Non-member Percent using Agri co-op services
Source: Field survey, Jan. 2012

The survey revealed that ACs charged members a discounted service price for using the irrigation service and gave other priority services to members. For example, the AC discounted the irrigation service fee by 5 - 15% for members compared with that of non-members. As a priority service, the cooperative provided high quality seed to members at a price lower than that provided by a private seed company. Most members and non-members need cooperative services such as combine harvesters, credit and pesticide. However, the AC provides insufficient services than that needed by members and non-members because it has only limited capital and capital assets.

2) Agricultural cooperative contributions to farming practices

An AC contributes to an increase in profit/ha. Table 3 reports that members have a 20.4% higher profit/ha than that of non-members. This result represents a ACs contribution because profit is calculated as P = R − PC , where P = profit/ha, R = total revenue/ha and PC = total production cost/ha [3]. Thus, if farmers want to increase P, they must increase R and reduce PC. In raw numbers, members earn 3,503 thousand VND, equivalent to 14,000 Yen, from the 20.4% profit/ha, which is higher than that of non-members. This is because members have higher revenue/ha and lower production cost/ha than non-members (Table 3).

Table 3: Profit/ha of Rice between Group A & B

Unit: 1,000VND/ha

	GA	GB
Total revenue (1)	42,505	41,796
Total production cost (2)	21,807	24,602
Net profit (3) = (1) - (2)	**20,698**	17,194
Difference profit GA - GB	3,503	
% profit higher/ha of GA	**20.4**	

Source: Field survey in Jan. 2012.
Note: 1,000 VND = 4 Yen
GA: member; GB: Non-member

ACs contribute to increased revenue/ha. Farmers' total revenue/ha increased because ACs contributed to the increase of selling price/kg of rice. Table 4 reports that members earned 709 thousand VND revenue/ha higher than did non-members, because members sold their rice at a 5% higher selling price than did non-members. The statistical analysis by regression analysis demonstrates a high coefficient between revenue/ha and yield/ha and revenue/ha and price sold/kg, significant at the 1% level (Table 5). The correlation between revenue and price sold/kg is stronger than that between revenue/ha and yield/ha. This result reveals that although members have yield/ha lower than that of non-members, members earn revenue/ha higher that of non-members.

Table 4: Differences in Yield, Selling Price & Revenue

	Yield	Selling price	Total Revenue
Unit	Kg/ha	VND/kg	1,000VND/ha
Member GA	**6,543**	**6,501**	**42,505**
Non-member GB	6,769	6,180	41,796
GA - GB	-226	321	709
Percent difference GA/GB	**-3.3**	**5.2**	

Source: Field survey in Jan. 2012

Table 5: Correlation of Revenue to Yield & to Selling Price/kg

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	-4483.7	516.25		-8.685	*
Yield	6.856	0.549	.679	12.500	*
Selling Price/kg	651	49.19	.719	13.240	*

Note: Dependent variable: Revenue; (*) Significant at the 1% level

ACs in An Giang have engaged in many activities to increase the selling price of product prior to members and certain non-members. Cooperatives provide high quality seed, hold many agricultural training courses, market members' products to rice export companies, provide market information to members and certain non-members, and perform other services. As a result, members' selling price is higher than that of non-members due to the use of high quality seed, more marketing information and higher opportunities to sell their products directly to rice export companies. These factors enable members to earn revenue/ higher ha than that of non-members.

ACs contributed to reducing production cost by reducing component cost because they provide service costs lower than those provided to individual farmers. For example, Table 6 reports that individual farmers paid 2,515 thousand VND/h[4] for irrigation cost in 2010 (P0). In 2011 (PT), ACs provided irrigation service cost lower than that provided to individual farmers. Cooperatives charged a service fee of 1,608 thousand VND/ha for non-members and 1,453 thousand VND for members, an average 9.6% discount. We compared irrigation costs during PT and P0, and found that members saved 42.2% and non-

Table 6: Irrigation Cost by Individual Farmers and by ACs Services

Irrigation cost: before AC service (P0) & after AC service (PT)	Unit	An Giang province GA	An Giang province GB	Vinh Trach AC GA	Vinh Trach AC GB
Cost by individual farmers in 2010* (P0)	1,000 VND/ha	2,515	2,515	2,461	2,461
Cost by AC in survey (PT)	1,000 VND/ha	1,453	1,608	1,710	1,800
AC's value contribution (PT - P0)	1,000 VND/ha	**-1,062**	**-907**	**-751**	**-661**
% of AC contribution & farmers' savings	%	-42.2	-36.1	-30.5	-26.9
Price discount for members	%	9.6		5.0	

Source:* DARD of AG report in 2011 & Field survey in Jan. 2012 members saved 36.1% on irrigation costs by using the AC service. The Vinh Trach AC in Table 6 also contributed to reducing irrigation cost. P0 was the period in which the Vinh Trach Cooperative did not provide an irrigation service. In 2009, farmers independently performed irrigation at a cost of 2,461 thousand VND/ha. PT began in 2011 when Vinh Trach provided irrigation service and charged a service fee of 1,800 thousand VND/ha for non-members and discounted 5% for members. We compared irrigation cost/ha during PT and P0, and found that the Vinh Trach Cooperative saved 30.5% irrigation cost for members and 26.9% for non-members. The cooperative could provide irrigation services at a low service fee because it used an electric pump station, whereas individuals had used diesel engines; the use of electrical power costs less than that of diesel. The cooperative also obtained a government subsidy for an irrigation system, and the government required that ACs charge a low service fee.

In addition, Table 7 reports the contribution measurements of ACs for reducing harvest costs. For the Phu Thanh AC farmers, the manual harvest cost was 4,890 thousand VND/ha in 2010 (P0). When the cooperative provided combine harvester service in 2011 (PT), harvest cost decreased to 2,275 thousand VND/ha for members who used its harvester machine of cooperative. We found that the Phu Thanh Cooperative saved 53.5% of the P0 period's manual harvest cost for members. For the Vinh Trach AC farmers, the manual harvest cost was 4,312 thousand VND/ha in 2010 (P0). When Vinh Trach provided combine harvest services to all members (PT) beginning in 2011, the 92% of the sampling's farmers who were non-members continued to harvest manually because there was no other combine harvester in the Vinh Trach area at that time. We found that members saved 46.3% of their previous (P0) harvest cost during the PT period by using the cooperative service's equipment. Non-members, who could not harvest mechanically, continued paying high harvest costs (Table 7, column GB). Thus, the Vinh Trach Cooperative reduced members' component and production costs.

Table 7: Harvest Cost/ha by Hand and by Combine Harvester

Cost/ha before AC service (P0) & after AC service (PT)	Unit	Phu Thanh Coop (a) GA	Phu Thanh Coop (a) GB	Vinh Trach Coop(b) GA	Vinh Trach Coop(b) GB
Cost hand-harvested rice (P0)	1,000 VND/ha	4,890	4,890	4,312	4,312
AC Cost for machine harvest (PT)	1,000 VND/ha	2,275	2,833	2,317	4,037
AC's value contribution (PT - P0)	1,000 VND/ha	-2,615	-2,057	-1,995	-275
% of AC contributions & farmers's savings	%	-53.5	-42.1	-46.3	-6.4

Source: DARD of AG report in 2010 and Field survey in Jan. 2012

Note: (a) GA & GB used machine; (b) GA used Agri coop machine but GB used hand

In other cases, ACs reduced components cost for both members and non-members. As Figure 1 depicts, our survey revealed that the percentages of members that used AC services are higher than those of non-members. Therefore, we assume that members used more AC services than did non-members and benefitted more from production cost reduction than did non-members. Table 8 reports that members incurred production costs 2,794 thousand VND/ha (equivalent to 11,000 Yen) lower than those of non-members. Members also obtain many components at prices lower than those for non-members. We found several reasons for members having lower component and production costs. Members have an average harvest cost that is 30.2% lower than that for non-members because 66.8% of members harvested rice using the AC's combine harvester service compared to 22.8% of non-members who harvest mechanically, using the cooperative's and other providers' services. Our previous study[5] demonstrated that mechanically harvesting rice is 50.4% of the cost of manual harvesting. Therefore, the AC combine harvester service reduced

Table 8: Components of Cost & Production Cost/ha of Rice for Member & Non-member Unit: 1,000 VND/ha

Components cost	Harvest	Land prep	Pesticide	Irrigation	Seed	Fertilizer	Herbicide	Take care	Labor rent	Management	Farm tools	Production cost
Member GA	23,070	14,905	50,062	14,531	14,665	59,917	3,952	8,990	13,471	9,753	4,757	21,807
Non-member GB	33,062	17,935	56,214	16,082	16,079	64,771	3,885	8,896	13,563	10,558	4,973	24,602
Value cost GA - GB	-9,992	-3,030	-6,151	-1,551	-1,414	-4,854	66	94	-92	-805	-216	-2,794
% lower cost GA/GB	-30.2	-16.9	-10.9	-9.6	-8.8	-7.5	1.7	1.1	-0.7	-7.6	-4.3	

Source: Field survey in Jan. 2012 *Note: 1,000 VND = 4 Yen* production costs for members. Further, members have an irrigation cost lower than that incurred by non-members because the AC discounts its irrigation service fee for members at an average of 9.6% of non-member fee.

Members obtained additional components at costs lower than those incurred by non-members because many national subsidy programs apply through the AC, which then provides prior those opportunities to members. For example, the government distributes special discount price tickets to ACs for buying high quality seed. National extension courses, other agricultural courses and the new model '1 Must Do and 5 Reductions'[6] are organized by ACs. Therefore, ACs have contributed to reducing total production costs by reducing components costs (Table 8).

3) Contribution of agricultural cooperatives in improving farming practices

ACs have contributed to improving farming practices such as using a seeding machine, high quality seed, new technology, less fertilizer and pesticide, environment protection measures and water conservation. Cooperatives have also improved levels of farming practices for PT over those in P0; this has been done for more members than for non-members.

Cooperatives change farmers' habits by using the seeding machine. Figure 2 depicts that in 2007 (P0) 78.3% of farmers in An Giang province manually sowed compared the 11.2% of those who used a seeding machine. In 2009, cooperatives began providing free seeding machines to members because the government wanted to encourage farmers to use them. In the same year, the government provided five free seeding machines and subsidized 50% of the cost for another five for each AC. The cooperatives also organized many landless farmer groups and provided them the seeding machine sowing service. Members borrowed seeding machines from the AC and sowed their own fields or hired landless farmer groups through the ACs. Figure 2 depicts the result: The percentage of member (GA) using seeding machines to sow increased from 11.2% in 2007 to 58.1% in 2011, and 24.6% of non-members (GB) sowed using seeding machines in PT, whereas only 11.2% did so during P0.

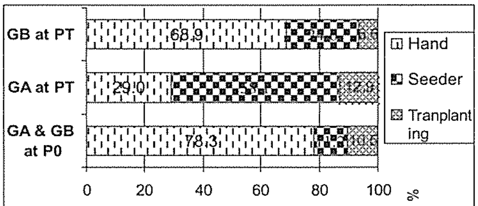

Figure 2: Sowing Method at P0(2007) & PT(2011)
Source: Field survey in Jan. 2012 & DARD in AG 2007

Our survey revealed that 72.6% of members applied the '1 Must Do, 5 Reductions' model, whereas only 32.8% of non-members did so. This is because if members registered to apply the model, they obtained 30 kg of high quality seed free from a government project for ACs' and the AC would provide the necessary training and guidance upon applying the model. Therefore, ACs help members follow the model's guidance and members derived greater advantages, as shown in the 2009 IRRI report[7].

ACs increased the percentage of members using certified seed because certified seed has high insect and disease resistance and low fertilizer demand and produces a high quality product, which is easier to sell at a higher price[8]. Figure 3 depicts the results that members (GA) used 54.8% normal seed, 40.3% certified seed and 4.8% registered seed in 2009[9] (P0). By contrast, in 2011 (PT), members (GA) used 12.9% normal seed, 66.1% certified seed and 21% registered seed. When we compared PT and P0, we found that members (GA) used less normal seed and more high quality seed, including certified and registered seed, in the PT period.

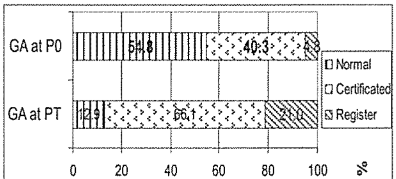

Figure 3: Seed Level Used at P0(2009) & PT
Source: Field survey in Jan. 2012 & DARD in AG 2009

ACs improve farmers' farming skills through organizing agricultural training courses. Figure 4 demonstrates members attended an agricultural training course more than non-members. Thus, members learned more than non-members about using fertilizers, pesticides and farming tools and improving living conditions. The higher member attendance was for several reasons. Members were aware of the benefit of training courses and state government policy. Vietnam's government encourages more farmers to enrol in ACs. Thus, the government provides extension programs, farmer training and agricultural training and subsidizes projects for farmers through AC organizations. In addition, members receive priority seating in government programs.

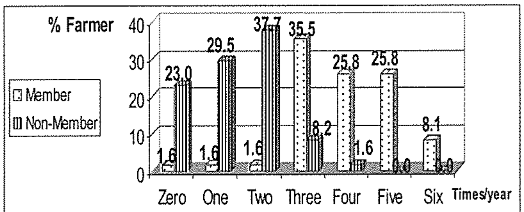

Figure 4: Times Attending Agricultural Training Courses/Year
Source: Field survey in Jan. 2012

We assume that if members attend agricultural training courses, they reduce their fertilizer and pesticide cost. Table 9 reports our correlation test between the independent variable - fertilizer and pesticide cost - and the dependent variable - attending training (dummy variable: member attend = 1, member does not attend = 0). The statistical result reveals that only pesticide cost reduction significantly correlates with attending training at the 10% level, whereas fertilizer cost reduction positively correlates, but not significantly, with attending training. We found reasons for fertilizer not significantly correlating with training. First, the fertilizer market has not been monopolized by state-owned companies since 2011, but instead has competition among state-owned, private and foreign investment companies. Many foreigner fertilizer companies produce 'special fertilizer packed with application guide' for rice and guide farmers in how to use the fertilizer. Farmers easily follow these instructions and have many choices among fertilizers. Second, in contrast, pesticide products rapidly change because many insects and diseases develop resistance to pesticides; therefore, farmers need updated information for pesticide use, which the courses provide.

Table 9: Correlation between Fertilizer/Pesticide cost & Training

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	1.5	0.355		4.295	
Fertilizer	0.000	0.001	-0.073	-0.768	Ns
Pesticide	-0.001	0.000	-0.181	-1.890	***

Note: Dependent variable: Attend training code =1
*** significant level at the 10% level; Ns: Non-significant

In short, ACs increased profit, total revenue and the effectiveness of farming practices, and reduced total production cost per hectare of rice. Cooperatives also offered more services to members than to non-members. Hence, ACs' improvement of farming practices is more effective for members than non-members.

4) Reasons for the low proportion of farmers' enrolment in agricultural cooperatives

To date, many South Vietnam farmers have been afraid of the term 'agricultural cooperative' because the government used to expand the 'old agricultural cooperative'[10] from North to South during 1975 - 1986. At that moment, the government collected the land, capital assets and property of individual farmers in the South and added it to the local AC, and then equally distributed the profits to each farmer. However, the old AC in Vietnam largely collapsed and could not conduct activities. Thus, all the farmers' capital was not returned to them when Vietnam became a market-oriented economy in 1986. In 1996, the government introduced the New Agricultural Cooperative model, following the International Cooperative Alliance (ICA) model.

Furthermore, the ACs model has not been attractive to farmers. In An Giang province, 24.7% of farmers had enrolled in ACs in 2010. The percentage of farmer enrolment in ACs in

An Giang province is higher than the 21.9% in the Mekong Delta but lower than the nationwide rate of 28.1%. This percentage of farmers in ACs is far lower than that of JAs in Japan, in which almost 100% of Japanese farmer have enrolled.

Figure 5 presents the reasons for which farmers join in ACs: they recognize the benefits and advantages (27.3%), cooperative members and the local government have campaigned for an AC (18.6%), the AC has been a good place for gaining and sharing farming practices (17.4%), ACs provide a cheap service price (14.9%), farmers' farmland in cooperative service area (9.9%) and other reasons. We found that farmers' primary reason for enrolment is their awareness of ACs' profit, benefits and contributions. In contrast, Figure 6 presents the reasons for which farmers do not join in ACs: they do not recognize the benefits and advantages (28.4%), membership takes too much time in terms of meetings and training (24.2%), farmers received no invitation or campaign from cooperative members and the local government (22.1%), ACs provide a not cheap service price (10.5%), ACs do not allow farmers to join to AC (8.4%) and various other reasons.

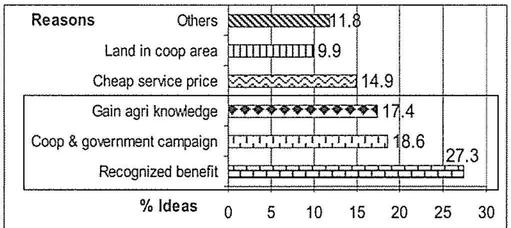

Figure 5: Reasons for Joining Cooperatives
Source: Field survey in Jan. 2012

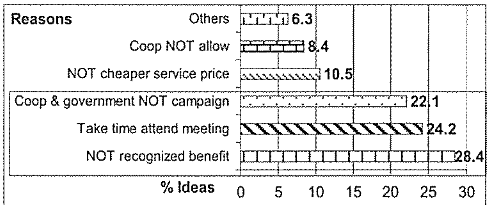

Figure 6: Reasons for NOT Joining Cooperatives
Source: Field survey in Jan. 2012

Moreover, ACs have only a limited capacity in capital, human resources, property and tools. Cooperatives provide services lesser than those required by members and non-members. As Figure 1 reports, cooperatives' highest priority is services for members.

5) Suggestions to increase agricultural cooperative contributions to farming practices

To expand the contributions and development of ACs in An Giang province, Mekong Delta, in the future, we suggest the following actions. (i) Improve ACs' capacity for expanding the scale of services and activities for farmers by increasing capital, property, tools and member numbers. (ii) Increase the number and types of services that ACs offer. Table 10 reports farmers' ideas about most-needed AC services. However, our opinions are that ACs should expand the combine harvester service in the short term, rather than the fertilizer and pesticide service because the markets for them have not been monopolized by state-owned companies since 2011. The market is very competitive among state-owned companies, private companies and foreign investment companies, and farmers will benefit more from that competition without any further intervention by the cooperatives. ACs should provide services for market information and marketing and provide services for improving farmers' lives in the long run. This is because such services are new in Vietnam and no ACs have yet provided them. (iii) Increase the percentage of farmer enrolment in ACs through various activities, such as offering membership to non-members and advertising the benefits of membership and the cooperatives' contributions to farming practices to non-members. (iv) Provide more inexpensive and useful services in response to farmers' needs reported in Table 10, maintain current agricultural services (Figure 1) and develop new non-agricultural services, such as those for market information and marketing, and farmers' overall lives. (v) The local government and cooperative board management members should improve the quality of training courses vi) Local government

Table 10: Services ACs Should Perform

#	The most necessary service	% Ideas	# Ideas
1	Fertilizer& pesticide supply	**23.6**	29
2	Harvest by combine harvester	**16.3**	20
3	Market & marketing	**16.3**	20
4	Service for improving life	**15.4**	19
5	Seed provision	**13.0**	16
6	Credit for member	**10.6**	13
7	Land preparation	**4.9**	6
	Source: Field survey in Jan. 2012	**100**	123

Note: Q "What is the most necessary service from AC?"

should support and assist in management to many small-scale ACs in communities during the merge process and create infrastructures for providing services.

4. Conclusion

Agricultural cooperatives have contributed to the improvement of farming practices in An Giang province for both members and non-members. The contribution of ACs to farming practices widely differs between P0, when the AC did not give services, and PT, when it provided services. Moreover, ACs' contributions have greater effects on the members than the non-members because the former have more opportunities to use cooperative services than do non-members. Members use a greater variety of services from ACs than do non-members. Hence, contributions of ACs to farming practices have more significant effects on members than on non-members.

The most significant contribution of ACs to farming practices is the reduction of farmers' component and production costs, thus increasing profit/ha. This advantage is the farmers' main reasons for enrolling in an AC. Members also increase their profit/ha to a greater degree than do non-members because the AC provides more services to members.

The greater the number of services and the greater scale of services ACs perform, the greater their positive contributions to farming practices. Therefore, cooperative management members, government and farmers must increase the capacity of ACs by improving the amount of share capital, business capital, property, tools, infrastructure and members.

Notes

[1] Five economic sectors in Vietnam[1]: The state-ownee, collective economy (including cooperative and farmer group), individual economic (no state share holder), private economic (household business) and FDI.

[2] Daman [5], 2000, JA is good example of Integrated framework in the service of the farmers. They delivery multipurpose services and operate as multi-function economic institution directly responding to felt need of the members. They serve the members at the same time being under the control of members, p4.

[3] Production cost includes land preparation, irrigation, seed, fertilizer, pesticide, labor rent, farm tool & family cost.

[4] DARD in AG report in 2011, individual farmers had used diesel engines for pumping water over 60% rice area in the province and It cost average 2,515 thousand VND/ha.

[5] Tran Minh Hai,& Iwamoto Izumi, agricultural cooperatives provided combine harvester service and charged 50.4% service fee compare with that of individual farmers' manual harvest cost.

[6] Model "1 Must Do and 5 Reductions": 1 must use certified seed and 5 Reductions for reducing seed rate, fertilizer use, pesticide use, water use, and postharvest losses.

[7] The study of IRRI in 2009 reported that the yield of farmers who applied "1 must Do, 5 Reductions" was 0.2 to 0.4 tonne per hectare higher than other farmers, whose yield was average 5.3 tonnes per hectare. Farmers' profit increased by US$208 equivalent to 15,600 Yen/ha, if farmers applied the model "1 Must Do, 5 Reductions".

[8] Thanh[4], a good quality seed needs a high care technique and do not have very high yield but a good quality seed benefits to farmers because high quality seed has high insect and disease resistance and low fertilizer demand and produces high quality product, which is easier to sell at a higher price.

[9] DARD, An Giang in 2009, Famer in An Giang province used 54.8% normal seed, which farmers exchanged among farmers in village, 40.3% certified seed and 4.8% registered seed.

[10] Period 1959 -1996[3], the cooperatives (old cooperative) were formed of collective assets, lands, labors and equal distribution. Every farmer had to enroll & worked together to cooperatives in government plan.

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Market Power of the Japanese Soybean Import Market: GMO, Non-GMO, and Vertically Differentiated Products

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1. Introduction

Since 1996, most countries consume genetically modified (GM) soybeans used in soybean oil and soybean meal for livestock and direct human consumption. However, Japan consumes non-genetically modified (non-GM) soybeans for direct food consumption since new rules for GM labeling came into Japan in 2001. Therefore, Japan has a unique soybean importing market where they import non-GM soybeans for direct human consumption and GM soybeans for soybean oil and soybean meal. Japan imports more than 1$ billion worth of GM and non-GM soybeans from the U.S. annually. In terms of U.S. dollar value, Japan is the third-largest importing country of GM and non-GM soybeans and the second-largest soybean importing country. The U.S. share of both GM and non-GM soybeans in Japan stands at approximately eighty percent (Yamaura [6]; Yamaura [7]).

To analyze the soybean import market in Japan, we first analyze GM and non-GM soybeans separately since GM and non-GM soybeans have different prices and are treated like different crops in Japan. Then we include the interaction of vertically differentiated products, a subject that has been largely ignored in previous studies, to analyze the market power of exporters and importers in the world markets of agricultural commodities. GM and non-GM soybeans are vertically differentiated products in the sense that GM soybeans are largely defined as an inferior substitute to non-GM soybeans.

The aim of the present paper is to analyze market power for imported GM and non-GM soybeans in the Japanese soybean market by estimating price elasticities. First, we compare market power in the imported non-GM soybean market since most consumers prefer non-GMO soy products. Second, we estimate GM soybean mainly consumed as soy-meal or soy-oil. Finally, we consider GM soybeans as a vertically differentiated product in the non-GM soybean trade.

2. Models

Baker and Bresnahan [2] originally developed the residual demand elasticity (RDE) model to measure the market power of a single firm in an imperfectly competitive market. Goldberg and Knetter [4] measured the market power of German beer exporters and U.S. linerboard exporters in specific destination markets based on the RDE model. They estimated residual demand elasticities to derive measurements of the market power of German beer exporters and U.S. linerboard exporters in each destination country without firm-specific data. Based on a theoretical model for the general case of exporter i in a single destination, Goldberg and Knetter obtained an export price function as:

$$P^{ex} = D^{res,ex}(Q^{ex}, \boldsymbol{W}^N, \boldsymbol{Z}, \theta^N),$$

where P^{ex} is the export price, $D^{res,ex}(.)$ is the inverse residual demand curve, Q^{ex} is the quantity of exported good, $\boldsymbol{W}^N$ is a vector of all firm-specific cost shifters excluding the exporter group of interest, $\boldsymbol{Z}$ is the vector of demand shifters in the destination market, and θ^N is the union of all the conduct parameters (Goldberg and Knetter [4]).

We adopt and extend Goldberg and Knetter (GK)'s approach to examine market power in international soybean markets. The analysis includes three models: RDE and residual supply elasticity (RSE) models for non-GM soybeans, GM soybeans and non-GM soybeans with GM soybeans. Yamaura [9] introduces vertically differentiated products in RDE and RSE models. Theoretically, GK's RDE model is built by the inverse demand functions faced by a specific exporting country and its competitors in other countries. A RDE model with vertically differentiated products is built by three inverse demand functions: a specific exporting country, its competitors in other countries, and a vertically differentiated product in a specific country. For calculating the profit maximization problem for a specific exporting country, we obtain an additional vector of cost shifter, vertically differentiated products from source country, in an export price function (Yamaura [9]). Therefore, an empirical RDE model contains a GM soybean export price as a vertically differentiated product[1].

Following Goldberg and Knetter [4], we use a logarithm functional form in the empirical specification so that it is straightforward to express elasticities in simple forms of model parameters. Three versions of the RDE and RSE models are specified as:

$$Non-GM\ Soybean\ Trade \begin{cases} RDE: lnP^{ex} = \alpha_0 + \alpha_1 lnQ^{ex} + \boldsymbol{\Gamma} ln\boldsymbol{Z} + \boldsymbol{\Phi} ln\boldsymbol{W}^N + \epsilon^{ex} \\ RSE: lnP^{im} = \beta_0 + \beta_1 lnQ^{im} + \boldsymbol{\Upsilon} ln\boldsymbol{H} + \boldsymbol{\Psi} ln\boldsymbol{R}^L + \epsilon^{im}, \end{cases}$$

$$GM\ Soybean\ Trade \begin{cases} RDE: lnP^{GM,US} = \alpha_0 + \alpha_1 lnQ^{GM,ex} + \boldsymbol{\Gamma} ln\boldsymbol{Z} + \boldsymbol{\Phi} ln\boldsymbol{W}^{GM,N} + \epsilon^{ex} \\ RSE: lnP^{GM,JP} = \beta_0 + \beta_1 lnQ^{GM,im} + \boldsymbol{\Upsilon} ln\boldsymbol{H} + \boldsymbol{\Psi} ln\boldsymbol{R}^L + \epsilon^{im} \end{cases} \quad and$$

$$\begin{matrix} Non-GM\ Soybean\ Trade \\ with\ GM\ soybeans \end{matrix} \begin{cases} RDE: lnP^{ex} = \alpha_0 + \alpha_1 lnQ^{ex} + \alpha_2 lnP^{GM,US} + \boldsymbol{\Gamma} ln\boldsymbol{Z} + \boldsymbol{\Phi} ln\boldsymbol{W}^N + \epsilon^{ex} \\ RSE: lnP^{im} = \beta_0 + \beta_1 lnQ^{im} + \beta_2 lnP^{GM,JP} + \boldsymbol{\Upsilon} ln\boldsymbol{H} + \boldsymbol{\Psi} ln\boldsymbol{R}^L + \epsilon^{im}. \end{cases}$$

where P^{ex}, $P^{GM,US}$, P^{im} and $P^{GM,JP}$ are the U.S. non-GM soybean export price to Japan, the U.S. GM soybean export price to Japan, the Japanese non-GM soybean import price from the U.S., and the Japanese GM soybean import price from the U.S., respectively. $Q^{ex}$and Q^{im} are the U.S. non-GM soybean export and import quantity to Japan, and $Q^{GM,ex}$ and $Q^{GM,im}$ are the U.S. GM soybean export and import quantity to Japan. $\boldsymbol{Z}$ is a vector of demand shifters of the Japanese market such as Japanese real income and a time trend, $\boldsymbol{W}^{N\ (GM,N)}$ is a vector of the cost shifters for n competing non-GM (GM) soybean exporting countries including exchange rates between Japan and other non-GM (GM) soybean exporting countries: Canada and China (Argentina and Brazil), and ϵ^{ex} is the error term. $\boldsymbol{H}$ is a vector of supply shifters in the U.S.: energy price, labor cost, soybean-corn price ratio futures prices and a time trend, $\boldsymbol{R}^L$ is a vector of the cost shifters for L competing non-GM (GM) soybean importing countries which includes the exchange rates between the U.S. and other non-GM (GM) soybean importing countries: the EU, China, and South Korea, and ϵ^{im} is the error term.

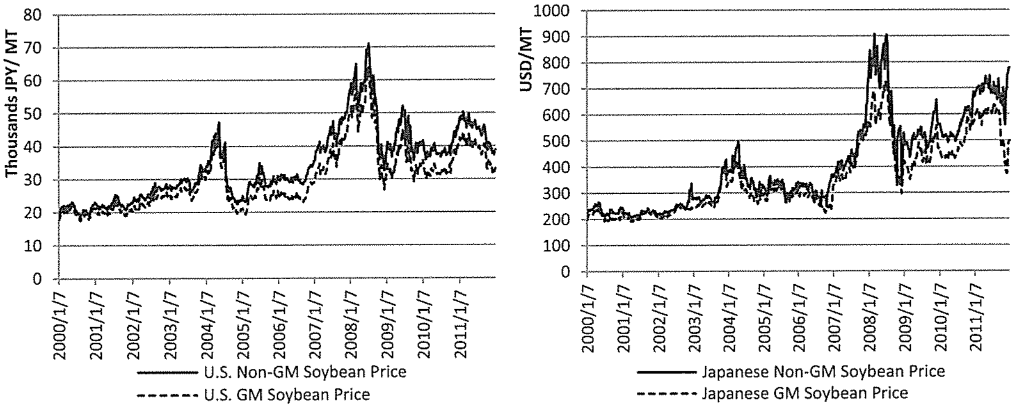

Figure 1. Non-GM and GM Soybean Prices in U.S. (left) and Japan (right) from Jan. 2000 to Jan. 2012
Source: Yamaura [9].

3. Data

Weekly data from January 2000 to January 2012 are used in the estimation. The weekly export price data for U.S. GM soybeans were obtained from Chicago Board of Trade (CBOT). The weekly export price data for U.S. non-GM soybeans[2)] were obtained from Yamaura [9]. The weekly price and quantity[3)] of Japanese non-GM soybean imports and the weekly price of Japanese GM soybean imports from the U.S. were obtained from Tokyo Grain Exchange[4)] (TGE). Those data are illustrated in Figure 1[5)].

4. Results

We estimate the RDE and RSE models with OLS and 2SLS[6)], respectively. The Hausman-Wu test results reject the null hypothesis of the exogeneity of the quantity variable at the 1% significance level. Thus, the 2SLS method is preferred. We focus on the results from the 2SLS estimation. For $Q^{ex(GM,ex)}$ in the RDE model, the instruments we use are the supply shifters in the U.S. and the exchange rates between the U.S. and other non-GM (GM) soybean importing countries. Similarly, for $Q^{im(GM,im)}$ in the RSE model, the instruments we use are the demand shifters of the Japanese market and the exchange rates between Japan and the other non-GM (GM) soybean exporting countries. The Durbin-Watson statistic in the 2SLS and the White robust standard errors are used and reported.

Table 1. Selected Estimated Results (2SLS) of the U.S. RDE Model and Japanese RSE Model (N = 626)

	Non-GM Soybean Trade		GM Soybean Trade		Non-GM Soybean Trade with GM Soybeans	
	RDE eq.	RSE eq.	RDE eq.	RSE eq.	RDE eq.	RSE eq.
$lnQ^{NGM,ex}$	-0.5268***				-0.3076***	
	(0.1640)				(0.1119)	
$lnQ^{GM,ex}$			-0.0917***			
			(0.0142)			
$lnP^{GM,US}$					0.7359***	
					(0.0759)	
$lnQ^{NGM,im}$		0.2084**				0.0612*
		(0.0869)				(0.0304)
$lnQ^{GM,im}$				-0.0483		
				(0.1140)		
$lnP^{GM,JP}$						0.9652***
						(0.0260)
$Adjusted\ R^2$	0.9602	0.9608	0.9531	0.9716	0.9577	0.9925
DW	2.1631	2.0265	2.0309	2.2294	2.1904	2.1387
$Hausman-Wu$	9.79***	12.21***	10.69***	15.77***	16.53***	23.78***

Note:
1) RDE model: Dependent variables are price of U.S. Non-GM (GM) soybean exports (in Japanese Yen).
2) RSE model: Dependent variables are price of Japanese Non-GM (GM) soybean imports (in U.S. Dollar).
3) *, **, and *** indicate coefficient estimates are statistically significant at the 10%, 5% and 1% level, respectively.
4) The values in the parenthesis are White robust standard errors.
5) The results for the other variables are available from the author upon request.

1) Non-GM Soybean Trade

The coefficient estimates of the two quantity variables in the 2SLS estimation show that the U.S. non-GM soybean exporters' market margin is 52.7%, and the Japanese non-GM soybean importers' market margin (adjusted Lerner Index[7)]) is equal to 0.208/(1+0.208) = 17.2%. These results are mostly comparable to the estimates of market margins in previous studies. For example, though the data and independent variables differ from those of this study, Andersen et al. [1] showed that Norwegian exporters had a market margin 1.7 times larger than that of Portuguese importers. Yamaura [8] showed that U.S. non-GM soybean exporters had a market margin five times larger than that of Japanese importers. However, we need to keep in mind that these estimated market margins of the traditional approach may not be accurate, because the interaction between non-GM and GM soybeans is not taken into account.

2) GM Soybean Trade

The coefficient estimate of the quantity variable in the RDE equation shows that the U.S. non-GM soybean exporters' market margin is 9.2% while the coefficient estimate of the quantity variable in the RSE equation is insignificant so that the profit margin of the Japanese GM soybean importers is zero.

3) Non-GM Soybean Trade with a Vertically Differentiated Product

In the 2SLS estimation, the coefficient estimate (-0.3076) of the quantity variable in the RDE equation implies that the U.S. non-GM soybean exporters' market margin is 30.8%. Thus, the inclusion of the interaction between non-GM and GM soybeans has greatly reduced the estimate of U.S. non-GM soybean exporters' market margin from 52.7% to 30.8%. In addition, the coefficient estimate (0.0612) of the quantity variable in the RSE equation shows that the Japanese non-GM soybean importers' market margin (adjusted Lerner Index) is 0.0612/(1+0.0612)=5.8%. Thus, the estimate of importers' market margin has also been reduced from 17.2% to 5.8% when the interaction between non-GM and GM soybeans is included in the estimation. The coefficient estimate (0.7359) of the U.S. GM soybean price in the RDE equation has the expected positive sign and is significant at the 1% level. In the RSE equation, the coefficient estimate (0.9652) of the Japanese GM soybean price also has the expected positive sign and is significant at the 1% level. Both results indicate that the model with the interaction between non-GM and GM soybeans is preferred.

5. Conclusions

Using the traditional approach to estimate the RDE and RSE models, we find that the U.S. GM soybean exporters' market margin is 9.2% and the Japanese GM soybean importers' market margin is zero, and U.S. non-GM soybean exporters' market margin is 52.7% and the Japanese non-GM soybean importers' market margin is 17.2%. However, the results from using the new approach show that the market margins of U.S. exporters and Japanese importers are 30.8% and 5.8%, respectively. By taking the interaction between non-GM and GM soybeans into account, we believe that the new approach improves the accuracy of the estimates of market margins of soybean exporters and importers. U.S. non-GM soybean exporters have a significant market margin in international markets, but it is not as large as the traditional approach suggests. Finally, market margin for Japanese non-GM soybean importers is relatively small, though they enjoy some market margin. This study has addressed only the question of analyzing market power for imported GM and non-GM soybeans in the Japanese soybean market. To elucidate magnitudes of market margins based on the characteristics of the U.S. or Japanese soybean market lefts for future research.

Acknowledgements

Thanks for suggestions and discussions go to Jason Fewell, Alexi Thompson and Shin Sakaue, and workshop participants at Kansas State University, the Missouri Valley Economic Association the 47th Annual Meeting and the Southern Economics Association the 80th Annual Conference. Referees and the editor of this journal provided insightful suggestions.

Note:

1) For details, see Yamaura [9].
2) Non-GM soybean price is sum of GM soybean price and the premium. For details, see Yamaura [9].
3) Yamaura [9] obtained the quantity by TGE and CBOT.
4) TGE closed in February, 2013. We lastly accessed TGE in March 2012.
5) For the other variables, see Yamaura [5] and Yamaura [7].
6) There are similar results in the 3SLS. Therefore, we focus on the 2SLS results in this paper.
7) For details, see Yamaura [9].

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