



THE SCOPE FOR INCREASING BIOFUEL CROP PRODUCTION IN JAPAN: AN ANALYSIS OF ALTERNATIVE POLICIES



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ABSTRACT

In 2010, concerns regarding Japan's excessive dependence on imports for food and energy caused the Japanese government to introduce subsidies to stimulate biofuel crop production. In this paper, we study the viability of price subsidies and certain other policies with respect to increasing the production of biofuel crops. First, we estimate the elasticity of the supply of Japanese agriculture with respect to price (inclusive of the subsidy for each unit of production). For this purpose, we use a longitudinal database of 1822 municipalities that covers all 47 prefectures of Japan. This database includes information about the production of 116 crops and their respective revenues, including subsidies. Using panel data regression techniques, we determine that although the long-run supply of certain crops is highly elastic, this supply is highly inelastic if the production of other crops is held constant. Therefore, an increase in the demand for biofuel crops will cause substantial price increases of agricultural products, largely crowding out the demand for food crops. We then discuss the viability of encouraging various agricultural practices, such as multiple cropping and the cultivation of recently abandoned land. Instead of using abandoned land, which produces a lower yield and requires abundant labor, we recommend a multiple cropping system that involves the rotation of rice and wheat. Although these measures will increase biofuel crop production to a certain extent in the short run, full-scale biofuel crop production can only take place after substantial reforms are implemented to increase the production capacity of the Japanese agricultural sector.

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Contribution/ Originality

This paper contributes to the literature by analyzing the impact of subsidies on biofuel production using a large data set. This paper finds that subsidies for biofuel crops will cause substantial price increases of agricultural products, largely crowding out the demand for food crops.

1. INTRODUCTION

Crop-based biofuel production has received substantial attention as one of the methods to address concerns regarding climate change, energy/food security, and decreasing rural incomes. With respect to climate change concerns, the Intergovernmental Panel on Climate Change (IPCC, 1996) does not classify the combustion of biomass

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as a source of CO₂ emissions, and crop-based biofuel production has been identified as a method to increase soil carbon sequestration and reduce greenhouse gas (GHG) emissions (e.g., (Smith *et al.*, 2000; Grogan and Matthews, 2001; Smith *et al.*, 2001; Lemus and Lal, 2005; Lal, 2008)).

However, the recent increase in global demand for bioenergy has demonstrated certain drawbacks of bioethanol production; in particular, bioethanol production has been implicated in the food price spike of 2008, land degradation, and land use changes. An increasing proportion of available agricultural land has been allocated to biofuel crops, which produced increases in the price of other food crops. Moreover, because there was insufficient agricultural land to keep pace with the fast-growing demand for biofuels, carbon-rich lands, such as rainforests, peatlands, savannas or grasslands, have been converted to agricultural land to grow biofuel crops. In Brazil, for example, to increase biofuel production, the cultivation of biofuel crops has begun to occur in rangelands, pushing the rangeland frontiers further into the Amazon forest. In accordance with these developments, several studies have warned of the great loss in carbon sequestration and the subsequent increase in carbon emissions that have resulted from the transformation of these carbon-rich lands into agricultural regions (e.g., (Fargione *et al.*, 2008; Searchinger *et al.*, 2008; Anderson *et al.*, 2009; Lapola *et al.*, 2010)). In particular, Fargione *et al.* (2008) estimated that the carbon losses from these land use changes will be between 17 and 420 times higher than the carbon reductions that would be caused by replacing biofuels with fossil fuels. These researchers also estimated that the carbon losses from using the Amazon forest for cattle could only be replaced over a time frame of 250 years or more, whereas the losses from using tropical forest regions to cultivate biofuel crops would require several decades to replace.

Japanese agricultural policy provides several types of subsidies for the purpose of increasing the domestic production of agricultural products and Japan's proportion of calorie-based food self-sufficiency. Certain of these subsidies are provided per unit of crop produced, whereas other subsidies are allocated on the basis of cultivated land area. Most Japanese agricultural policies are decided at the national level; however, prefectures can use their local budgets to increase the subsidies for particular crops of regional interest. The agricultural sector is highly regulated, and large firms must obtain permission from municipalities to cultivate land on a large scale. These larger firms have recently been granted entry into the agricultural sector, but many of these firms have only been allowed to use abandoned land (Ohnaka, 2008) which tends to produce lower yields.

In 2010, concerns regarding Japan's excessive dependence on imports for food and energy caused the Japanese government to introduce subsidies to stimulate crop and biofuel productions. These subsidies are provided for each unit of area on which biofuels are cultivated and are also distributed to farmers who switch their rice production from food to biofuel. In addition, there are subsidies for using abandoned land. The Japanese government has expressed a desire to produce 6 million kiloliters (i.e. around 1600 million US gallons) of bioethanol from domestically grown crops by 2030 (Ministry of Agriculture, Forestry and Fisheries (MAFF, 2007) this quantity of biofuel represents approximately 10 % of the current gasoline consumption in Japan¹. To achieve this objective, a set of agricultural policies has been proposed to reverse recent increases in the quantities of abandoned land in Japan and thereby increase Japanese food and biofuel production capacities.

The purpose of this paper is to evaluate the feasibility of increasing biofuel crop production in Japan and to estimate the impact of increased biofuel crop production on the production of other crops. Previous studies addressing the feasibility of the plan to increase Japanese biofuel crop production (e.g., (Hattori, 2010)) have used descriptive statistics regarding the quantity of abandoned agricultural land that exists and the yield of this land. However, before any conclusions can be reached with respect to this topic, it is important to estimate the reactions of agricultural producers to new subsidies. This paper first uses a large longitudinal database that includes 1822 municipalities and covers all 47 Japanese prefectures to estimate the elasticity of supply with respect to income (including subsidies).

¹ http://www.asiabiomass.jp/topics/1005_02.html

The database includes information on the production of 116 crops and the revenues of each of these crops. We use this analysis to assess the extent to which the new demand for biofuels will be met either by creating new supply (i.e., by expanding the production capacity of the agricultural sector) or by diverting resources from the production of food crops to the cultivation of biofuel crops. We then discuss the viability of encouraging certain agricultural practices, such as multiple cropping and the cultivation of recently abandoned land.

This paper is divided into several sections. Section 2 provides a brief overview of the current subsidy policies in the Japanese agricultural sector, and Section 3 summarizes several of the policies that have been proposed to stimulate biofuel crop production in Japan. Section 4 estimates the elasticity of the agricultural supply for several crops that are likely to be used for biofuel production. Section 5 discusses the implications of these results for the policy debate and considers alternative policies, such as the promotion of higher-productivity agricultural practices. Section 6 provides the conclusions of the paper.

2. AN OVERVIEW OF CURRENT AGRICULTURAL SUBSIDIES

Farmers who voluntarily take part in the Rice Farming Income Stabilization (RFIS) Program, which began in 1998, receive 80 % of the difference between the current price of rice and a previously fixed standard price of rice for each unit of output that they produce. This compensation is received only by the farmers who participate in the program and satisfy the requirements of the production adjustment scheme, which implements incentives to reduce the total production of rice. Under this scheme, farmers receive diversion payments, which are distributed in the form of subsidies for each unit of cultivated area, for growing crops other than rice in a paddy field. The amount of the subsidy varies with the type of crop grown in the paddy field, and higher subsidies are given to young farmers who succeed previous generations of farmers. Within the same program, subsidies are also given for creating large-scale fields or forming farming associations. The government has changed the subsidy amounts three times between 1998 and 2005².

With respect to wheat and barley, the New Wheat and Barley Policies approach was implemented during the 2000-2003 time period¹. Under the New Wheat and Barley Policies, although producers sold their wheat and/or barley directly to private firms, they would receive an additional subsidy for each unit that they sold (an income stabilization payment) if the wheat or barley in question was of higher quality than grade 2. The income stabilization payment for 2003 was 106 yen/kg. Furthermore, producers who were part of the RFIS Program would receive an additional payment per unit of area cultivated if they were growing barley or wheat in a paddy field.

With respect to sugar beet and sugar cane, MAFF guaranteed farmers a minimum price that was established each year, although this guaranteed price has decreased from 20.28 yen/kg in 1985 to 16.64 yen/kg in 2005.

3. A DISCUSSION OF PROPOSED POLICIES TO INCREASE THE PRODUCTION OF BIOFUEL CROPS IN JAPAN

Ethanol can be produced from sugar cane, beet, rice, barley, sweet potatoes, and potatoes in Japan (Hattori, 2010). Of the various potential ethanol sources, sweet sorghum appears to be one of the most desirable crops for biofuels with respect to its ethanol production (Hattori, 2010; Takahashi *et al.*, 2010) production/hour (derived from dividing yield by working hours), and carbon emissions (Arakawa, 2007) whereas wheat appears to be one of the least suitable ethanol sources (Arakawa, 2007; Hattori, 2010). In particular, ethanol production from sweet sorghum is estimated to be 3.4 kL/ha, whereas the estimated ethanol production from barley is 1.2 kL/ha. In addition, less carbon is emitted from sweet sorghum than from barley. Moreover, barley emits carbon when its grains are dried, although it does have the lowest production costs among the potential biofuel crops that have been examined (0.5

¹ For a detailed review of the New Wheat and Barley Policies, please see Fukuda, Dyck and Sout (2003).

million yen /ha; (Hattori, 2010). Other advantages of sweet sorghum are that the crop can be cultivated in a variety of regions in Japan and can be grown rapidly (between 4 and 5 months; (Hattori, 2010; Takahashi *et al.*, 2010).

The Japanese government has announced plans to use abandoned cultivated land to grow biofuel crops. To be classified as abandoned agricultural land, a region of agricultural land must have been kept fallow for more than one year, and the land's owner must have no plans to grow any crops on the land in question in the future. The area of abandoned agricultural land in Japan has increased from 130,000 ha in 1960 to 386,000 ha in 2005 (e.g., Statistics and Information Department, MAFF (2006)). The Japanese government's objective is to produce 6 million kiloliters of biofuel in Japan by 2030 (MAFF, 2007) and it envisions that approximately a third of this biofuel total should be produced from agricultural land that is currently abandoned. Hattori (2010) estimated that to achieve this target through the use of only abandoned agricultural land, between 5.2 and 5.7 kL/ha of ethanol production would be required. He further estimated the ethanol production per hectare for several crops; in particular, he projected that approximately 3.5, 5.3, 2.8, 3.2 and 1.2 kL/ha of ethanol could be produced from sugar cane, beet, potatoes, sweet potatoes, and barley, respectively. Therefore, 100 % of the target could be met if all of the abandoned land were used to produce ethanol from beet, whereas other crops could achieve approximately 20 to 60 % of the targeted ethanol production per hectare. Furthermore, it has been estimated that if only abandoned land is used, between 2 and 2.2 million kL of bioethanol could be produced from sweet sorghum, sugar cane, potatoes, and sweet potatoes if the biomass of these crops that is produced is increased by a factor of 1.5 to 2 (Hattori, 2010). However, one difficulty with sugar cane and sweet potatoes is that they require intensive labor; specifically, labor expenses account for 58.6 and 67 %, respectively, of the total cost of each of these 2 crops (Hattori, 2010).

Hu (2008) proposed prioritizing municipalities according to their rice yield per area; in particular, he recommended growing rice in the 708 municipalities in which the yield is greater than 5060 kg/ha and growing other crops in the remaining municipalities. In addition, he suggested using fallow converted paddy fields for fuel-production crops. This suggestion is a promising proposal that we discuss in Section 5 of this paper. Similarly, in the UK, Powelson *et al.* (2005) estimated that the use of 80 % of set-aside land² for growing biomass crops would be sufficient to meet 3 % of the nation's electricity demand.

However, it would be difficult to use abandoned agricultural land alone to achieve the governmental biofuel targets, particularly because the abandonment of land has been caused by (1) labor scarcity (including demographic considerations involving the number and age of available workers and their successors) and (2) the low productivity of the farmland in question (including its slope, size, consolidation, and grade, as well as damages to the land that were caused by birds and animals). With respect to these considerations, Takamo *et al.* (2004) demonstrated that the proportion of abandoned land was higher among farm households without successors and among farmers who were older than 60 years of age. It has also been found that households with no workers who can work more than 30 days in a year are more likely to abandon parcels of land (Imai *et al.*, 1997). Furthermore, farmers in Gifu prefecture expressed labor-related reasons for abandoning portions of their land, including shortages in the number of available workers and time shortages caused by other jobs (Imai *et al.*, 1997). With respect to the characteristics of abandoned land, studies in the Chiba and Gifu prefectures and the Chugoku region have indicated that abandonment is dependent on the size of the cultivated land in question. Farmers with large areas of cultivated land are more likely to cease cultivating in a portion of their land (Takada, 2006). However, farmers with less than 0.25 hectares (ha) typically chose to either cultivate all of their land or to completely cease cultivation of any of this land (Takada, 2006). Farmers with less than 0.5 ha land in the Chugoku region of Japan, which is a hilly and mountainous area, ceased cultivating their land because declining rice prices produced a negative net return from their farming efforts (Senda, 2006). Farmers with small or hilly lands ceased cultivating their land due to difficulties with the use of agricultural

² Under the Common Agricultural Policy of the European Union, farmers were requested to set aside (i.e., not cultivate) a proportion of their land to reduce production.

machines (Imai *et al.*, 1997; Senda, 2006). Moreover, the ratio of abandonment was inversely correlated with the land grade according to the land register (Takada, 2006) thus, farmlands of grades 1 or 2 were more likely to be kept for cultivation. The ratio of abandonment increased with lower progress in land consolidation, particularly in hilly and mountainous areas Takamo *et al.* (2004). In these regions, the impact of adjoining cultivation grids (i.e., land that is contiguous to the land of another farm) was more influential than various other factors (e.g., the vertical drop, the maximum angle of inclination, and the density of valleys) in causing the greater abandonment of farmland (Sasaki *et al.*, 2007).

Finally, Kaneta *et al.* (2010) found that because of the continued presence of weeds in formerly abandoned fields, the yield from recovered abandoned farmland was lower than the yield of farmland that had been continuously cultivated. However, several other papers have found that for abandoned land, the soil carbon storage of the land is positively correlated to the number of years of abandonment (e.g. (Ota *et al.*, 1996)).

4. THE ESTIMATION OF THE ELASTICITY OF SUPPLY OF AGRICULTURAL PRODUCTS

We use a longitudinal database of 1822 municipalities³ that covered all 47 Japanese prefectures during the 1998-2005 time period⁴. The data are publicly provided by the Ministry of Agriculture, Forestry and Fisheries (MAFF) through their official webpage⁵. The database includes information on the production of 116 crops and their respective revenues, including subsidies, for each unit of crop that was produced⁶.

Note that the revenue measure that we use does not include subsidies that are distributed per unit of cultivated land; thus, we are only examining the impact of price subsidies.

Table-1. The production (in tons) and revenue (in 10⁷ yen) information that was obtained from the MAFF official webpage. If seasonal production rates were reported for the same crop, we added these seasonal rates to obtain the annual production levels. Because there was no corresponding information on production, the revenue from millet was not included in our analysis. The production levels of forage crops were included as control variables (despite the fact that revenue information was unavailable for these crops).

Revenue Category	Crops
Rice	paddy field rice and dryland rice
Cereals	wheat, six-row barley, two-row barley, naked barley
Beans	red beans, soy beans, peanuts, <i>phaseolus vulgaris</i>
Potatoes	sweet potatoes, potatoes
Industrial Crops	sugar cane, sugar beet, <i>Juncus effuses</i> , tea, tobacco, konjac
Vegetables	root vegetables (8 varieties), leaf stalk vegetables (17 varieties), ginger, fruit-type vegetables (13 varieties)
Fruits	18 types of crop
Flowers	cut flowers (18 varieties), bulbs (4 varieties), pot flowers (10 varieties), seeds (5 varieties)
Millet	no production information available
No revenue information available	forage crops (corn, sorghum, pasture grass, blue oat grass)

Source: MAFF

³ The number of municipalities changed during the sample period because certain municipalities merged. To address mergers of municipalities during the sample period, we treated the merged municipalities as a single municipality throughout the sample period; thus, we combined the production and income of these municipalities for all of the sampled years, including the years prior to the merger.

⁴ Although production data through 2011 were readily accessible, at the time of this study, the income data that were available on-line only extended through 2006.

⁵ The internet address for the data regarding agricultural revenues is http://www.maff.go.jp/j/tokei/kouhyou/sitvo_tvouki/index.html. The internet address for the data regarding crop production is: http://www.maff.go.jp/j/tokei/kouhyou/sitvo_tvouki/index.html.

Although we have information regarding the production of each of the 116 crops in the database, we do not have revenue information regarding each of these crops. Instead, we have the total revenue obtained for each of 8 categories of crops: rice, cereals, beans, potatoes, industrial crops, vegetables, fruits and flowers. Furthermore, although the production information on forage crops (corn, sorghum, pasture grass and blue oat grass) is available, the revenue data for these crops could not be obtained. For this reason, we will not look at the supply elasticity of forage crops. Instead, we will concentrate on the following 6 crops that previous research studies (described in Section 3) have proposed as likely crops for biofuel production in Japan: rice, wheat, sweet potato, potato, sugar beet and sugar cane. Table 1 summarizes the types of crops and revenue categories that are considered in this study.

The internet address for the data regarding agricultural revenues is

http://www.maff.go.jp/j/tokei/kouhyou/sityo_tyouki/index.html. The internet address for the data regarding crop production is: http://www.maff.go.jp/j/tokei/kouhyou/sityo_tyouki/index.html.

The datasets available on-line are provided in separate Excel files for each crop, city and year. Therefore, to build the dataset for our estimations, we wrote computer code to download and combine more than 210000 Excel files.

To explain our empirical approach, we introduce certain mathematical notations. Let $y_{i,t}^j$ be the production of crop j by municipality i in period t (with $j=1, \dots, 116$, $i=1, \dots, 1822$, $t=1998, \dots, 2005$), and let $p_{i,t}^j$ be the corresponding price (the revenue per produced unit), including any applicable price subsidies. Note that changes to the product quality, local market conditions and local subsidy policies can cause $p_{i,t}^j$ to vary among municipalities. The data do not provide us with $p_{i,t}^j$ but with the total revenue for each of the 8 categories of crops:

$$I_{i,t}^s = \sum_{j \in s} p_{i,t}^j y_{i,t}^j \quad s=1, \dots, 8$$

From the seminal work of Nerlove (1956) it is common practice to model acreage (the planted area) as a function of lagged acreage, lagged price and a trend. This framework assumes that acreage is a function of expected price, and that expected price is a function (a weighted moving average) of past prices. In our case we do not have price information, but instead can include income for each category of crops and quantity produced for each crop. This approach is valid provided that we make the reasonable assumption that the price of a crop can be written as a function of these two variables plus an error term (as in a linear projection, see for example Wooldridge (2002)). Furthermore, instead of using acreage we use quantity produced as a dependent variable. Although in some cases quantity produced could be almost a deterministic function of acreage, more generally the quantity produced will be affected not only by the acreage, but also by other inputs such as the effort applied by the farmer, quality of the soil, weather, etcetera. As our interest is mostly on the elasticity of supply, a model with quantity produced as the dependent variable will be able to give an answer to our research question in a more direct manner. Finally, note that we will not control for acreage in our regression. This is because we are not seeking to estimate the price induced change in production when acreage is held constant. Rather, we want to estimate the change in production after farmers have adjusted all inputs of production. Because of these considerations, we model the production in period t as a function of past production, past revenues and location/time dummies according to the following equation:

$$\ln(y_{i,t}^j) = \sum_{s=1}^8 \beta_s \ln(I_{i,t-1}^s) + \sum_{m=1}^{116} \rho_m \ln(y_{i,t-1}^m) + \sum_{r=1}^{47} \theta_r f_{ir} + \sum_{r=1998}^{2005} \lambda_r a_{tr} + u_{i,t} \quad (1)$$

Where $(\beta_s, \rho_m, \theta_r, \lambda_r)$ are unknown parameters. In the above equation, $u_{i,t}$ is an error term. We run regression (1) separately for each crop j , but for simplicity we do not attach the subindex j to the unknown parameters $(\beta_s, \rho_m, \theta_r, \lambda_r)$, although they are different for each crop j . A set of prefectural dummies is denoted by f_{ir} , and the a_{tr} values are a set of time dummies. The prefectural dummies are included to control for differences in production

capabilities, policies, crop quality, soil quality and climate among the different prefectures. The time dummies are added to control for changes in subsidy policies and market conditions that occurred during the sample period, as well as changes in weather and any possible trend.

Using equation (1), we can calculate the short-run and long-run response of $y_{i,t}^j$ to a change in $p_{i,t}^j$. In particular, assuming that crop j belongs to revenue category s , it can be shown that the short-run elasticity (e_j^{Short}) is given by the following expression:

$$e_j^{Short} = \frac{\partial y_{i,t}^j}{\partial p_{i,t-1}^j} \frac{p_{i,t-1}^j}{y_{i,t}^j} = \beta_s \Phi_{js} \leq \beta_s$$

Where Φ_{js} is the proportion of revenue category s that corresponds to crop j :

$$\Phi_{js} = \frac{y_{i,t-1}^j p_{i,t-1}^j}{I_{i,t-1}^s} = \frac{y_{i,t-1}^j p_{i,t-1}^j}{\sum_{j \in s} p_{i,t-1}^j y_{i,t-1}^j}$$

The long-run elasticity can be calculated by making $y_{i,t}^j = y_{i,t-1}^j$ and $p_{i,t}^j = p_{i,t-1}^j$ in equation (1) and taking the total differential with respect to $(y_{i,t}^j, p_{i,t}^j)$ while holding other variables constant:

$$e_j^{Long} = \frac{\partial y_{i,t}^j}{\partial p_{i,t}^j} \frac{p_{i,t}^j}{y_{i,t}^j} = \frac{e_j^{Short}}{1 - \rho_j - e_j^{Short}} \leq \frac{\beta_s}{1 - \rho_j - \beta_s}$$

Because we are holding the production of other crops constant, we will call $(e_j^{Short}, e_j^{Long})$ conditional elasticities.

The conditional elasticities provide information about the impact of $p_{i,t}^j$ on $y_{i,t}^j$ if the production of other crops is kept constant, and they measure how much the supply of a product can expand without decreasing the supply of other crops. We will also calculate unconditional elasticities, which do not maintain the production of other crops at a constant level. To calculate unconditional elasticities, we will work with the following equation, which only incorporates information on the past production/revenue of the crop in question:

$$\ln(y_{i,t}^j) = \tilde{\beta}_s \ln(I_{i,t-1}^s) + \tilde{\rho}_j \ln(y_{i,t-1}^j) + \sum_{r=1}^{47} \tilde{\theta}_r f_{ir} + \sum_{r=1998}^{2005} \tilde{\lambda}_r a_{ir} + u_{i,t} \quad (2)$$

From this equation, the unconditional short- and long-run elasticities are given by the following expressions:

$$\tilde{e}_j^{Short} = \frac{dy_{i,t}^j}{dp_{i,t-1}^j} \frac{p_{i,t-1}^j}{y_{i,t}^j} = \tilde{\beta}_s \Phi_{js} \leq \tilde{\beta}_s$$

$$\tilde{e}_j^{Long} = \frac{dy_{i,t}^j}{dp_{i,t}^j} \frac{p_{i,t}^j}{y_{i,t}^j} = \frac{\tilde{e}_j^{Short}}{1 - \tilde{\rho}_j - \tilde{e}_j^{Short}} \leq \frac{\tilde{\beta}_s}{1 - \tilde{\rho}_j - \tilde{\beta}_s}$$

We estimate equations (1) and (2) using Ordinary Least Squares (OLS) with cluster standard errors, which allow for heteroskedasticity and autocorrelation in the $u_{i,t}$ values for the same prefecture. Note that because we have included prefectural dummies, the OLS estimator is equivalent to a fixed effect estimator at the prefectural level (Wooldridge, 2002). This implies that we are effectively controlling for any prefectural characteristic that is constant over time (e.g. climate, soil quality, crop quality, and policies that have been constant over time)⁷. To avoid having to obtain an estimate of the proportion Φ_{js} , we report in Table 2 estimates of conditional elasticities that assume $\Phi_{js} = 1$, and we interpret these estimates as upper bounds on the elasticities (because the elasticities increase as Φ_{js} increases). Because our main result is that conditional elasticities are small even when we fix $\Phi_{js} = 1$, our conclusion would be qualitatively the same if we used an accurate estimation of the proportion Φ_{js} . As Table 2

⁷ We tried the fixed effects estimator at the municipality level, but the standard errors became very large. Hence we decided to use dummies at the prefectural level only.

shows, the conditional elasticities have values smaller than one, and we therefore conclude that the conditional supply is inelastic. Only the conditional elasticities of wheat, sweet potatoes and potatoes are significantly different from zero, with wheat and sweet potatoes being the most responsive of the studied crops to price fluctuations.

Table 3 presents estimates of unconditional elasticities that assume $\Phi_{js} = 1$. Unsurprisingly, these elasticities are substantially larger than the conditional elasticities of Table 2. If we do not keep other crops constant, land/labor will be diverted from other crops to the crop that has become more profitable. For this reason, we observe in the unconditional situation that the supplies of rice and wheat are highly elastic (i.e., these crops have elasticities greater than one). However, the supplies of other crops (sugar beet, sugar cane and potatoes) continue to be inelastic.

Table-2. Estimates of conditional elasticities and corresponding 95% confidence intervals, assuming that. SR indicates short run, whereas LR indicates long run.

		Lower Bound	Estimate	Upper Bound	P-Value
Paddy Rice	SR	-0.01	0.02	0.04	0.267
	LR	-0.13	0.19	0.50	0.239
Dryland Rice	SR	-0.13	0.13	0.40	0.324
	LR	-3.20	1.04	5.28	0.631
Wheat	SR	0.04	0.09	0.14	0.000
	LR	0.10	0.51	0.91	0.014
Sweet Potato	SR	0.15	0.29	0.43	0.000
	LR	0.14	0.53	0.91	0.007
Potato	SR	0.01	0.02	0.03	0.003
	LR	0.02	0.08	0.13	0.004
Sugar Beet	SR	0.00	0.00	0.00	0.670
	LR	-0.03	-0.01	0.02	0.632
Sugar Cane	SR	0.00	0.00	0.00	0.509
	LR	0.00	0.00	0.00	0.508

Table-3. Estimates of unconditional elasticities and corresponding 95% confidence intervals, assuming that $\Phi_{js} = 1$. SR indicates short run, whereas LR indicates long run.

		Lower Bound	Estimate	Upper Bound	P-Value
Paddy Rice	SR	0.06	0.10	0.14	0.000
	LR	1.02	2.89	4.75	0.002
Dryland Rice	SR	0.01	0.02	0.03	0.000
	LR	0.09	0.18	0.27	0.000
Wheat	SR	0.12	0.14	0.16	0.000
	LR	1.14	1.71	2.28	0.000
Sweet Potato	SR	0.18	0.20	0.23	0.000
	LR	0.26	0.32	0.37	0.000
Potato	SR	0.00	0.01	0.01	0.041
	LR	0.01	0.05	0.09	0.022
Sugar Beet	SR	0.01	0.02	0.02	0.000
	LR	-0.12	0.39	0.89	0.132
Sugar Cane	SR	0.00	0.00	0.01	0.056
	LR	0.00	0.01	0.02	0.047

Source: Authors' calculations.

5. A DISCUSSION OF ALTERNATIVE POLICIES FOR INCREASING BIOFUEL CROP PRODUCTION

In Section 3, we argued that attempts to achieve the target of biofuel production set by MAFF solely through increasing the use of currently abandoned land are unlikely to succeed due to labor scarcity and the lower quality of abandoned land. In Section 4, we found that increasing subsidies for biofuel crop production will primarily divert production away from other crops and result in price increases. In this section, we argue that biofuel crop production could be increased to a certain extent by increasing the utilization rate of cultivated land through multiple cropping.

First, we note that the utilization rate of cultivated land decreased from 138 %⁸ in 1960 to 93.4 % in 2005 (e.g., (MAFF, 1961; MAFF, 2006)). As depicted in Figure 1, the utilization rate of cultivated land decreased in all

⁸ The utilization rate can be greater than 100 % because of multiple cropping. If all of the available farmland were used to grow two crops within the same year, the utilization rate would be 200 %.

prefectures except for Hokkaido during the 1960 to 2005 time period, although this decrease occurred at different speeds. One important reason for this reduction is a decrease in multiple cropping. Figure 2 indicates that the percentage change from 1960 to 2005 in the proportion of paddy field area that was used for multiple cropping decreased in every prefecture. The possible reasons for this decreasing trend include decreases in the price of wheat, which is a crop that is frequently utilized in multiple cropping. Another possible reason underlying this trend is the use of rice-planting machines that require an earlier rice-planting season, which overlaps in part with the season during which other crops, such as wheat, can be grown (Inaba, 2006). The decrease in the utilization rate of cultivated land also appears to be related to labor and to the percentage of fallow land. With respect to labor, the percentage of full-time farmers decreased during the course of the examined time period (Figure 3), whereas the percentage of farmers who were over 60 years old increased substantially in all of the prefectures of Japan (Figure 4). With respect to fallow land, the percentage of paddy field area that was kept fallow at the national level increased from 0.15 % in 1960 to 9.5 % in 2005, whereas in upland fields in particular, this percentage increased from 1.5 % in 1960 to 5.0 % in 2005.

In our empirical analysis, we found wheat to be responsive to a price stimulus. Moreover, wheat is a crop that can be planted in paddy fields after harvesting rice. In this sense, rice-wheat multiple cropping appears to be an optimal agricultural practice that will increase the quantity of biofuel crops that are produced without decreasing the quantity of rice that is produced for food. To a lesser extent, we also found sweet potatoes to be responsive to price; therefore, this crop could also be combined with rice in crop rotations.

One further advantage of multiple cropping is related to carbon sequestration. Less carbon is lost into the atmosphere in multiple cropping than in single cropping⁹ (Nakadai *et al.*, 1996; Yokozawa *et al.*, 2010). The carbon loss from multiple cropping is also smaller than the quantity of carbon that is released during the reuse of previously abandoned land, particularly land that has been abandoned for more than three years on poorly drained sites¹⁰ (Ota *et al.*, 1996).

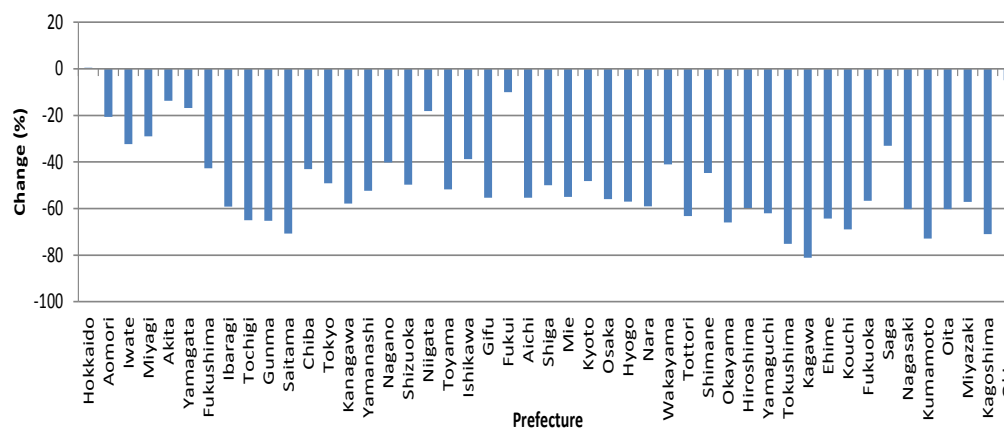


Figure-1. The change in the utilization rate of cultivated land over the 1960-2005 time period (MAFF Census)
Source: Authors' calculations with MAFF data.

⁹ In particular, for the single cropping of upland rice, corn and soybean, the estimated carbon loss is between 270 and 320 g/cm². By contrast, the estimated carbon loss is between 160 and 279 g/cm² for the multiple cropping of upland rice and barley; upland rice and wheat; or corn and barley Koizumi, Kibe, Nakadai, Bekku, Tang, Nishimura, Kawashima, Kobayashi and Mariko (1998). Similarly, Yokozawa *et al.* found that carbon loss produced by double cropping (of rice and wheat) was smaller than the carbon loss produced by single cropping.

¹⁰ Ota, Ichio, Kusaba, Mori and Araya (1996). found that carbon in the surface horizons accumulates at a much greater speed in poorly drained sites than in well-drained sites after the cultivation of these sites has been stopped. In particular, for the poorly-drained sites that were examined, carbon in the surface horizons increased by 25 % and 140 % after 12 years and 20 years of abandonment, respectively. By contrast, for the well-drained sites that were examined, carbon in the surface horizons increased by 146 % after 20 years of abandonment, but did not display any significant increase after 12 years of abandonment *ibid.*

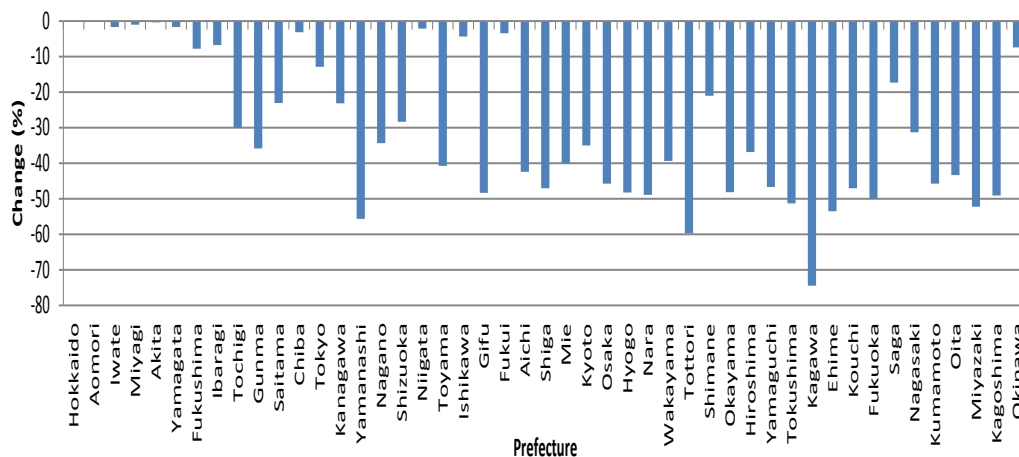


Figure-2. The change in the percentage of double cropping in paddy fields over the 1960-2005 time period (MAFF Census)
Source: Authors' calculations with MAFF data.

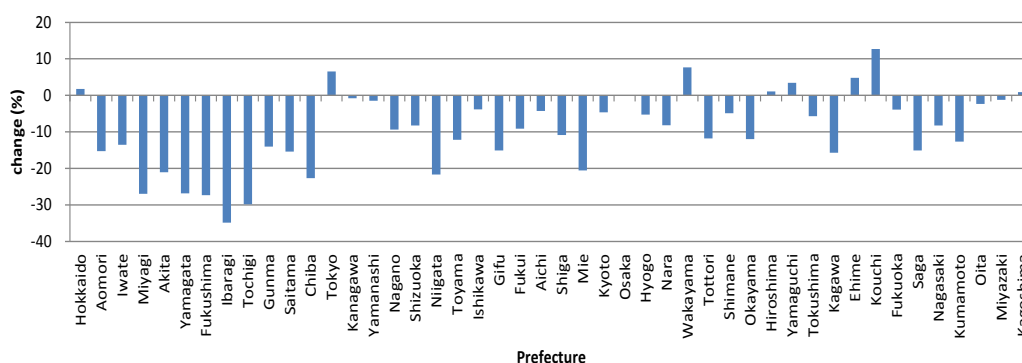


Figure-3. The change in the proportion of full-time farmers over the 1960-2005 time period (MAFF Census)
Source: Authors' calculations with MAFF data.

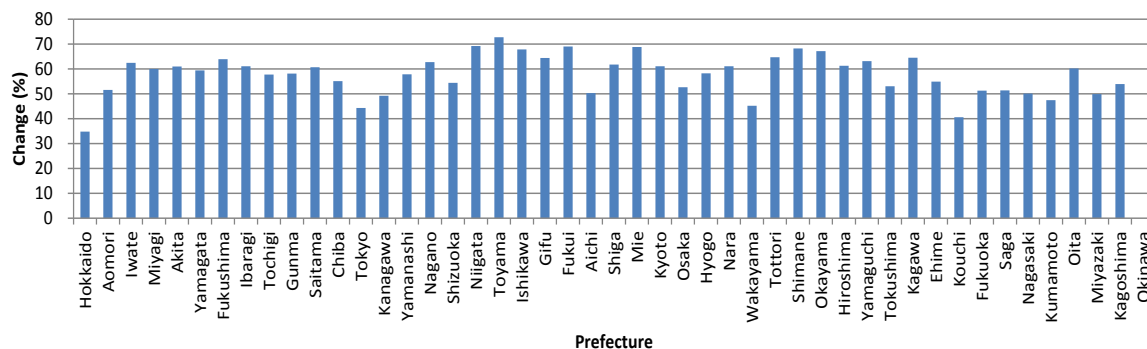


Figure-4. The change over the 1960-2005 time period in the proportion of primarily agricultural workers who are over 60 years old (MAFF Census)
Source: Authors' calculations with MAFF data.

6. CONCLUSIONS

In this paper, we examine the viability of price subsidies and other policies for increasing the production of biofuel crops. First, we use a large longitudinal dataset that encompasses 1822 municipalities and contains detailed information on the production of 116 crops and agricultural incomes to estimate the elasticity of the supply of Japanese agriculture with respect to price (inclusive of subsidies for each unit of production). We find that even though the long-run supply of certain crops is highly elastic, the supply of these crops becomes highly inelastic if the production of other crops is held constant. Thus, an increase in the price of a biofuel crop will induce greater supply, but primarily at the expense of the lower production of other crops. In other words, if we were to hold the production of other crops constant, the capacity to increase the supply of biofuel crops would be very small. Therefore,

increasing the demand for biofuel will not proportionately increase the agricultural production capacity of Japan. Instead, increased biofuel production will cause the production of other crops to decrease, producing price increases.

We then discuss the viability of encouraging various agricultural practices, such as multiple cropping and the cultivation of recently abandoned land. Instead of using abandoned land, which has a lower yield and requires abundant labor, we recommend encouraging farmers to follow a system of rotation in the multiple cropping of either rice and wheat or rice and sweet potato. This approach would increase the available supply of biofuels (which could be derived from the wheat or sweet potato) without reducing the supply of rice that is available for food. Furthermore, compared with leaving farmland fallow, multiple cropping has the additional advantage of increasing the carbon sequestration of the farmed soil. However, although the measures suggested above will increase biofuel crop production to a certain extent in the short run, they will not be sufficient to meet the goal of producing 6 million kiloliters of bioethanol by 2030 (MAFF, 2007). Full-scale biofuel crop production can only take place after substantial reforms that increase the production capacity of Japanese agriculture.

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