

Trade Liberalization, Part-time Farming, and the Use of Agrochemicals*

Keisaku Higashida[†]

International College of Arts and Sciences

Yokohama City University

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Abstract

This paper investigates the effects of changes in prices and wages, which may be caused by trade liberalization, on the micro behavior of farmers, in particular, on the use of agrochemicals and part-time farming. I demonstrate that a small decrease in the price of an agricultural product decreases the use of agrochemicals if there are no arable land rental transactions. On the other hand, if a change in those transactions is taken into consideration, the price decrease may increase the use of agrochemicals in an rural area. Moreover, a small increase in the local wage decreases the use of agrochemicals in the area.

Keywords: trade liberalization, agrochemicals, part-time farming.

JEL classification: F18.

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[†]Corresponding Address. 22-2 Seto, Kanazawa-ku, Yokohama, 236-0027, Japan. e-mail: keisaku@yokohama-cu.ac.jp.

1 Introduction

Changes in prices of agricultural products and factors affect farmers' behavior. In terms of the environment, the effect on the use of agrochemicals, such as pesticides, herbicides, and fertilizers, is an important issue. People have been more concerned with the relationship between agrochemicals and their health problems. Moreover, these chemical matters may influence the ecosystem around arable land.

One possible candidate for effecting changes in prices of agricultural products is trade liberalization on agriculture. The Agreement on Agriculture was negotiated in the Uruguay Round, and the process of trade liberalization on agricultural products began in 1995 under the World Trade Organization. Numerical targets for liberalization were set for three categories of policies: market access, domestic support, and export subsidies. Although some agricultural products had been liberalized before 1995, this agreement was the beginning of comprehensive trade liberalization on agriculture.¹ Accordingly, in particular for importing countries, the volume of trade in agricultural products has been increasing. This means that the agricultural sector is becoming less distorted, and further liberalization will be discussed in the new Doha round.

On the other hand, many people are worried about environmental damage caused by the increase in agricultural trade. One possible process is that trade liberalization encourages highly capital-intensive production, which implies that generally more agrochemicals are used. Thus, environmental damage increases. Moreover, specialization implies that one country produces less variety of crops. Then, it loses its biodiversity, and its agriculture becomes vulnerable to insects and bacteria. On the other hand, there

¹For example, Japan lifted tariffs on vegetables by 1970s, and some kinds of fruits by 1992.

is a possibility that, the less distorted agricultural markets are, the less environmental damage is generated during the production stage. The reason is as follows: as trade is liberalized, countries that have comparative advantage (resp. disadvantage) increase (resp. decrease) their output. Consequently, production becomes more efficient, which implies that it uses less agrochemicals.

Many studies have been devoted to estimating the effects of trade liberalization on the environment (Anderson (1992), Cooper et al. (2005), Nkunjimana et al. (2003), Sullivan and Ingram (2005)). Williams and Shumway (2000) set up a simulation model to estimate the effect of the North American Free Trade Agreement (NAFTA) on the use of agrochemicals in both the United States and Mexico. They concluded that the NAFTA would increase the use of both pesticides and fertilizers in the US and the use of fertilizers in Mexico, while decreasing pesticide use in Mexico. In general, however, the effect is not very clear.

When considering the influence of agricultural trade reform, one important point should be taken into consideration. In developed countries, there are many part-time farmers. In the case of Japan, more than 80 percent of farm households were part-time farm households as of 2000.² Their behavior is different from that of managers or owners of firms. They also choose between consumption and leisure to maximize their utility. Therefore, to introduce part-time farming into the model is crucial for the analysis of agricultural trade liberalization.³ There are many empirical studies of

²The data is from the Census of Agriculture and Forestry. The explanation about this census can be browsed at the website of the Ministry of Agriculture, Forestry, and Fisheries of Japan.(<http://www.maff.go.jp/census/2005/engindex.html>)

The data are published only in Japanese as of November 2006.

³Zusammenfassung (1991) emphasized the importance of considering part-time farmers when considering environmental aspect of agriculture.

part-time farming (Evans and Ilbery (1993), Janvry et al. (1991), Pfafferemayr (1991), Pfeffer (1989), Robson (1987), Singh and Williamson Jr (1981), Zhou et al. (2001)). On the other hand, theoretical analyses have been made in the context of the development of rural areas in developing countries (Sen (1966), Stiglitz (1969)).

The behavior of part-time farmers is influenced by trade liberalization not only on agriculture but also on other industries through changes in wages. Intuitively, as wages become higher in industry, farmers increase their labor hours for off-farm work. They may give up farming, and migrate from rural areas to urban areas. As a result, the amounts of inputs and production technologies change.

Part-time farming itself is sometimes considered as a problem, since small-scale farms are usually less competitive than larger scale farms. The fact that small part-time farmers survive trade liberalization implies that the agricultural sector of the country will unnecessarily lose its competitive ability in total. As far as I know, there are few theoretical studies that investigate the relationship among agricultural trade liberalization, the behavior of part-time farmers, and the use of agrochemicals in terms of environmental damage.

The purpose of this paper is to investigate the effects of changes in prices and wages, which may be caused by trade liberalization, on the micro behavior of farmers, in particular, on the use of agrochemicals and part-time farming.

One important feature of this paper is that I consider the situation in which farmers may rent (resp. rent out) arable land from (resp. to) other farmers in a rural area. In fact, this type of transaction is commonly seen in rural areas. Moreover, governments sometimes encourage these transactions because they want to promote larger scale farms

to make the agricultural sector more competitive. For example, the Ministry of Agriculture, Forestry, and Fisheries of Japan amended its policies and is now making an effort to accumulate arable land in the hands of large-scale, productive farmers.

The main results are as follows. First, a small decrease in the price of an agricultural product in a rural area decreases the use of agrochemicals in the area, if arable land rental transactions are not taken into consideration. A small decrease in the price of the agricultural product, however, discourages those transactions, which increases small-scale farmers with lower productivity. Thus, if farmers with low productivity use more agrochemicals than farmers with high productivity, total use of agrochemicals in the area may increase due to a decrease in the price of the agricultural product.

Second, a small increase in the wage decreases the use of agrochemicals if arable land rental transactions are not taken into consideration. Moreover, the increase influences rental transactions so that fewer agrochemicals are used. Therefore, total use of agrochemicals in an area decreases due to an increase in the wage.

Third, even if arable land rental transactions are not taken into consideration, when a change in the price of an agricultural product affects the local wage, the use of agrochemicals may increase. The reason is that the local wage decreases due to a decrease in the price of the agricultural product, which make farmers input more production factors.

The rest of the paper is organized as follows. Section 2 describes the model. Sections 3 and 4 investigate the effects of changes in the prices of agricultural products and the wage, respectively. Section 5 considers the case in which changes in the prices of agricultural products affect the local wages. Section 6 provides concluding remarks.

2 The Model

A small country, which is called the home country, consists of N rural areas and an urban area. In each rural area, there is one industry I^i ($i = 1, 2, \dots, n, \dots, N$). There are also farmers and industrial workers in each rural area. Farmers own their own arable land, and input their own labor into the production of agricultural products unless they give up farming. They are also able to take off-farm jobs, or hire industrial workers at their farms. Industrial workers are able to take part-time jobs at farms. It is assumed, however, that they cannot be farmers since the initial cost to begin agriculture is very high. On the other hand, in the urban area, there are all kinds of industries and industrial workers. Some industries are exporting industries, and the other industries compete with imports in the home market. All exporting industries are symmetric, and all importing industries are also symmetric. Moreover, the population of the urban area is much greater than the total population of rural areas.

In an industry, firms produce consumer goods by using both labor and capital. They compete competitively in both goods and labor markets. Thus, the wage is equal to the marginal product of labor. It is assumed that capital is fixed in the industry, and it cannot move across industries and areas in the short run. Consequently, the marginal product of labor is decreasing in the input of labor, and accordingly, the labor demand curve is downward sloping.

In each rural area, each farmer j has the same utility structure⁴ :

$$u^j = U[E^j, Y^j], \quad u_E > 0, \quad u_{EE} < 0, \quad u_Y > 0, \quad u_{YY} < 0, \quad u_{EY} > 0, \quad (1)$$

⁴In reality, each house hold may determine its members' labor hours. In this paper, "farmer" could be "household".

where E and Y denote leisure hours and income, respectively. Throughout the paper, square brackets and subscripts denote functions and partial derivatives, respectively. Since the same results are obtained for every area, superscript i is excluded in the following.

Each farmer has \bar{E} hours, and use them either for leisure or labor:

$$\bar{E}^j = E^j + l^{jF}, \quad (2)$$

where l^F denotes labor hours of each farmer. A farmer could be a part-time farmer. Therefore, s/he can use her/his labor hours for either farming or/and off-farm work. Off-farm work implies that farmers work in the industry which is established in the area.

Each farmer j faces the following production structure:

$$Q^j = f^j[L^j, B^j; T], \quad L^j = l^{jF} + l^{jP}, \quad (3)$$

where Q , L , B , and T denote the output of the agricultural product, total labor hours, the amount of agrochemicals, and land used for the production of the agricultural product.⁵ Moreover, l^P denotes labor hours for off-farm work if it is negative, and it denotes labor hours which a farmer hires from the outside of the farm if it is positive. The production technology has constant-returns-to-scale in the sense that $\lambda Q^j = f^j[\lambda L^j, \lambda B^j; \lambda T]$.

There is only one kind of agricultural product in each area. It is assumed that:

$$Q_L > 0, \quad Q_{LL} < 0, \quad Q_B > 0, \quad Q_{BB} < 0, \quad Q_{LB} > 0, \quad Q_{LL}Q_{BB} - Q_{LB}^2 > 0. \quad (4)$$

Each farmer has the same amount of arable land.

⁵ B could be “capital”. Usually, in the real world, labor and capital are substitutes in the agricultural sector, and labor and agrochemicals are also substitutes.

On production technologies, a farmer's productivity is different from any other farmer in the same area.⁶ At given amounts of inputs, or at give factor prices, $Q^j \neq Q^k$ for any j and k ($j \neq k$). Then, the income of each farmer is represented as:

$$Y^j = p^A Q^j - p^B B^j - w l^{jP}, \quad (5)$$

where p^A and p^B denote the prices of the agricultural product grown in the area and agrochemicals. Moreover, w denotes the wage rate determined in the local labor market. For simplicity, it is assumed that agrochemicals can be freely imported at p^B .

Each farmer chooses the amounts of l^{jF} , l^{jP} , and B^j to maximize her/his utility ((1)) subject to the production function ((3)), income constraint ((5)), and constraint on labor hours ((2)). Assuming interior solutions, the first-order conditions are obtained:

$$u_E^j + u_Y^j \cdot p^A Q_L^j = 0, \quad (6)$$

$$u_Y^j \cdot (p^A Q_L^j - w) = 0, \quad (7)$$

$$u_Y^j \cdot (p^A Q_B^j - r) = 0. \quad (8)$$

Each worker in both rural and urban areas has the following utility structure:

$$v = V[e, y], \quad v_e > 0, \quad v_{ee} < 0, \quad v_y > 0, \quad v_{yy} < 0, \quad v_{ey} > 0, \quad (9)$$

where e and y denote leisure hours and income, respectively. Each worker has \bar{e} hours, and use them either for leisure or labor:

$$\bar{e} = e + l^I, \quad (10)$$

where l^I denotes labor hours of each worker. S/he chooses l^I to maximize her/his utility

⁶A possible source of the difference in the productivity is ability on farm management. In fact, the frequency of sprinkling pesticides is depend on the farmer even if there is a standard set by the government.

subject to (10), and income constraint

$$y = wl^I. \tag{11}$$

Assuming interior solutions, the first-order condition is obtained:

$$-v_e + v_y \cdot w = 0. \tag{12}$$

The wage rate in the area is determined so that the labor demand by industrial firms is equal to the labor supply from both workers and farmers.

3 Changes in the Prices of Agricultural Products

In this section, first, I consider the effects of changes in the prices of agricultural products on farmers' labor hours, their use of agrochemicals, and their welfare. Then, I investigate those effects through a change in arable land rental transactions. Trade liberalization is one of the factors that can change prices. When the home country imports agricultural products, trade liberalization lowers those prices. On the other hand, when the home country is an exporting country, the direction of the price change is ambiguous. The domestic prices increase if foreign importing countries lift tariffs, whereas domestic prices decrease if this country cuts back on export subsidies.

To extract the effects of changes in the prices of agricultural products, I set up three assumptions for this section. The first one is about the local wage.

Assumption 1 *The ratio of farmers to industrial workers is very low in each rural area.*

Thus, a change in the labor hours of farmers does not affect the local wage.

The second assumption is about the utility structure.

Assumption 2 *Changes in the prices of agricultural product do not affect the farmer's and worker's marginal rate of substitution given income and leisure hours.*

As noted in the previous section, the utility of each farmer explicitly depends on income and leisure hours. This implies that it implicitly depends on the prices of industrial goods and the agricultural product. Therefore, changes in prices could affect the shape of the indifference curve. For simplicity, however, I exclude this effect in this section. For example, suppose that trade in the agricultural product grown only in a few areas is liberalized. When the share of expenditure for the agricultural product is very low, the income effect is negligible.⁷

The third assumption is about farm productivity.

Assumption 3 *Farmers are uniformly distributed from the lowest productivity to the highest productivity in each rural area. The higher productivity is defined as follows. For any given p^A ($p_0^A \leq p^A \leq \bar{p}^A$) and w ($w_0 \leq w \leq \bar{w}$), the higher is a farmer's productivity, the more output s/he produces, and the price of the agricultural product and the wage are in the ranges described above. Moreover, as a farmer's productivity becomes higher, the amounts of inputs are either monotonically increasing or decreasing.*

Examples of production functions for the cases in which the amounts of inputs are monotonically increasing and decreasing are described in Appendix A. In the following, I focus on one rural area in which one kind of agricultural product is grown.

⁷In Japan, tea is mainly produced only in several prefectures out of 47 prefectures. The situations for apples, oranges, and garlic are the same.

Totally differentiating the first-order conditions and (5) for each farmer, I obtain:

$$\begin{pmatrix} -R_E - p^A Q_{LL} & -p^A Q_{LL} & -p^A Q_{LB} & R_Y \\ p^A Q_{LL} & p^A Q_{LL} & p^A Q_{LB} & 0 \\ p^A Q_{LB} & p^A Q_{LB} & p^A Q_{BB} & 0 \\ -p^A Q_L & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \frac{dl^F}{dp^A} \\ \frac{dl^P}{dp^A} \\ \frac{dB}{dp^A} \\ \frac{dY}{dp^A} \end{pmatrix} = \begin{pmatrix} Q_L \\ -Q_L \\ -Q_B \\ Q \end{pmatrix}, \quad (13)$$

where

$$R \equiv \frac{u_E}{u_Y}. \quad (14)$$

For simplicity, j is not described explicitly. From (1), it is obtained that

$$R_Y > 0, \quad R_E < 0. \quad (15)$$

On labor hours, the solutions are

$$\frac{dl^F}{dp^A} = -\frac{p^A R_Y Q(Q_{LL} Q_{BB} - Q_{LB}^2)}{\Omega_1} < 0, \quad (16)$$

$$\frac{dl^P}{dp^A} = \frac{p^A R_Y Q(Q_{LL} Q_{BB} - Q_{LB}^2) + (p^A Q_L R_Y - R_E)(Q_B Q_{LB} - Q_L Q_{BB})}{\Omega_1} > 0, \quad (17)$$

$$\frac{dL}{dp^A} = \frac{(p^A Q_L R_Y - R_E)(Q_B Q_{LB} - Q_L Q_{BB})}{\Omega_1} > 0, \quad (18)$$

where

$$\Omega_1 \equiv p^A \cdot (p^A Q_L R_Y - R_E)(Q_{LL} Q_{BB} - Q_{LB}^2) > 0. \quad (19)$$

A small increase in the price of the agricultural product increases the marginal income from inputting one unit of labor into production. Thus, a farmer increases the labor input for the agricultural production. Since the wage obtained by taking an off-farm job becomes less attractive for a farmer as compared with the marginal agricultural income, s/he decreases the labor hours for the off-farm work. Moreover, the real income for each farmer increases given labor hours, s/he decreases her/his own total labor hours in terms of the income effect.

The inequality $\partial l_P / \partial p^A > 0$ implies that, when a farmer hires labor, s/he increases the amount of hired labor. On the other hand, when a farmer takes an off-farm job, s/he decreases the labor hours for the job.

Proposition 1 *A small decrease in the price of the agricultural product (a) increases the total labor hours of each farmer, (b) decreases the labor hours of each farmer for the agricultural production.*

Let me turn to the effect of a change in p^A on the use of agrochemicals (B). From (13),

$$\frac{dB}{dp^A} = \frac{p^A(p^A Q_L R_Y - R_E)(Q_{LB} Q_L - Q_{LL} Q_B)}{\Omega_1} > 0 \quad (20)$$

A small change in the price of the agricultural product does not affect the relative amount of agrochemical use as compared with the labor input unless the wage and/or p^B change. Therefore, the input of agrochemicals increases according to an increase in the price.

Proposition 2 *A small decrease in the price of the agricultural product decreases the use of agrochemicals.*

Thus, if only the price of the agricultural product is affected, trade liberalization decreases the use of agrochemicals when the home country imports agricultural products.

Finally, let me focus on the effects of a change in p^A on income and welfare. From (13),

$$\frac{dY}{dp^A} = -\frac{p^{A2} Q R_E (Q_{LL} Q_{BB} - Q_{LB}^2)}{\Omega_1} > 0. \quad (21)$$

Moreover, from (1) and (6), the effect on a farmer's welfare is given by:

$$\frac{du}{dp^A} = u_Y Q > 0. \quad (22)$$

Consequently, the following proposition is established.

Proposition 3 *A small decrease in the price of the agricultural product decreases each farmer's income and welfare.*

Let me now introduce the transaction of renting arable land. For simplicity, I focus on the case in which a farmer chooses between renting out her/his all arable land to another farmer, renting another farmer's all arable land, and keep cultivating only her/his own land.

First, let me consider a farmer who rents out arable land. If farmer j keeps her/his land, her/his income is represented as (5). If s/he gives up farming and works only at a firm of the industry, and if s/he keeps her/his labor hours the same as that when farming, s/he gains wl^{jF} . The difference is

$$Y^{jO} = Y^j - wl^{jF}. \quad (23)$$

Therefore, if the rent offered is higher than Y^{jO} , farmer j has an incentive to rent out her/his arable land.

Second, let me consider a farmer who rents arable land from another farmer. If farmer k rents another farmer's land, s/he cultivates twice as much as her/his own land. Let $Y^{k'}$ and $l^{kF'}$ denote the income and her/his own labor hours in this case. Then, assuming that

$$Y^{kO'} = Y^{k'} - wl^{kF'}, \quad (24)$$

it is obtained that a farmer has an incentive to rent arable land from another farmer when the rent is lower than $Y^{kO'} - Y^{kO}$. Moreover, the transaction cost δ exists.

Consequently, for a transaction to hold, the following condition must hold:

$$Y^{kO'} - Y^{kO} - \delta \geq Y^{jO}, \quad j \neq k. \quad (25)$$

Since constant-returns-to-scale is assumed, $2Y^{jO} = Y^{jO'}$ for any farmer j holds. The lower is a farmer's productivity, the lower is the lowest price for renting out her/his arable land. Similarly, the lower is a farmer's productivity, the lower is the highest price for renting arable land from another farmer. Therefore, the demand (resp. supply) curve can be depicted as a downward (resp. upward) sloping curve. If there are no transaction costs, demand and supply curves cross at the medium-productivity farmer, which implies that every farmer either rents or rents out arable land, and half of total arable land is rented. Thus, if there are transaction costs, less than half of arable land is rented. Thick curves in Figure 1 indicate this situation. Some farmers with higher productivity rent arable land and become large-scale farmers, some farmers with lower productivity rent out their arable land, and the other farmers cultivate only their own land.

From (5), (7), and (8), the effects of a change in the price of the agricultural product grown in the area on Y^{jO} and $Y^{kO'}$ are given by:

$$\frac{dY^{jO}}{dp^A} = Q^j, \quad (26)$$

$$\frac{dY^{kO'}}{dp^A} = Q^{k'}. \quad (27)$$

Therefore, when the price of the agricultural product decreases, both demand and supply curves shift downward. Since the productivity of a farmer who rents land from another farmer is higher than that of any farmer who rents out her/his land, the shift of the demand curve is greater than that of the supply curve. Thus, the following proposition

is established.

Proposition 4 *A small decrease in the price of the agricultural product discourages the renting of arable land. This implies that the price decrease expands the number of small-scale farmers.*

Broken lines in Figure 1 show this situation. In other words, when a country imports agricultural products, trade liberalization could increase the number of small-scale farmers. Moreover, from Proposition 1, each farmer increases labor hours working in industry if s/he is a part-time farmer. Thus, part-time farming survives trade liberalization.

Turning now to the use of agrochemicals, from Proposition 2, each farmer uses fewer agrochemicals, as the price of the agricultural product decreases. However, from Proposition 4, a decrease in the price also makes the average scale of farms smaller. From Assumption 3, the latter effect on the use of agrochemicals depends on the production technology. Suppose that the higher is a farmer's productivity, the more use s/he makes of labor and agrochemicals. Then, a decrease in the number of large-scale farmers reduces the use of agrochemicals. On the other hand, suppose that the higher is a farmer's productivity, s/he inputs less labor and agrochemicals. Then, a decrease in the number of large-scale farmers increases the use of agrochemicals.

In the former case, a decrease in the price of the agricultural product necessarily decreases the use of agrochemicals. In the latter case, however, if the effect of a change in the average scale dominates the effect of a change in the input of agrochemicals by each farmer, the use of agrochemicals increases.

In the real world, the relationship between the average scale and the use of agro-

chemicals is ambiguous. Table 1, which is from the Survey on the farm management by the Ministry of Agriculture, Forestry, and Fisheries Japan, shows the ambiguity in the case of vegetables and fruits, although this data is category data. For example, the expenditure for fertilizers of the sixth group (5.0ha-7.0ha) is about twice as much as that of the fifth group (3.0ha-5.0ha). When it comes to the scale, the median for the former group is one and a half times as large as that for the latter group. Therefore, when focusing on these two groups, it is possible that, the larger is the scale of a farm, the more fertilizers farmers use. On the second and third groups, however, the result seems to be the opposite. In general, it is considered that the result depends on the product and the area.

One point should be noted. If a change in the price of the agricultural product increases both the number of small-scale farms and the input of agrochemicals, a policy which encourages arable land rental transactions may be justified. In general, a country gains from trade liberalization. Therefore, if changes in the prices of agricultural products are caused by trade liberalization, the government may expend some of its budget on this type of policy.

4 A Change in The Wage

Factor prices are also candidates which influence the behavior of farmers. In particular, wages are sometimes important, since farmers determine whether or not they give up farming according to wages in other sectors.

Trade liberalization is one of the factors that affect wages. In the past several decades, trade barriers on industrial products have been removed more rapidly than those on

agricultural products. Accordingly, in both the short and long runs, wages in one country have been influenced by changes in industrial structures. In this section, I examine the effects of a change in the wage on farmers' labor hours, their use of agrochemicals, and their welfare. Then, I investigate those effects through changes in arable land rental transactions. Although workers in the industry also change their labor hours, I focus on the farmers' behavior.

First of all, for simplicity, I rewrite Assumption 2 as follows for this section.

Assumption 4 *The prices of industrial products change, but the prices of agricultural products do not change. The changes in the prices of these industrial products do not affect the farmer's marginal rate of substitutability given income and leisure hours.*

See Appendix B for an example of the case in which this assumption holds. Moreover, it is assumed that Assumptions 1 and 3 hold.

First, I focus on the short run situation in which workers and farmers do not move across areas. In a rural area, there is only one industry. Therefore, if it is an industry in which the country has comparative advantage (resp. disadvantage), the wage in the area is likely to increase (resp. decrease) in the short run due to trade liberalization on industrial products.

Totally differentiating the first-order conditions and (5), I obtain:

$$\begin{pmatrix} -R_E - p^A Q_{LL} & -p^A Q_{LL} & -p^A Q_{LB} & R_Y \\ p^A Q_{LL} & p^A Q_{LL} & p^A Q_{LB} & 0 \\ p^A Q_{LB} & p^A Q_{LB} & p^A Q_{BB} & 0 \\ -p^A Q_L & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \frac{dl^F}{dw} \\ \frac{dl^P}{dw} \\ \frac{dB}{dw} \\ \frac{dY}{dw} \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ l^P \end{pmatrix}, \quad (28)$$

On labor hours, the solutions are

$$\frac{dl^F}{dw} = \frac{p^A(1 + l^P R_Y)(Q_{LL}Q_{BB} - Q_{LB}^2)}{\Omega_1}, \quad (29)$$

$$\frac{dl^P}{dw} = \frac{-p^A(1 + l^P R_Y)(Q_{LL}Q_{BB} - Q_{LB}^2) + p^A(p^A Q_L R_Y - R_E) \cdot Q_{BB}}{\Omega_1}, \quad (30)$$

$$\frac{dL}{dw} = p^A \frac{(p^A Q_L R_Y - R_E) \cdot Q_{BB}}{\Omega_1} < 0. \quad (31)$$

An increase in w decreases the marginal benefit of hiring one unit of labor, and increases the opportunity cost of not taking one unit of off-farm job. Thus, a farmer decreases the total labor input for the production of agricultural products ($dL/dw < 0$). A farmer also changes her/his own labor hours (l^F). In terms of the substitution effect, s/he increases l^F , which does not depend on whether s/he hires labor or s/he works at an off-farm workplace. This effect is represented by 1 in the first parentheses in the numerator of (29). On the other hand, in terms of the income effect, s/he increases her/his own labor when s/he hires labor, whereas s/he decreases it when s/he has off-farm work. The reason is that a farmer compensate income loss with her/his own labor when s/he hires labor, and a farmer prefers leisure hours to labor hours due to an increase in income when s/he has off-farm work. This effect is represented by $l^P R_Y$ in the numerator of (29). In total, an increase in w increases a farmer's own labor hours when s/he hires labor ($l^P > 0$), whereas the effect is ambiguous when a farmer has off-farm work ($l^P < 0$).

Moreover, l^P also changes due to a small increase in w . As noted above, when a farmer hires labor, s/he decreases the amount of hired labor. On the other hand, when s/he has off-farm work, the effect on l^P is ambiguous due to the income effect. An increase in the wage implies an increase in the real income. Thus, s/he has an incentive to decrease her/his labor hours for the industry.

Consequently, the following proposition is established.

Proposition 5 *An increase in the wage decreases the amount of labor for the production of agricultural products. Moreover, when a farmer hires labor, an increase in the wage increases (resp. decreases) the farmer's own labor hours (resp. hiring labor hours). On the other hand, when a farmer works at a off-farm workplace, the effect of an increase in the wage on her/his own labor hours is ambiguous.*

Let me turn to the effect of a change in the wage on the use of agrochemicals (B).

From (28),

$$\frac{dB}{dw} = -\frac{p^A Q_{LB}(p_A Q_L R_Y - R_E)}{\Omega_1} < 0. \quad (32)$$

In terms of the substitution effect, a farmer increases the use of agrochemicals as the wage increases, since the relative price of agrochemicals becomes lower. However, a farmer decreases the output of the agricultural product. This effect dominates the substitution effect.

Proposition 6 *An increase in the wage decreases the use of agrochemicals.*

Finally, let me focus on the effect of a change in the wage on income and welfare.

From (28),

$$\frac{dY}{dw} = \frac{p^{A2}(p_A Q_L + l^P R_E) \cdot (Q_{LL} Q_{BB} - Q_{LB}^2)}{\Omega_1}. \quad (33)$$

When a farmer has an off-farm work, $l^P < 0$. Thus, the sign of the first parentheses in the numerator is positive. Moreover, from (1) and (6), the effect of a change in the wage on the farmer's welfare is given by:

$$\frac{du}{dw} = (-u_E + u_Y p_A Q_L) \cdot \frac{dl^F}{dw} - u_Y l^P = -u_Y l^P. \quad (34)$$

Thus, whether or not the farmer's welfare or income increases depends on the sign of l_2 .

The results are summarized as follows.

Proposition 7 *An increase in the wage increases a farmer's income and welfare, if s/he takes an off-farm job. On the other hand, if s/he hires labor, her/his welfare necessarily decreases, whereas the effect on income is ambiguous.*

Let me now consider the transaction of renting arable land. Similar to the previous section, I focus on the case in which a farmer chooses among renting out her/his all arable land to another farmer, renting another farmer's all arable land, and keep cultivating only her/his own land.

The condition for the transaction to hold is given by (25). Then, from (5), (7), and (8), the effects of a change in the wage on Y^{jO} and $Y^{kO'}$ are given by:

$$\frac{dY^{jO}}{dw} = -L^j, \quad (35)$$

$$\frac{dY^{kO'}}{dw} = -L^{k'}. \quad (36)$$

Therefore, when the wage increases, both demand and supply curves shift downward. The reason is that farmers have incentives to take more off-farm jobs. In this case, whether the amount of transactions increases or decreases depend on the technology.

Since there are transaction costs (δ), in equilibrium, the productivity of farmers who rent arable land is greater than that of renters. Thus, the following proposition holds.

Proposition 8 *If a farmer whose productivity is greater uses more inputs, a small increase in the wage discourages the renting of arable land. On the other hand, a farmer whose productivity is greater uses less inputs, a small increase in the wage encourages the renting of arable land.*

When the wage decreases in the latter situation, arable land rental transactions decrease, which is depicted in Figure 2.

From Propositions 6 and 8, the following proposition is established.

Proposition 9 *A small increase in the wage decreases the use of agrochemicals, even if a change in rental transactions is taken into consideration.*

When trade in industrial products is liberalized, whether or not the wage in a rural area increases depends on the industry established in the area. If there is an exporting industry, trade liberalization raises the wage in the area. Therefore, the industrial structure of a rural area may influence the change in the farmer's behavior.

Turning now to the medium and long run effects, the medium term effect is a little more complicated. It is assumed that, in the medium term, there is a difference in the wage between areas, and farmers and workers move across areas. In the case of the area in which the wage increases, the results are the same as the short run effect, since farmers do not have incentives to work in other areas. Hence, I focus on the area with a comparative-disadvantage industry.

Unless farmers give up farming, Propositions from 5 through 7 hold. Therefore, I focus on arable land rental transactions.

First, let me consider a farmer who rents out arable land. In this case, when a farmer determines to give up farming, s/he is likely to work in any other area in which the wage is higher. Therefore, s/he compares the present utility with the utility which s/he will gain when s/he works in the other area. If the former utility is greater than the latter, s/he claims a positive price to rent out her/his arable land. On the other hand, if the latter is greater than the former, s/he may give up farming without any deal on renting.

Suppose that the wages in areas with comparative-disadvantage industries decrease marginally, whereas the wages in areas with the comparative-advantage industries are fixed. In this case, the utility which a farmer will gain when s/he works in one of the latter areas does not change, while the present utility decreases. Therefore, the lowest price to rent out her/his arable land decreases, which implies that the supply curve shifts downward. The direction of the shift is the opposite from that in the short run.

Moreover, the utility obtained when s/he gives up farming and works in this area reduces as the wage decreases, which implies that the farmer's lowest price for renting out is lower when s/he has a choice of working in the other area.⁸ Therefore, as compared with the short run, the supply is larger in the medium term. In fact, as noted above, some farmers give up farming even if no one rent her/his arable land.

Second, let me consider a farmer who rents arable land from another farmer. If her/his present utility is greater than the utility obtained when s/he gives up farming and works in the other area, the direction of the change in demand is the same as the short run effect. Therefore, as the wage decreases, the highest price s/he offers to rent arable land becomes higher. This implies that the demand curve shifts upward.

On the other hand, if a farmer's present utility is smaller than the utility obtained when s/he gives up farming and works in the other area, s/he compares the utility which s/he gains when s/he rents land from another farmer with the worker's utility in the other area. In this case, the highest price s/he offers to rent arable land is lower than that in the short run. Moreover, the utility when s/he rents arable land from another farmer reduces as the wage in this area decreases as far as s/he is a part-time farmer.

⁸The moving cost is not taken into consideration for simplicity.

Therefore, as the wage in this area decreases, the highest price s/he offers to rent arable land becomes lower. This implies that the demand curve shifts downward.⁹

In summary, if the difference in the wage between areas is small, the amount of transactions is greater than that in the short run. Moreover, a small decrease in the wage in the area with a comparative-disadvantage industry is likely to encourage the transaction of renting arable land. This situation is depicted in Figure 3. On the other hand, if the difference in the wage between areas is large, the amount of transactions is smaller than that in the short run. Some farmers give up farming without any deal on renting. This situation is indicated in Figure 4, in which the thick line (resp. the broken line) represents the supply (resp. demand) curve. Moreover, a small decrease in the wage in the area with a comparative-disadvantage industry may discourage the transaction.

Finally, let me consider the long run effect. In the long run, production factors move across industries, and the wage is the same in all areas.¹⁰ Thus, the results are the same as those in the short run. However, there is one important difference. In the long run, even if the wages in all areas are the same, some workers including farmers who have given up farming work in the other area. Therefore, the populations of areas with comparative-disadvantage industries are smaller than those before the wages change.

One point should be noted. In the real world, there is irreversibility. For example, once a farmer (resp. a farm household) gives up farming and move to the urban area, it

⁹In the case of a full-time farmer who hires labor from the outside of the farm, the demand curve shifts upward, since a decrease in the wage raises the farmer's utility.

¹⁰Whether or not the wage in the home country increases depend on the production technologies, the industrial structure, and the endowment of production factors.

is difficult to come back to her/his home area and to begin farming again. Similarly, once a certain space of arable land is abandoned, it is costly for farmers to cultivate the land again. Therefore, once a large scale of arable land is abandoned in the medium term, the long run effect may not be the same as noted above. In such a case, abandonment of cultivation and a decrease in the population of a rural area may cause serious problems for the area. Even if the number of large-scale farmers increases, and even if they become full-time farmers, they may face difficulty in hiring part-time workers for their farms. In fact, some areas in Hokkaido, in which the average scale is much greater than that of other parts of Japan, has been facing this difficulty.

5 Local Labor Markets and Changes in Prices

In Section 3, I have investigated the effects of changes in the prices of agricultural products. In the analysis, however, the effect of the price change on the local wage of an rural area was not taken into consideration. In this section, introducing a change in the wage due to a change in the price of the agricultural product grown in the area, I examine the short run effect of the price change. Thus, Assumption 1 is dropped, whereas Assumptions 2 and 3 hold. For example, farmers cannot affect the wage in terms of the whole country. In a specific rural area, however, the ratio of farmers to industrial workers is not very small, and accordingly, a change in their behavior may influence the local wage of the area. In the following, I focus on part-time farmers.

First, let me examine the local labor market. Firms in the industry demand labor for their production activities, while both workers and farmers supply labor. Then, the

equilibrium condition is given by:

$$L^D[w] = L^I[w] + L^P[w, p^A], \quad (37)$$

where L^D and L^I denote total labor demand in the local labor market and total labor supply by workers in the area, respectively. Moreover, L^P is labor supply by farmers for the industry. Since l^P is negative when a farmer takes an off-farm job in the previous sections, it is defined that $L^P = -\sum l^P$.

Thus, the effect of a change in the price of the agricultural product on the wage is given by:

$$\frac{dw}{dp^A} = \frac{\frac{\partial L^P}{\partial p^A}}{\frac{\partial L^D}{\partial w} - \frac{\partial L^I}{\partial w} - \frac{\partial L^P}{\partial w}} \quad (38)$$

From (17), $\partial L^P/\partial p^A$ is negative. Moreover, from the definition of the structure of the industry, $\partial L^D/\partial w$ is also negative. On the other hand, labor supply could be either increasing or decreasing in the wage. When the income effect dominates the substitution effect, $\partial L^I/\partial w$ is negative, and the similar result may be obtained for labor supply by farmers ((30)). However, for the local labor market to be stable, the denominator of (38) must be negative. Thus, the following proposition holds.

Proposition 10 *Suppose that the local labor market is stable. A small decrease in the price of the agricultural product lowers the local wage.*

Let me examine the effect of a change in the price of the agricultural product on the part-time farming of farmers, which is given by

$$\frac{dL^P}{dp^A} = \frac{\partial L^P}{\partial p^A} + \frac{\partial L^P}{\partial w} \frac{dw}{dp^A}. \quad (39)$$

The first term is negative from (17), and dw/dp^A is positive. Therefore, if $\partial L^P/\partial w$ is negative, the sign of (39) is negative, which implies that a decrease in the price of the

agricultural product encourages the part-time farming even if a change in the wage is taken into consideration.

On the other hand, if $\partial L^P/\partial w$ is positive, workers behavior play a key role in determining the change in the farmers' behavior. The substitution effect dominates the income effect for workers, $\partial L^I/\partial w$ is positive. Thus,

$$\frac{\partial L^P}{\partial w} \frac{dw}{dp^A} = \frac{\partial L^P}{\partial w} \cdot \frac{\frac{\partial L^P}{\partial p^A}}{\frac{\partial L^D}{\partial w} - \frac{\partial L^P}{\partial w} - \frac{\partial L^I}{\partial w}} < -\frac{\partial L^P}{\partial p^A} \quad (40)$$

holds. Therefore, a decrease in the price encourages the part-time farming.

Only in the case in which the income effect dominates the substitution effect for workers, (40) may not hold, and a decrease in the price of the agricultural product may discourage the part-time farming. The intuition is as follows. When the price decreases, farmers increase their labor hours for off-farm work. On the other hand, a decrease in the wage decreases the labor hours for off-farm work. However, since workers increase their labor hours, and the wage may greatly lower. In such a case, the latter effect dominates the former effect for farmers, and their labor hours for off-farm work decrease.

Let me turn to the effect of a decrease in the price on the inputs for the agricultural production, which are given by

$$\frac{dl^F}{dp^A} = \frac{\partial l^F}{\partial p^A} + \frac{\partial l^F}{\partial w} \frac{dw}{dp^A}, \quad (41)$$

$$\frac{dB}{dp^A} = \frac{\partial B}{\partial p^A} + \frac{\partial B}{\partial w} \frac{dw}{dp^A}. \quad (42)$$

The first terms in the right-hand side of both equations are positive, and the second terms are negative. It is more likely that dl^F/dp^A and dB/dp^A are negative when workers increase their labor hours as the wage decreases than when they decrease them. The fact that they are negative implies that a decrease in the price of the agricultural

product increases the use of agrochemicals.

Moreover, even if the substitution effect dominates the income effect for workers, each of them could be negative. For example, using (17), (30), and (38), it is obtained that

$$\frac{\partial l^F}{\partial p^A} - \frac{\partial l^F}{\partial w} \frac{\frac{\partial L^P}{\partial p^A}}{\frac{\partial L^P}{\partial w}} < 0 \quad (43)$$

holds, when $-Q_{BB}p^AQR_Y > (1+l^pR_Y)(-Q_LQ_{BB}+Q_BQ_{LB})$. Therefore, even if $\partial L^D/\partial w$ and $\partial L^I/\partial w$ are added as (38), dl^F/dp^A could be negative.

Proposition 11 *Even if there is no change in arable land rental transactions, a small decrease in the price of the agricultural product in a rural area may increase both labor inputs and the use of agrochemicals in the area. It is more likely to happen when workers in the industrial sector increase their labor hours as the wage decreases.*

The medium and long run effects are the same as the results in the previous section. If the prices of industrial products do not change, the wage does not change as far as the ratio of farmers to industrial workers in the whole country is very small. In this case, in the long run, the wage comes back to the initial level, although some farmers or/and workers work in the other area.

6 Concluding Remarks

In this paper, taking into consideration arable land rental transactions, I have investigated the effects of changes in prices and wages on the micro behavior of farmers, in particular, on the use of agrochemicals and part-time farming.

I have obtained three main results. First, a small decrease in the price of an agricultural product grown in a rural area decreases the use of agrochemicals in the area if arable

land rental transactions are not taken into consideration. A small decrease in the price of the agricultural product, however, discourages those transactions, which increases small-scale farmers with lower productivity. Thus, if farmers with low productivity use more agrochemicals than farmers with high productivity, total use of agrochemicals in the area may increase due to a decrease in the price of the agricultural product.

Second, a small increase in the wage decreases the use of agrochemicals if arable land rental transactions are not taken into consideration. Moreover, the increase influences rental transactions so that fewer agrochemicals are used. Therefore, total use of agrochemicals in an area decreases due to an increase in the wage. Moreover, in the case of a change in the wage, the medium and long term effects were examined.

Third, even if arable land rental transactions are not taken into consideration, when a change in the price of the agricultural product affects the local wage, the use of agrochemicals may increase. The reason is that the local wage decreases due to a decrease in the price of the agricultural product, which makes farmers input more production factors.

It is clear that countries gain from trade liberalization. Assuming the trend towards more liberalized trade, there are three important factors that determine the states of rural areas (the use of agrochemicals, part-time farming, and welfare): production technology, rental transactions of arable land, and local wages. When it comes to production technology, whether or not large-scale farmers use fewer inputs is crucial for determining the effect of trade liberalization. In reality, the development of new pesticides or new sprinkling techniques is directed so that sprinkling is less frequent and the remaining time is shorter. It can be said that this type of effort for the development should be

encouraged by public research institutions.

Assuming the development of new technology and techniques as noted above, to decrease the transaction costs may also be needed. It is often not very easy to make a deal on renting arable land even if the deal is economically rational. In some cases, regulations on those transactions sometimes prevent farmers from renting or renting out arable land to or from other farmers. In other cases, arable land in an area is divided into small lots and the ownership is complicated. Therefore, unnecessary regulations and obstacles should be removed.

I did not take into consideration the dynamic process of changes in arable land rental transactions, part-time farming, and the use of agrochemicals. As noted in Section 4, the irreversibility may cause serious problems in rural areas. Therefore, the dynamic process of this issue should be investigated more in detail. Given the trend toward liberalized trade, domestic policies consistent with international trade rules to improve the situations in rural areas are also important subjects in this field. These subjects are my future tasks.

Appendix A

Suppose that the production function is given by:

$$Q = L^\alpha B^\alpha T^{1-2\alpha}. \quad (44)$$

From (44), the first-order conditions are:

$$\frac{\partial Y}{\partial L} = \alpha L^{\alpha-1} B^\alpha T^{1-2\alpha} = \frac{w}{p}, \quad (45)$$

$$\frac{\partial Y}{\partial B} = \alpha L^\alpha B^{\alpha-1} T^{1-2\alpha} = \frac{p^B}{p}. \quad (46)$$

From these first order conditions, it is obtained that:

$$\frac{B}{L} = \frac{w}{p^B}, \quad Q = \left(\frac{w}{p^B}\right)^\alpha L^{2\alpha} T^{1-2\alpha}. \quad (47)$$

Solving the profit maximization problem, it is obtained that:

$$L = \alpha^{-\frac{1}{2\alpha-1}} \left(\frac{w}{p}\right)^{\frac{1-\alpha}{2\alpha-1}} \left(\frac{p^B}{p^A}\right)^{\frac{\alpha}{2\alpha-1}} T, \quad (48)$$

$$Y = \alpha^{-\frac{2\alpha}{2\alpha-1}} \left(\frac{wp^B}{p^{A2}}\right)^{\frac{\alpha}{2\alpha-1}} T. \quad (49)$$

Suppose that α is small, such as around 0.1. Then, it is likely that, the smaller is α , the less inputs a farmer uses, and the more output s/he produces. Thus, as a farmer's productivity becomes higher, the amounts of inputs are monotonically decreasing.

On the other hand, suppose that α is relatively large, such as around 0.4. Then, it is likely that, the smaller is α , the more inputs a farmer uses, and the more output s/he produces. Thus, as a farmer's productivity becomes higher, the amounts of inputs are monotonically increasing.

Appendix B

Suppose that the utility function is given by:

$$u = U[E, g[A, x_1, x_2, \dots, x_N]]. \quad (50)$$

The subutility is:

$$g[A, x_1, x_2, \dots, x_N] = A^{\frac{1}{N+1}} \prod_{i=1}^N x_i^{\frac{1}{N+1}}, \quad (51)$$

where A and x_i denote the consumption of the agricultural product and the industrial product i , respectively. Solving the utility maximization problem for the subutility (51) subject to the budget constraint:

$$p^A A + \sum_{i=1}^N p^i x^i = I, \quad (52)$$

where I denotes the income, the indirect subutility function is obtained:

$$G[p^A, p_1, p_2, \dots, p_N, I] = \frac{I}{N+1} \cdot (p^A p_1 p_2 \dots p_N)^{\frac{1}{N+1}}. \quad (53)$$

Therefore, any changes in prices that does not change $p^A p_1 p_2 \dots p_N$ do not influence the marginal rate of substitution between leisure and income.

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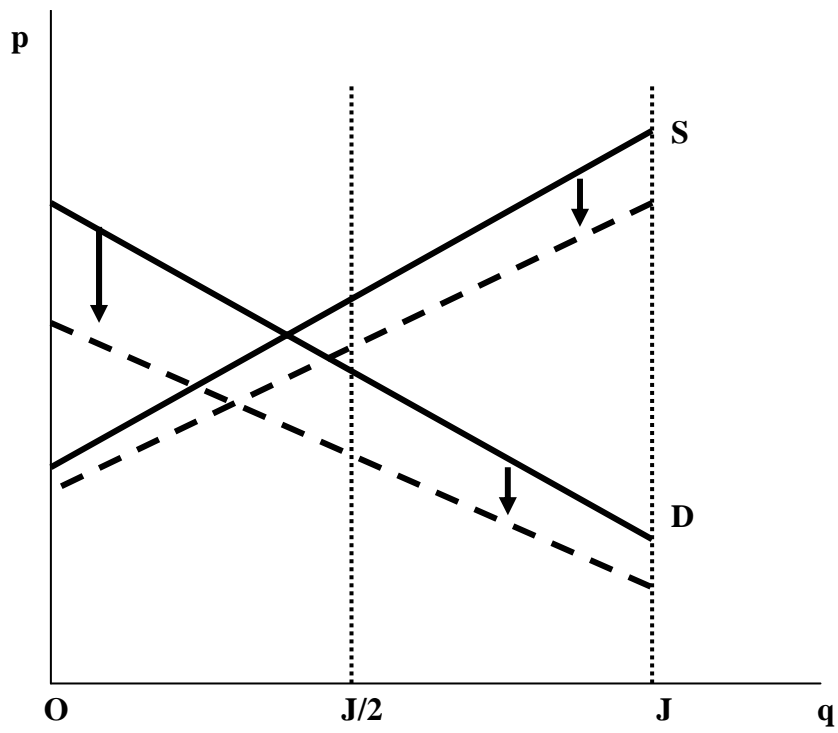


Figure 1. Demand and Supply of Arable Land

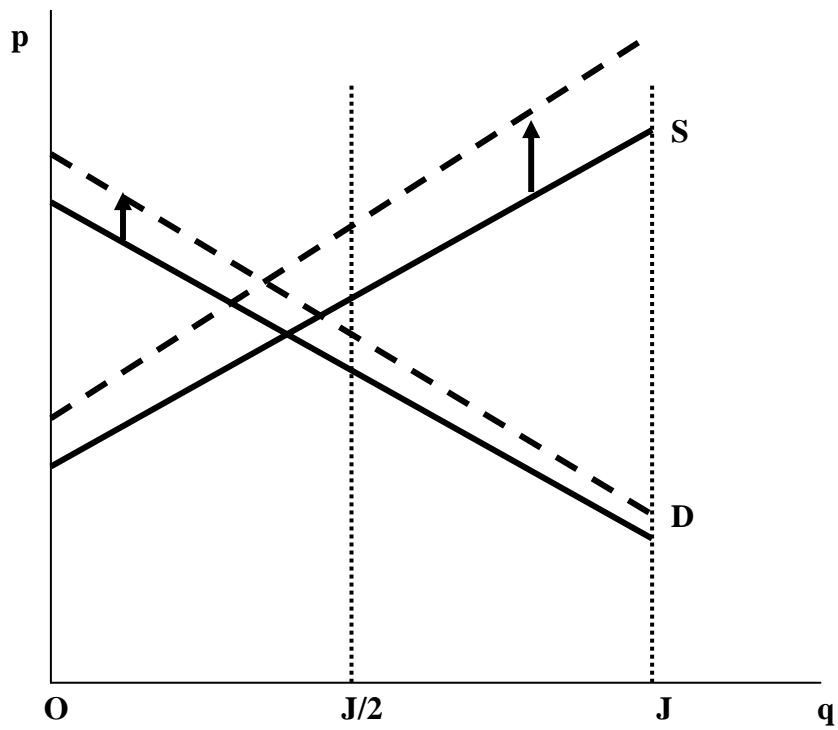


Figure 2. A decrease in the wage in the short run

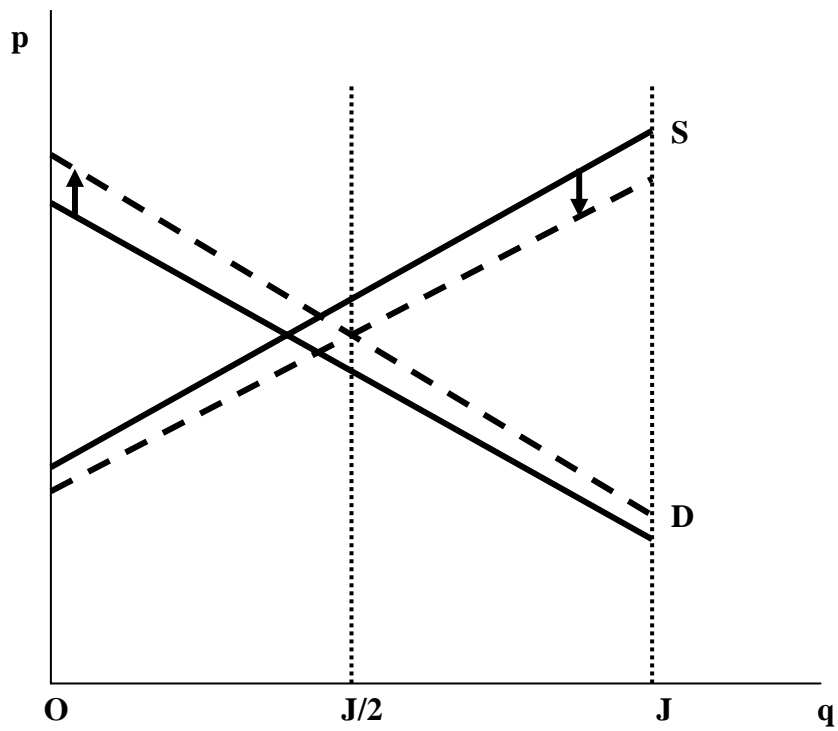


Figure 3. A decrease in the wage in the medium term (1)

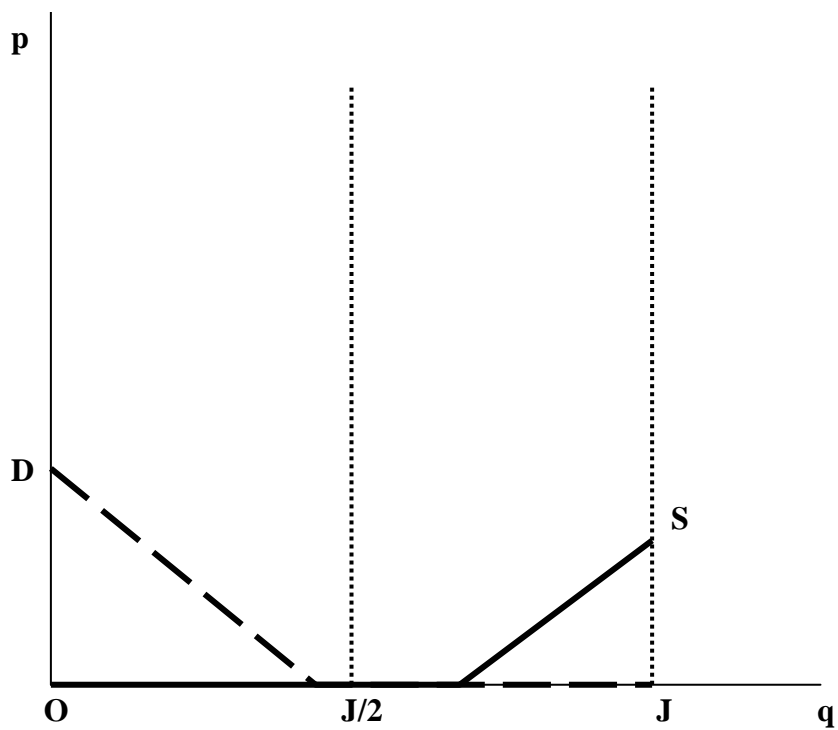


Figure 4. A decrease in the wage in the medium term (2)

Scale(ha)	Fertilizer Use for Vegetables	Pesticide and Herbicide Use for Vegetables	Fertilizer Use for fruits	Pesticide and Herbicide Use for fruits
less than 0.5	205	144	110	132
0.5 - 1.0	357	234	206	249
1.0 - 2.0	482	349	327	463
2.0 - 3.0	756	532	476	642
3.0 - 5.0	1076	791	735	1000
5.0 - 7.0	2086	1660	(more than	(more than 3.0)
more than 7.0	2712	2050		

(thousand yen, 2004)

Table 1. The Expenditure for Fertilizers, Pesticides, and Herbicides

Source: Survey on Farm Management, the Ministry of Agriculture, Forestry, and Fisheries Japan.

This data is downloadable in Japanese.

(<http://www.maff.go.jp/toukei/sokuhou/data/einou-yasaikajukaki2004/einou-yasaikajukaki2004.pdf>)