Proposal method for avoiding risk and stabilizing farmer income with derivatives

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Abstract: - In this study, we propose a put option on a farm product to stabilize farmer income and a call option to stabilize consumer cost. Agriculture in Japan involves many problems, including an aging and decreasing farmer population, and price competition with imports. Particularly for farm products vulnerable to insufficient sunlight and to typhoons and other inclement weather, market price tends to rise and fall, and farmer income is unstable. This in turn strongly affects market sales of processed foods made from these farm products, and on the dietary habits of and costs to us as their consumers. Although derivatives are a means of avoiding the risk of market price fluctuation, they have had little application to farm products. Futures trading on vegetables is a form of derivatives for existing farm products, but again has only been applied to a few products and only on a small scale; furthermore, a method of pricing that reflects the characteristics of farm products has not been well established. The effect of futures trading for stabilizing farmer income is therefore small, so risk to the farmer from market price fluctuation and the burden on the farmer remain large.

In the present study, we take the potato as an example of a farm product with a market price liable to change, and focus in particular on potato farmers in Hokkaido, who serve as the mainstay of potato farming in Japan, and as their trading counterparts, we focus on the companies that produce and sell processed foods with Hokkaido potatoes as production material. We use as a reference data their market prices and shipment amounts over the past 20 years of trading at the Tokyo Metropolitan Central Wholesale Market, which is the main destination of potatoes produced in Hokkaido. We take as the farmer income the amount paid by the company for the potato purchases. The farmer income and the company cost vary with the market price at the time of trade. In this study, we propose a derivative for stabilization of farmer income and company cost. The farmer is given a put option to avoid the risk of the market price going below a strike price set in advance. The company is given a call option with a strike price set in advance to avoid the risk of the market price rising above the strike price.

The annual farmer income and company cost are calculated from the market price and shipment amount, and the standard deviations are taken as the variations in income and cost. Under adoption of these options, the derivative is evaluated in terms of the reduction in the standard deviations of farmer income and company cost, and thus the stabilization obtained.

The farmer and company option holders each pay a premium to the option provider, who obtains boundaries for the strike price and the premium pricing that will allow it to gain a certain profit. Within these boundaries, the strike prices yielding the smallest standard deviations in farmer income and company cost are calculated. When the strike prices are set, in order to gain a profit, the option provider sets the premiums as the consideration necessary for stabilization of farmer income and company cost. The derivative is evaluated on the basis of the standard deviation reductions due to holding the options and the related consideration.

Trading models applicable to farm products other than potatoes are constructed by investigating the characteristics of trading on the farm product from the call and put option pricing. The effectiveness of the derivative proposed in this study at reducing the burden on the farmer is demonstrated by comparing the reductions in the standard deviations in income and cost and the related consideration to cases in which no option was adopted and in which futures trading was performed.

Key-Words: - Derivative, Real option, Call option, Put option, Futures trading, Market analysis

1 Introduction

1.1 Background of study

Japan farm production involves many problems, including an aging and decreasing farmer population, a successor shortage, declines in farm production and self-sufficiency in farm products due to Trans-Pacific Partnership Agreement participation, and price competition with imports. Farm products vulnerable to insufficient sunshine, typhoons, and other intemperate weather are particularly apt to pose problems of rising and falling market prices and instability in farmer income. They also pose problems of declining farm product harvests and sharp fluctuations in market prices, which strongly affect our dietary habits as food product consumers.

Potatoes are a primary example of farm products strongly affected by weather conditions. Hokkaido potato farming, which accounts for approximately 80% of total domestic production, suffered major damage in June 2016 due to a lack of sunshine and again two months later in August due to successive typhoons, resulting in a soaring market price. This in turn led to a discontinuation of sales of some food products by food processing companies using potatoes produced in Hokkaido because of the difficulty of obtaining these materials.

1.2 Problems in farm product trading

With fluctuation in market prices for farm products, both farmer income and cost to the consumer become unstable. Derivatives are a means of avoiding risk in fluctuating market prices. They are typically composed of contracts and trading derived from basic assets and commodities, and commonly involve futures trading and option trading. The value of a derivative is determined relative to the basic product market price as an indicator.

At present, however, derivatives trading mainly comprises trading on stock exchanges, and other securities and currency transactions, and only slightly involves farm products.

Futures trading for vegetables provides examples of farm product derivatives. In 2004, futures trading was available for potatoes and 13 other main vegetables used largely in commercial applications and processing. The trading was performed on average vegetable prices. In 2006, however, potato trading was discontinued and vegetable futures trading was delisted the following year. At present, only soybeans, corn, and adzuki beans are listed on the Tokyo Commodity Exchange. In the futures trading now performed, pricing is not done in accordance with the characteristics of farm products, but rather emphasis is placed on the consumer, so the burden on the producer remains large.

1.3 Study objectives

The objectives of this study are to propose a new derivative on farm products for which market prices are apt to change as the result of inclement weather, to allow the risk of market price fluctuation to be avoided, and stabilize both farmer income and consumer cost. By giving the farmer a put option, the derivative avoids the risk of falling market price. By giving the consumer a call option, it avoids the risk of rising market price. This study takes the standard deviations of annual farmer income and consumer cost as the variations. Against past data, the changes in farmer income and consumer cost with the holding of each option proposed in this study are simulated. In years when market prices rose or fell, a reduction in fluctuations in farmer income and consumer cost is taken to indicate stabilization. The farmer income and consumer cost that occur in three cases are compared: with no derivative adoption, with futures trading on average price, and with adoption of the derivative proposed in this study. The effectiveness of the derivative is evaluated in terms of the calculated reductions in the standard deviations of income and cost, and the consideration required for that purpose. As the consideration for holding the options, premiums must be paid by the farmer and the consumer. The premium must be able to yield a certain profit to the derivative provider for taking over the risk of variation in market price, and under that condition, the farmer and the consumer must obtain the market price setting that can most reduce fluctuations in income and cost, to construct a derivative that can enable trading and pricing appropriate to the farm product.

More specifically, the primary objectives of this study are to create a new derivative for farm products, show a method for pricing the derivative that reflects the characteristics of farm products, show its effect by simulation, compare the proposed derivative and existing farm product derivatives, and show its effectiveness by investigating its reduction of the standard deviations of income and cost and related considerations.

In Section 2, we take potatoes as an example of a farm product with a large variation in market price and examine potato farming characteristics, trading partner selections, and market price transitions. In Section 3, we define the call option and put option trading proposed in this study, the farmer income, and the consumer cost. In Section 4, we discuss the pricing of the call option proposed in this study and simulate the variation in cost to the consumer given this call option and the standard deviation reduction. In Section 5, we discuss the put option pricing and simulate the variation in income of the farmer given the put option and the reduction in standard deviation. In Section 6, we describe the option provider profit and show the effectiveness of this study by comparison with cases of option non-adoption and futures trading.

2 Potato producer and purchasing company

In this study, we focus on potatoes as a farm product apt to fluctuate in market price and take as an example potato farming in Hokkaido, which accounts for approximately 80% of total domestic production of potatoes in Japan.

As the market counterpart for potatoes produced in Hokkaido, we take the Tokyo Metropolitan Central Wholesale Market which is their main destination, and has nine locations: Tsukiji, Ota, Toshima, Yodobashi, Kasai, Kita Adachi, Itabashi, Setagaya, and Tama New Town.

The study period is the 20 years from 1998 to 2017, and the study focuses on the 'Danshaku' potato variety produced in Hokkaido and shipped to the Tokyo Metropolitan Central Wholesale Market. The data used are the potato shipment amount and the price per kilogram (Fig. 1).

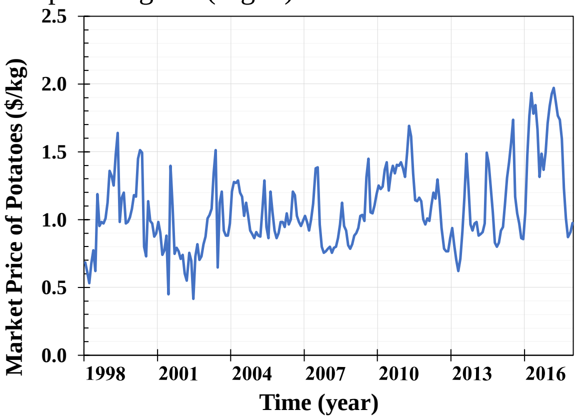

Fig. 1. Tokyo Metropolitan Central Wholesale Market price of 'Danshaku' potatoes produced in Hokkaido

The highest and lowest prices for 1 kg of potatoes were \$1.97 and \$0.414, respectively. The mean price was \$1.08 and the standard deviation was \$0.298.

As the trading counterpart for potatoes at Tokyo Metropolitan Central Wholesale Market, we selected a company that sells processed food using potatoes produced in Hokkaido as material. Derivatives were provided to both the farmers that sold the potatoes and to the companies that purchased them. The derivatives were priced both to stabilize the farmer income and the company cost and to allow the provider to gain a certain profit.

3 Proposed derivatives and trading model

3.1 Call option

The call option is the right obtained by paying a premium to purchase a product after a certain period for a price set in advance. In this study, it is given to the company that purchases the potatoes. In addition to the cost of purchase of the potatoes, the company pays the cost of the premium for the call option. The total cost is thus the sum of the cost of the potato purchase and the cost of the premium. The objective of the call option is to reduce the standard deviation of the total cost. The strike price of the call option and the premium are set for that purpose and the option is given to the company for all of the potatoes that it purchases.

Since the company can reduce its cost by purchasing potatoes at a low price, it is given the right to select the lower of the market price and the call option strike price for its purchase of potatoes (Fig. 2).

For the option provider to gain a certain profit, the price is set so that, in the long term, the cost of the premium is larger than the reduction in cost of potato purchase by the option of the company purchasing the potatoes.

3.2 Put option

The put option is the right obtained by paying the premium to sell a product after a certain time at a price set in advance. In the example in this study, it is given to the farmer selling the potatoes. Farmer income is gained by selling potatoes and the cost is generated by the premium on the put option. The difference between the income from potato sales and the cost of the premium is the net income. The objective of the put option is to reduce the standard deviation of the net income. To that end, the put option strike price and the premium are set, and the put option is given to the farmer for all potatoes sold.

The farmer, to increase income by selling potatoes for a high price, is given the right to select the higher between the market price and the put option strike price (Fig. 2).

For the option provider to gain a certain profit, the farmer sets the price so that in the long term the cost of the premium is higher than the increase by the option in income from potato sales.

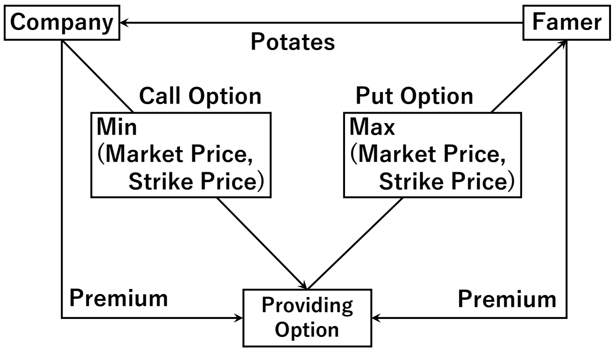

Fig. 2. Composition of triparty trading

3.3 Trading model and net income

If no option is adopted from the initial time to time n, then the farmer income cumulative total is F_0 and the company cumulative cost is G_0. Here, the company cost in payment for potato purchase all becomes farmer income in a simple market and the trading is

$$F_0 = G_0 = \sum_{t=1}^{n} X_t \cdot S_t \qquad \text{-----(1)}$$

X_t: Potato total shipment amount at time t
S_t: Potato market price at time t

The income from potato sales by the farmer holding the put option adjusted by the difference in cost as payment of the option premium gives the cumulative net income F_1 as

$$F_1 = \sum_{t=1}^{n} X_t \cdot \max(S_t, K_p) - \sum_{t=1}^{n} X_t \cdot P \qquad \text{-----(2)}$$

P : Put option premium
K_p: Put option strike price

The farmer can increase the income from selling potatoes by holding the put option. For the option provider to gain a certain profit, the cost of the premium to the farmer must not be larger than that increase. The difference becomes the profit of the option provider.

$$\sum_{t=1}^{n} X_t \cdot P \geq \sum_{t=1}^{n} X_t \cdot \max(S_t, K_p) - \sum_{t=1}^{n} X_t \cdot S_t \quad \text{-----(3)}$$

For the company holding the call option, with the total cost as the sum of the cost of purchasing the potatoes and the cost of the option premium, the cumulative total cost G_1 is then

$$G_1 = \sum_{t=1}^{n} X_t \cdot \min(S_t, K_c) - \sum_{t=1}^{n} X_t \cdot C \qquad \text{------(4)}$$

C: Call option premium
K_c: Call option strike price

The company can reduce the cost of purchasing potatoes by holding a call option. For the option proposer to gain a certain profit, the company cost for the premium must not exceed that reduction. The difference in amount becomes the profit of the option provider.

$$\sum_{t=1}^{n} X_t \cdot C \geq \sum_{t=1}^{n} X_t \cdot S_t - \sum_{t=1}^{n} X_t \cdot \min(S_t, K_c) \quad \text{-----(5)}$$

The profit and loss of the three parties—farmer, company, and option provider—vary with the market price as graphed in Fig. 3.

For the farmer and the company, profit is generated without limit accompanying rise and fall in market price. A flat market price results in a loss, but the loss is limited to the premium paid.

Against that, for the option provider, a flat market price results in income from the premiums received from both farmer and company, but the maximum is limited. Accompanying rise and fall in market price, loss is generated without limit.

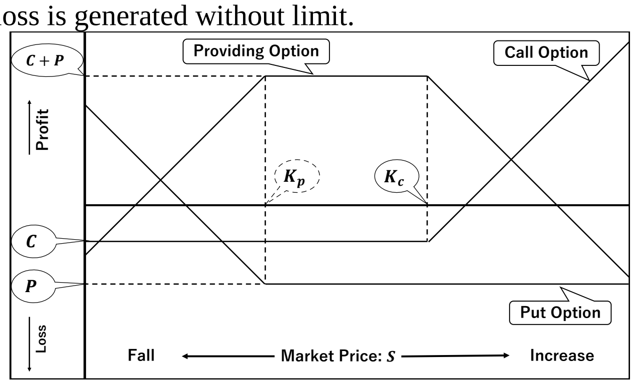

Fig. 3. Variations in triparty profit and loss

4 Call option pricing and variation in profit and loss

The cumulative cost of the premium paid by the company in the related period is

$$\sum_{t=1}^{n} X_t \times C \qquad \text{-----(6)}$$

and only the amount of potatoes shipped and the premium paid per unit potato amount in the related period are determined. As the strike price of the call option held by the company decreases, the frequency of option exercise increases, thereby decreasing the cost of potato purchase by the company. Figure 4 shows the potato purchase costs without and with call option adoption by companies, and the difference between them.

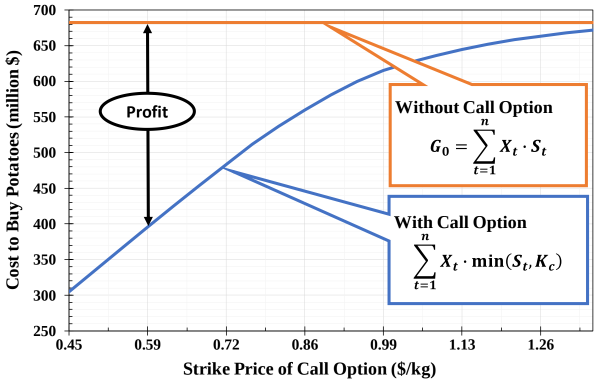

Fig.4. Call option strike price and cumulative cost

In Fig. 5, the vertical axis on the right indicates the premium C per unit amount of potatoes paid by the company. The vertical axis on the left indicates the corresponding cost of the premium calculated from Eq. (6). The horizontal axis indicates the strike price K_c of the call option. Based on Fig. 4, we take the difference in the company cost for purchase of potatoes between the cases without and with call option adoption, and find the point where it equals the cost of the premium (and thus Eq. (5) holds with equality) to create the graph shown in Fig. 5 for strike price K_c and premium C combinations.

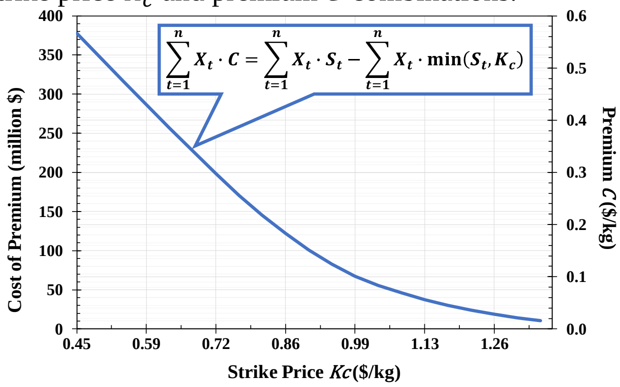

Fig. 5. Company break-even curve

The curve of these combinations of call option premium and strike price marks the boundary of pricing of the region where the option provider can gain a certain profit.

We substituted the pricing on this curve into Eq. (4) to find the company total cost with the call option adopted. We used the cumulative total cost for each year, obtaining 20 data points corresponding to the 20 years. The standard deviation based on these 20 data points is plotted in Fig. 6, where the vertical axis on the right indicates the call option strike price, the vertical axis on the left indicates the standard deviation, and the horizontal axis indicates the premium paid per unit amount. The price combination that minimizes the standard deviation is determined using this graph.

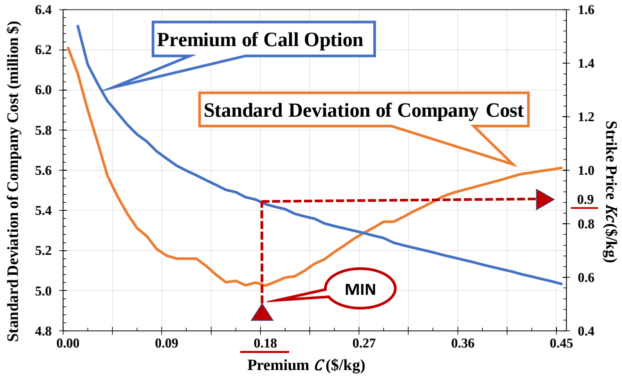

Fig. 6. Reduction of company cost standard deviation

It was found that with an increase in the premium for the call option, against a reduction in the strike price at which the option provider can gain a certain profit, the standard deviation of the total cost of the company rapidly decreases as the premium rises to approximately $0.09 and gradually increases from the minimum after the premium reaches approximately $0.18

With a premium up to approximately $0.09, the strike price was $1.4 to $0.8, and in this range, it was possible to suppress fluctuation in the market price. It can be seen, however, that if the premium exceeded $0.18, then variations in shipment amount appeared, and conversely the company cost varied. By well-balanced suppression of variations in market price and shipment amount, it was possible to obtain the price combination that most suppresses variation in the company cost.

Figure 7 shows a comparison of total cost between the company not adopting a call option and adopting a call option with a premium of $0.18 and a strike price of $0.9.

In a year when variation in market price was small, the cost increased by the amount of premium paid alone. In a year in which the market price rose, it was possible to greatly suppress the cost of potato purchase.

If an option was not adopted, the 1-year total cost to the company on average was $35.98 million, and in 1999, the year when it was largest, it was $50.79 million. In 2002, when it was smallest, it was $25.06 million. The cumulative cost over 20 years was $719.6 million and the standard deviation was $6.37 million.

When an option was adopted, the company total cost was approximately $734.16 million and the standard deviation of company cost was $5.25 million. With a $14.56 million increase in cost, it was possible to reduce the standard deviation by approximately 21.2%.

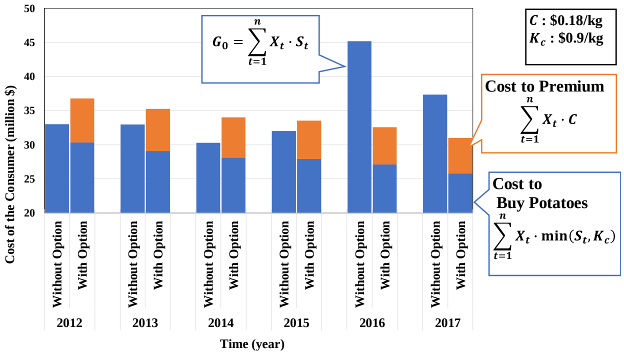

Fig. 7. Change in profit–loss by adoption of company call option

5 Put option pricing and change in profit–loss

The cumulative cost to the farmer for the premium paid in the related period was

$$\sum_{t=1}^{n} X_t \times P \qquad \text{----(7)}$$

which is a function of only the potato shipment amount in the related period and the premium paid per potato unit amount.

As the strike price of the put option held by the farmer increases, the frequency of exercising the right increases and therefore the farmer cumulative income by sale of potatoes increases. Figure 8 shows a comparison of the cumulative income by sale of the potatoes with and without the option adopted.

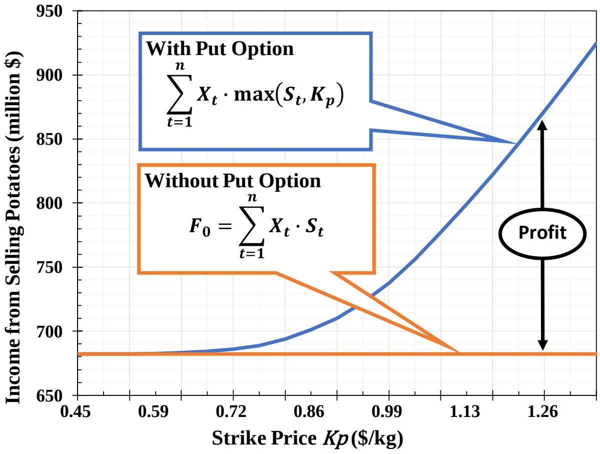

Fig. 8. Strike price of put option and cumulative income

In Fig. 9 the vertical axis on the right indicates the cost of premium P paid by the farmer per potato unit amount and the vertical axis on the left indicates the cumulative cost of the premium from Eq. (7). The horizontal axis indicates the strike price K_p of the put option. We take the cumulative difference in income from sale of potatoes between cases of option non-adoption and option adoption shown in Fig. 8 and find the point where it equals the cumulative cost of the premium. The results are plotted in Fig. 9, in which Eq. (3) becomes equality for the strike price and premium combination.

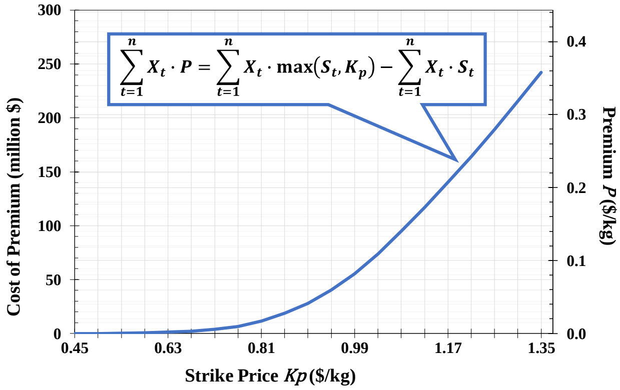

Fig. 9. Farmer break-even curve

The curve for the combination of the premiums for this call option and strike price forms the boundary for pricing that can yield a certain profit to the option provider.

Applying the pricing on this boundary to Eq. (2), we obtain the total cost to the company if it has adopted the call option. The standard deviation of the annual total cost is graphed in Fig. 10.

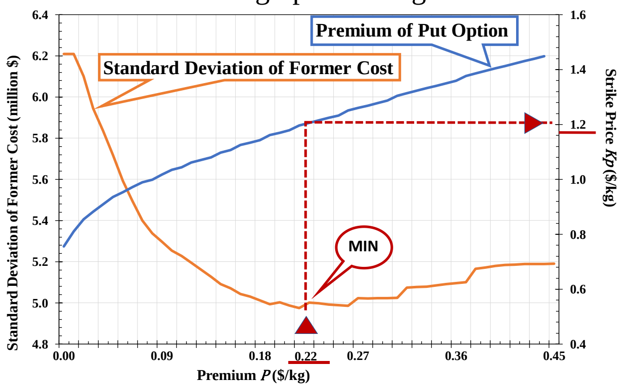

Fig. 10. Reduction of standard deviation of farmer cost and income

It can be seen that with increasing premium for the put option, the strike price at which the option provider can gain a certain profit increases; the standard deviation of the farmer cost for the premium rapidly declines to approximately $0.18 and then gently rises when the premium takes a minimum value of approximately $0.22.

With the premium at approximately $0.18, the strike price was $1.4 to $0.8 and it was possible to suppress market price variation in this range. It can be seen, however, that when the premium exceeded $0.22, variation in shipment amount arose, and conversely the farmer income varied. With well-balanced reduction of variations in market price and shipment amount, it was possible to obtain a price combination that most reduces farmer income variation.

Figure 11 compares cost and income between when the farmer did not adopt a put option and when the farmer adopted a put option with a premium of $0.22 and a strike price of $1.2.

In a year when the market price was flat, compared with when the option was not adopted, the income became smaller just by the amount paid for the premium when the option was adopted. In a year when the market price fell, it was possible to suppress the variation in cost and income. In 2016, the income from potato sales was approximately the same when the option was not adopted as when it was, and the income decreased only by the premium paid. In 2012 and 2013, the increase by exercise of the right of the put option was large, and after subtracting the premium paid, the incomes were larger than when no option was adopted.

The income of the farmer who did not adopt an option was $719.6 million and the standard deviation of the farmer net income was $6.37 million. The farmer net income with option adoption was $717.62 million, and the standard deviation of the farmer net income was $5.17 million. With a decrease of $1.97 million in net income, the standard deviation was reduced by 24.4%.

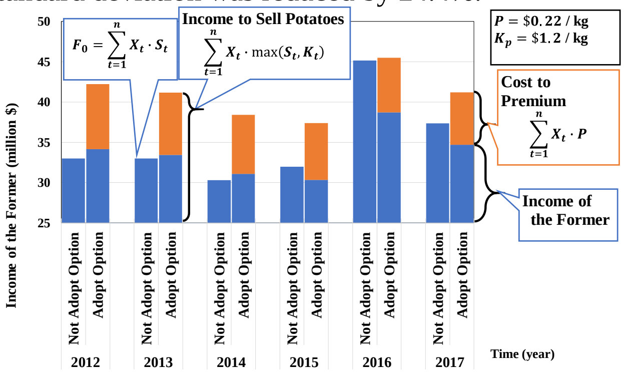

Fig. 11. Change in farmer profit-loss by adoption of put option

Figure 12 shows the change in net income when a call option with a premium of $0.18 and a strike price of $0.9 is provided to the company and a put option with a premium of $0.22 and a strike price of $1.2 is provided to the farmer.

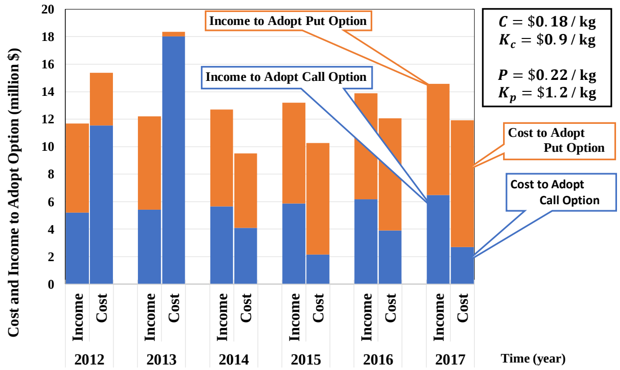

Fig. 12. Change in profit–loss of option provider

In 2012 and 2013, the cost of the exercise of the right of the options was larger than the income from the premiums. From 2014 to 2017, the income was larger than the cost. There was no large change in income from premiums in any year; that is, it was approximately constant. The costs of the exercise of the rights held by the farmer and the company varied greatly with the change in market price in the year because of the takeover of the risks of the farmer and the company holding the options relating to changes in market price.

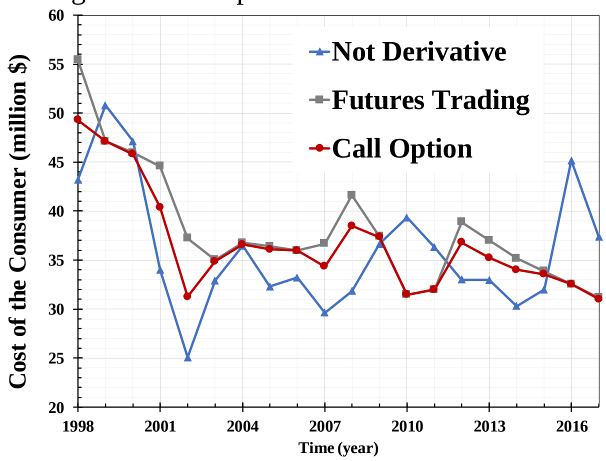

Fig. 13. Change by derivative in company total cost

Figures 13 and 14 show comparisons of company derivative non-holding, futures trading at average price, and trading with the call option proposed in this study. As stated above, we have 20 data points for annual total cumulative cost, and the standard deviation of the 20 data points is $6.37 million. Figure 13 shows the transitions in total cost. In particular, it shows results for a company holding no derivative (blue triangles), a company performing futures trading with an 20-year average annual price of $1.08 (gray squares), and a company with the call option proposed in this study with a premium of $0.18 and a strike price of $0.9 (red circles).

With no derivative, the cost varied greatly between years in which the cost was large and small due to market prices. Again, the 20-year cumulative total cost was $719.6 million and the standard deviation was $6.37 million.

In futures trading at average price, the variation in total cost was smaller, but overall the total cost was large throughout: the 20-year cumulative cost was $762.28 million and the standard deviation was $6.1 million. Thus, in exchange for an increase of $42.68 million in cost, the standard deviation was reduced by 4.4%.

When the call option proposed in this study was adopted, the 20-year cumulative total cost was $734.16 million and the standard deviation was $5.25 million. Thus, in exchange for an increase of only $14.56 million in cost, the standard deviation was reduced by 21.2%.

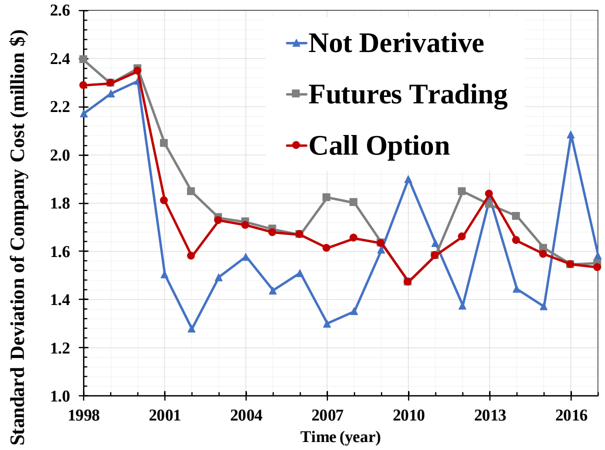

Fig. 14. Illustration of reduction of variation in company total cost by derivative adoption

Data for 20 years of total company monthly cost (12 data points per year) were obtained and the standard deviations within each year were calculated to capture the variation in company total cost by year (Fig. 14). As shown, there is visible variation in total cost in even as short a period as 1 year. Figure 14 shows that the call option proposed in this study functions effectively.

6 Conclusion

Farmer income from potato sales and company cost for potato purchase together with the variation in market price interact with variation in shipment amount in a structure that has become unstable.

A farmer holding a put option can perform trading at the strike price if the market price falls below that and can avoid the risk of income instability due to variation in market price. If the strike price is set higher, then income from selling potatoes can be made more stable, but for the option provider to gain a certain income with the increased strike price, a higher premium must be set. The premium is paid per unit amount of potatoes traded, and therefore if the premium is priced high, variation in the shipment amount will affect the net income.

The company holding the call option can perform trading at the strike price if the market price exceeds it and thus avoid the risk of cost instability due to market price variability. If the strike price is set lower, then a higher possible stability of the cost of purchasing the potatoes can be obtained, but a higher premium must be set for the option provider to gain a certain income. As the premium is paid per unit amount of traded potatoes, a high premium with cause variation in shipment amount to affect the cost.

The advantage of the option proposed in this study is that it can reduce variation in both market price and shipment amount, which are causes of variation in net income. Reduction of variations in both market price by the strike price and in shipment amount by the premium stabilizes the costs to both the farmer and the company.

From the graphs shown as Figs. 5 and 9, the option provider can find the pricing appropriate for gaining a certain profit. From Figs. 6 and 10, it is possible to set the price that will most minimize the standard deviations of both farmer income and company cost. By holding a put option, the farmer increases the income from potato selling and reduces total income by the cost of the premium. It can be concluded that by reducing the standard deviations of both income and cost, the risk of variation in market price shifts to the option provider, and it is possible to stabilize income and cost.

Similarly, by holding a call option, the company increases the income from potato purchasing, but the total cost is increased by the cost of the premium. The standard deviation of net income decreases, the variation in net income is reduced, and the net income is stabilized.

For the option provider, in a year when the market price rises and falls, the cost of the exercise of rights exceeds the income from the premiums and a loss occurs, but in a period in which the market price is stable, it is possible to gain a certain profit. The results also show that, as compared with vegetables futures trading performed in the past, the options proposed in this study are derivatives that reduce variations in farmer and company income and cost, and reduce loss for both parties. Taken together, the results show that in both their reduction in cost variation and their reduction in cost increase, the options proposed in this study are superior to futures trading at average price.

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