Risk Modelling of Agricultural Products

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Abstract. In the real world market, agricultural commodity are imposed with fluctuating prices. This means that the price of agricultural products are relatively volatile, which means that agricultural business is a quite risky business for farmers. This paper presents some mathematical models to model such risks in the form of its volatility, based on certain assumptions. The proposed models are time varying volatility model, as well as time varying volatility with mean reversion and with seasonal mean equation models. Implementation on empirical data show that agricultural products are indeed risky.

1. Introduction
Agriculture is a source of employment and income, contributes to a country’s food security, generates export revenues, sustains rural development, it provides nutrition and livelihoods for poor farmers, it is an important part of poverty eradication initiatives, and it supports human development of the poor [3]. Farming is typically a risky business, because facing a risk implies the possibility of losing property or income. Farm risks can be of financial and business nature. Financial risk refers to the method of financing. Business risk of a farmer is related to production, personal, price and institutional risk [1].

Agricultural products are different from other products manufactured in factories. Despite of the technologies advancements, the production depends heavily on the uncertainty of nature and climatic conditions. Being essential items for human consumption, demand of agricultural products remains constant, but supplies fluctuates widely, leading to price fluctuations, and occasional spikes. Methods of storage exist, but are added to the cost because agricultural products are perishable commodities. Such factors make agricultural products low margin, high volume, and fast moving items for traders.

The traditional pricing model for agricultural products is usually a cost based approach, where the selling price is a mark-up above the product cost, with the extent of mark-up depend on market conditions, such as demand and supply. Correct pricing is an important issue, because the yield of agricultural business that the farmers can enjoy depends largely on it. However, the actual condition is often not so promising. Instead, the farmers have to deal with fluctuating agricultural commodity prices in the world market. This leads to the fact that agricultural products’ price has relatively high volatility parameters, which means that agricultural business is a quite risky business. This means, volatility process is an important element in pricing management [2].

This paper is intended to propose some risk models for some main agricultural products in Indonesia, in the form of some volatility models. Moreover, to gain some insights on its implementation, some empirical data are collected and their volatility are analyzed.
2. The Proposed Risk Models

First of all, it should be noted that in the market we can only observe the price of certain product. Therefore, let’s start the model formulation by defining some mathematical process based on this price. Let $P_t$ be the price of the agricultural commodity at time $t$. The return process is defined as follows.

$$y_t = \ln \left( \frac{P_t}{P_{t-1}} \right).$$  \hspace{1cm} (1)

The variation of this return process will define its volatility.

The proposed models on risk of agricultural products include the model of time varying volatility, with its extension to the mean reversion model, and the seasonal model. The formulation of the proposed models is based on [2] and modified as follows.

2.1 Time varying volatility model

Under the assumption that the return follows the discrete time process

$$y_t = \mu + \varepsilon_t,$$  \hspace{1cm} (2)

then the volatility satisfies the following model

$$\sigma_t^2 = \omega + \alpha (\varepsilon_{t-1})^2.$$  \hspace{1cm} (3)

This model gives the measure of risk as the parameter $\sigma_{\varepsilon}$, which is the standard deviation of the error term $\varepsilon_t$ in (2).

2.2 Time varying volatility model with mean reversion

Under the assumption that the return satisfies the following mean reversion process

$$y_t = \alpha (\mu - \ln P_{t-1}) + \varepsilon_t,$$  \hspace{1cm} (4)

then the volatility model has the following form

$$\sigma_t^2 = \omega + \alpha (\varepsilon_{t-1})^2 + \beta (\sigma_{t-1}^2).$$  \hspace{1cm} (5)

This model gives the measure of risk as the parameter $\sigma_{\varepsilon}$, which is the standard deviation of the error term $\varepsilon_t$ in (4).

2.3 Time varying volatility model with seasonal mean equation

Assume that there exists weekly seasonal mean equation on the return process

$$y_t = \mu + \sum_{k=1}^{N} \left[ y_k \cos \left( \frac{2\pi kt}{5} \right) + \varphi_k \sin \left( \frac{2\pi kt}{5} \right) \right] + \varepsilon_t,$$  \hspace{1cm} (6)

then the volatility model has the following form

$$\sigma_t^2 = \omega + \alpha \left( y_{t-1} - \left( \mu + \sum_{k=1}^{N} \left[ y_k \cos \left( \frac{2\pi kt}{5} \right) + \varphi_k \sin \left( \frac{2\pi kt}{5} \right) \right] \right)^2 + \beta (\sigma_{t-1}^2).$$  \hspace{1cm} (7)

This model gives the measure of risk as the parameter $\sigma_{\varepsilon}$, which is the standard deviation of the error term $\varepsilon_t$ in (6).

3. The Empirical Data of Indonesian Agricultural Products

The collected data are daily prices of some agricultural products in the time frame of June – October 2016, obtained from the Indonesian Ministry of Trade. The agricultural products under consideration are rice, sugar cane, beef and chicken meat. The graphical visualization of the data is given in the following figure 1.
The price of all agricultural products under consideration in figure 1 show some significant fluctuations. Rice is the main source of food for most Indonesians, so the price of this strategic agricultural product is expected not to fluctuate widely. But it seems that this is not the case, the price of rice show quite significant fluctuation, similar to other agricultural products under consideration. For the case of chicken, it can be observed that there was significant price increase around beginning of the month July, which was the time of Ramadhan and Aidil Fitri celebration. It is widely known that, in this time of celebration, prices of almost all products in the market tend to increase significantly. On the other hand, the existing data show that rice and beef have the opposite trend, their price tend to decrease around this time. Nevertheless, both cases have similar impact, i.e. high fluctuation on the price of those agricultural products.

4. The Estimated Volatility

To obtain the idea of volatility, the following figure 2 gives graphical representation of the return according to (1) on the price of agricultural products under consideration. This graphical results show that there is significant fluctuation on the return process, which confirm that there are also fluctuations on the price of agricultural products. To be more specific, the fluctuation on the return of chicken price has the highest magnitude, so it can be estimated that this agricultural product has relatively high volatility. This will be discussed more closely in the next result of estimated volatility given in table 1.

Figure 1. Daily prices of some agricultural products in Indonesia.
As a measure of risk, the volatility of each agricultural product was then computed according to each abovementioned model, i.e. the time varying, time varying with mean reversion and time varying with seasonal mean equation models. Model-1 is the model of time varying volatility as given in (3), while model-2 is the model of time varying volatility with mean reversion as given in (5), and model-3 is the model of time varying with seasonal mean equation volatility as given in (7). The values of estimated volatility are given in the following table1.

Table 1. Estimated volatility of the agricultural product’s daily price.

| Agricultural Product | Model-1     | Model-2     | Model-3     |
|----------------------|-------------|-------------|-------------|
| Rice                 | 16.70%      | 16.65%      | 74.85%      |
| Cane Sugar           | 35.28%      | 36.05%      | 81.73%      |
| Beef                 | 29.48%      | 29.33%      | 75.73%      |
| Chicken              | 82.54%      | 82.36%      | 105.65%     |

Table 1 gives the estimated volatility for all agricultural products, which show similar results for the first two models, i.e. the model of time varying volatility and the model of time varying volatility with mean reversion. On the other hand, the model of time varying volatility with seasonal mean equation show way too high volatility estimates, which is unreasonable. Therefore, it can be concluded that the model of weekly seasonal time varying volatility is not suitable for this case.
Furthermore, evaluating more closely the volatility among the agricultural products presented in table 1, chicken show the highest volatility, which confirms the fact that the fluctuation of its return has the highest magnitude as noted earlier. The next high volatile product is the cane sugar at the second place. Beef has relatively moderate volatility, despite of its high price in the market. Finally, the rice has relatively lowest volatility as expected. But nevertheless, the estimated volatility of almost 20% for such an important food product is rather alarming. This all at once concludes, that agricultural products contain a great deal of risk in its market price. Therefore, it also confirms that agricultural business is indeed a risky business.

5. Conclusions

Price of agricultural products show some fluctuations in the real world market, which implies that agricultural products can be considered as risky products. Some risk models in the form of volatility models are proposed. The high estimated volatilities on the prices confirm that agricultural products are risky.

References
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