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Model Simulation Approach for Exploring Profitability of Small-scale Cavendish Banana Farmers in Davao Region from Harvest Allocation to Enterprises

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Changes that occurred in the agriculture-food system – for instance, increase in disease incidence compounded by climate change, as well as changes in contractual arrangements and policies – pose challenges to small-scale Cavendish banana farmers in the Davao region, the top producer of Cavendish in the Philippines, in terms of their vulnerability and ability to survive. The current challenges can be addressed by increasing the opportunity of small-scale farmers to increase their profit by exploring alternative enterprises. The current system of the farmers is to allocate their entire harvested Cavendish bananas into the contractual market or the spot market. While these farmers can improve their profit by processing raw bananas into alternative products such as banana flour, very few of them have embarked on this enterprise. One reason for this is the limited understanding of this market potential and its profitability relative to contractual or spot market. Hence, in this study, we explored through a model simulation – a novel yet simplistic approach – different scenarios of a farmer's profit as they venture into the banana flour market. Some model considerations include flour demand, the volatility of spot market prices, and banana production rates. Our simulations show that the total profit of the model farmer varies significantly with different allocations of bananas to contractual or spot markets for various demands in the banana flour market. Additionally, with our model assumptions, model farmers can further increase their profit if all their unsold fresh bananas have been processed to banana flour and sold them during high demand. Finally, we highlight the novelty of our approach as a diagnostic tool to initially assess the profitability of a commodity among different market options especially when there are unexplored scenarios and data is scarce.

Keywords: small-scale farmer, Cavendish banana flour, contractual farm, harvest allocation, profitability, simulation.

INTRODUCTION

Across the wet tropical and subtropical regions, bananas are considered as one of the most important economic crops for small-scale farmers. It is the most exported fresh fruit in the world with an estimated value of USD 8 bn/yr based on the 2016 export figures by the Food and Agriculture Organization of the United Nations (FAO 2020). Today, the banana industry has expanded in various countries in the Americas, Africa, Asia, and Melanesia and the Pacific – with

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Ecuador and the Philippines remaining as the two leading exporters (Workman 2020). Bananas provide staple food for millions of people, especially in places where green revolution – the world's technological response to the worldwide shortage – has little influence (Fitzgerald-Moore and Parai 2003). In the Davao region of the Philippines, bananas dominate with a relative proportion yield estimate of 36.12% out of all agricultural commodities (PSA 2017a).

Several different species of bananas that are cultivated today belong to the family Musaceae and genus *Musa*, but the Cavendish cultivar is the most cultivated globally (Smith 2015). It is reported that for the last quarter of the year 2018, 51.9% of the total banana productions in the Philippines are accounted for the Cavendish cultivar (PSA 2018) in the Davao region, the main producer of Cavendish bananas in the country (DA 2016). The agricultural sector accounts for about 35% of the Davao region's total employment for the year 2016 (PSA 2017a).

There are numerous small-scale banana farmers in the Davao region that produce the Cavendish cultivar, among other banana cultivars, from their farms. These farmers face challenges brought by various shifts in the agri-food system. One of these shifts is the increased incidence of diseases, particularly fusarium wilt, which is compounded by climate change (Hansl *et al.* 2017). Limited rainfall and Panama disease drastically lower productivity particularly for small farmers who have limited capital to invest in their own irrigation system or to apply expensive protocols to manage or control the disease (Digal and Balgos 2016). In fact, these diseases greatly affect both commercial and small-scale farmers growing Cavendish for the export market in the Davao region (Vézina and Bergh 2018). Another shift is the policy changes that increased costs and risks, for instance, the policy direction on labor that limits contract labor and the ban of aerial spray (Balgos and Digal 2016). Furthermore, the expansion of the spot market to some extent opens opportunities for small growers, however, it also increases risks for farmers due to price variability. Although small-scale farmers produce an estimate of 87% of all bananas grown worldwide for home consumption or sale both in local and regional markets (Frison *et al.* 2004), these farmers are unable to meet the high standards required in the market and so choose to be employed in different banana industries (SEARCA 2017).

Small-scale farmers are prone to having difficulty in participating in the market economy (Ebata and Hernandez 2017; Eaton and Shepherd 2001) despite the institutional development strategies implemented such as contractual farming, strengthening of producers' association and cooperatives, in response to market opportunities. The reasons behind this difficulty include the lack of capital, inputs, technology, and extension services, as well as limited volume and understanding of market potential (Birthdal *et al.* 2007). As a matter of fact, according to the Philippine Statistics Authority (PSA), farmers ranked first with the highest poverty index of 34.3% for the year 2015. This factor alone suggests their inability to cope with the changes in the agriculture-food system and challenges them in terms of their vulnerability and their ability to survive (SEARCA 2017).

One way to address the challenge is to provide opportunities for small-scale farmers to increase their profit. The usual practice of the farmers is to sell their harvested bananas to either the contractual market or the spot market. The contractual market is an enterprise for farmers that involves the production and supply of agricultural products between farmers and multinational companies under certain agreements (Eaton and Shepherd 2001). The spot market is an outlet for non-contractual farming. This market has expanded in the last 5–7 years due to the expiration of contracts. Contract growing arrangements started as early as 1999 immediately after implementing the CARP program for plantation agriculture in 1998. Farmers with expired contracts are now free to supply to this spot market. There had been farmers who were blacklisted by contractors because they sell bananas to the spot market that were produced under contracts. The number of buyers in this market increases especially during peak demand to ensure that bananas become available for markets abroad during this season. In some cases, the marketing intermediary for the spot markets can be the consolidator particularly buyers who need larger volumes.

For most small-scale farmers in Davao del Norte, contractual growing is the most common type. Based on the survey conducted in Sto. Tomas – the top producer of Cavendish banana in Davao del Norte – about 42% of the growers are contractual (WB 2014). Nevertheless, these markets do not necessarily guarantee promising economic returns. It is suggested that alternative markets, such as an enterprise for banana products (*e.g.* flour, chips, *etc.*) should be ventured.

While these farmers can improve their profit by processing raw bananas into alternative products such as banana flour, very few of them have embarked on this enterprise. There is a range of issues why small farmers have not ventured into this market. These include the limited understanding of the potential of this market, inability to meet market requirements – particularly on quality and volume due to lack of capital to purchase raw materials (banana rejects) – and other issues. In this study, we investigate the profitability of a farmer as s/he allocates the harvested bananas into three different enterprises: contractual, spot, and alternative product markets specifically banana flour. The aim of this investigation is to determine the conditions wherein farmers could gain more from venturing into banana flour enterprise under some assumptions.

Existing approaches for profitability evaluation of economic-related strategies are less mechanistic and empirical in nature (Smith *et al.* 1989; Bamire and Manyong 2003; Adinya *et al.* 2010; LeRoux *et al.* 2010; Bowen *et al.* 2018). That is, these approaches heavily rely on data in which insights generated are cumbersome to validate since a dataset is prone to measurement errors. The objective of this study, however, cannot be addressed fully with an empirical approach given only a few data at hand. Moreover, we find the existing approaches to be inappropriate for the problem's context especially that we also want to explore profitability for non-existent scenarios. For these reasons, a model simulation approach is developed where we consider a simple direct supply chain network for Cavendish bananas and mathematical models describing the profit gained from each enterprise are formulated. Our novel yet simple approach allows us to investigate the changes in the long-term monthly profit of a banana farmer as a result of venturing a combination of different aforementioned market options with minimal data available, which is impossible to perform in other simulation approaches, such as what had been done by Kim *et al.* (2014). In this study, we restrict our assumption that model farmers are small-scale farmers who have the capacity to efficiently process fresh bananas into banana flour of marketable quality standard.

MATERIALS AND METHODS

A Direct Supply Chain Model

We begin with a simple direct supply chain model, as shown in Figure 1. There are three stages in the direct supply chain model: production, processing, and the market. In the production stage, the total harvested Cavendish bananas of small-scale farmers were tracked. The processing stage, on the other hand, describes the allocation of the harvested Cavendish bananas into three different enterprises (*i.e.* contractual market, spot market, alternative product market). Here, we consider banana flour production as an alternative product market. Finally, in the market stage, the profit gained by the model farmer is formulated. Based on this simple supply chain model, a theoretical model is developed to simulate the profit of the model farmer from allocating the bananas into three enterprises. The model accounts for the varying production rate of bananas, efficiency of conversion from raw banana to banana flour, and selling rates of the banana product.

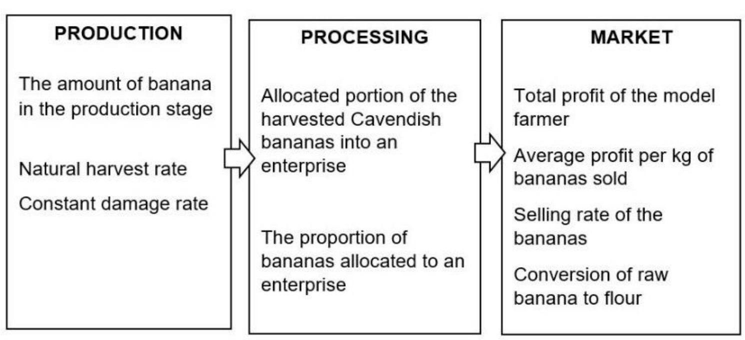

Figure 1. The direct supply chain model schematic diagram.

Model Development

First, we formulate a mathematical model for the dynamics of banana production. Let $B(t)$ be the amount of banana (in kg) in the production stage, which is affected by two factors – namely, the natural harvest rate (Λ) and a constant damage rate (ε) per month per kg of bananas.

Λ represents how often model farmers harvest Cavendish bananas at a time interval. In the case when the farmers harvest, on average, the same amount of banana per unit time, we have $\Lambda = \Lambda_0 = constant$.

On the other hand, ε represents loss per kg of bananas per unit time due to damage incurred during the harvest attributable to improper handling. Other factors such as diseases are not considered in this study. Further, it is assumed that the total damage rate is directly proportional to $B(t)$ with ε, i.e. average damage rate per kilogram (kg) of harvested banana. We set ε to be 0.05 to reflect the "minimal" damage rate from improper handling. This is based on the information provided by the key informants through personal interviews.

In this study, a model farmer is assumed to own a farm size of one hectare. This is done to normalize the parameter values with respect to the known total volume of production for Cavendish banana in Davao City for 2017. To calculate the initial harvest rate of the model farmer Λ_0, we can subtract the average banana yield per hectare in Davao City between two succeeding quarters given by the PSA (2017b). From our calculation, the average of these differences yields the initial harvest rate of 660 kg/mo and the average banana yield per month (B_0) of 5,063 kg.

Next, in the processing stage, we formulate a model to describe the allocation of bananas. Here it is assumed that a model farmer can venture in all three enterprises. Moreover, remaining bananas including off-grade bananas from the contractual and spot markets may be converted to banana flour. Now, let $b_i(t)$ – where $i = 1,2,3$ – be the allocated portion from the amount of Cavendish bananas (in kg) in the production stage into the contractual market, the spot market, and the banana flour market, respectively. The allocations of the bananas are given by:

$$b_i(t) = \sigma_i B(t) \qquad (1)$$

where σ_i is the percentage of bananas sold to a specific enterprise $i = 1, 2, 3$; and $\sigma_3 = 1 - \sigma_1 - \sigma_2$. The number of bananas sold to the market depends on the amount of Cavendish bananas in the production stage.

We then formulate a model for the profit, $P_i(t)$, gained by the model farmer from enterprise (i), as described above in the market stage. For the contractual and spot market enterprises, the profit gained depends on the product of the profit per kg of Cavendish bananas sold (ρ_i) and $b_i(t)$ for $i = 1,2$. That is, the profit from the contractual and spot markets is computed as:

$$P_i(t) = \rho_i b_i(t), \qquad i = 1,2 \qquad (2)$$

We consider the average profit per kg of banana sold for ρ_i when $i = 1$. Based on the key informant interview in a certain cooperative in the Davao region, the average profit per kg of Cavendish banana in the contractual market is Php 1.5. When $i = 2$, we consider ρ_i as a number for the profit per kilogram of Cavendish banana sold derived from the empirical distribution of historical profit values for the years 2013–2017.

For the banana flour market enterprise, ($i = 3$), the profit depends on the average profit per kilogram of Cavendish bananas sold in the market (ρ_3) with values Php 4 and Php 10 for feed-grade and food-grade flour, respectively, the proportion of bananas that will be converted to banana flour (α), the factor accounting for the conversion of raw Cavendish banana to flour (η), the demand of banana flour in the market (δ), and $b_3(t)$. Hence, the profit in banana flour market enterprise is computed as:

$$P_3(t) = \alpha \eta \rho_3 \delta b_3(t) \qquad (3)$$

Note here that $\eta = 1/10$. It has been observed that approximately 10 kg of fresh bananas is needed in order to produce 1 kg of banana flour.

The total profit gained by the model farmer $P(t)$ is the sum of the profits from different enterprises, given by:

$$P(t) = \sum_{i=1}^{3} P_i(t) \tag{4}$$

The estimated values for the profit per kg of the bananas in the spot market and the contractual market are based on the given prices per box of bananas in each enterprise multiplied by the grower profit margin of that enterprise.

Numerical Simulations

Model simulations are performed to show the variation of the total profit for different allocation scenarios and parameter settings. The following are the identified three allocation scenarios:

Case 1 – Absence of Spot Market ($\sigma_2 = 0$): farmers allocate their bananas in the contractual market while exploring potential marketability of banana flour.

Case 2 – Absence of Contractual Market ($\sigma_1 = 0$): farmers allocate their bananas in the spot market while exploring potential marketability of banana flour.

Case 3 – Pole-vaulting/Side-selling ($\sigma_1 \neq 0, \sigma_2 \neq 0$): farmers venture in pole-vaulting, *i.e.* they allocate their bananas in both contractual and spot markets while exploring potential marketability of banana flour. This scenario assumes that the farmers are obligated to sell 80% of their bananas to the contractual market, while they are free to allocate the other 20% to any of the three markets.

The case where the model farmers only allocate its whole resources in the banana flour market ($\sigma_1 = 0$ and $\sigma_2 = 0$) is not within the scope of our study as we only want to explore the potential of the banana flour market on top of venturing with the other two enterprises.

The general algorithm for the numerical simulation of the three allocation scenarios is presented in Figure 2. All simulations are implemented in MATLAB 9.4.0.813654 (R2018a).

NO POLE-VAULTING (side-selling or reneging)

Step 1: Define parameter settings
Step 2: for $\sigma_i = 0$ to 1 (increment for σ_i) for $i = 1,2$
Step 3: for $\alpha_i = 0$ to 1 (increment for α_i) for $i = 1,2$
Step 4: $Long\ Time\ Profit(\sigma_i, \alpha_i) = [\sigma_1\rho_1 + \sigma_2\rho_2 + \alpha(1 - \sigma_1 - \sigma_2)\eta\delta\rho_3]B_\infty$
where $B_\infty = (\Lambda_0/\varepsilon) + C$
Step 5: Long Time Profit = Long Time Profit(σ_i, α_i).
Step 6: $\alpha_i = 0 + 0.001$
Step 7: $\sigma_i = 0 + 0.001$
Step 8: Visualize simulation using Color Maps.

POLE VAULTING
Step 1: Define parameter settings
Step 2: for $i = 0.8$ to 0.95 (increment for σ_1)
Step 3: for $j = 0.05$ to 0.2 (increment for σ_2)
Step 4: if $\sigma_1 + \sigma_2 \leq 1$
$Long\ Time\ Profit = [\sigma_1\rho_1 + \sigma_2\rho_2 + \alpha(1 - \sigma_1 - \sigma_2)\eta\delta\rho_3]B_\infty$
where $B_\infty = (\Lambda_0/\varepsilon) + C$
Step 5: $j = 0 + 0.001$
Step 6: $i = 0 + 0.001$
Step 7: Visualize simulation using Color Maps.

Figure 2. Algorithm for the numerical simulation of the scenarios for Case 1 and 2 without pole-vaulting, and Case 3 with pole-vaulting.

For both scenario cases 2 and 3, we initially observe the profit values for the three allocation scenarios by assuming the average profit per kg of Cavendish banana sold for ρ_2. This average value is computed to be Php 2.5. Then, we study the volatility of the spot market by assuming random values for ρ_2 based on the empirical distribution of historical profit values in this market. Box plots are drawn to illustrate the variability in profit.

We also explore the potential of banana flour enterprise (*i.e.* food-grade, feed-grade) with high and low demand of food-grade and feed-grade banana flour for each of the identified scenarios. For scenario cases 1 and 2, we set $\delta = 0.05$ when the demand for food-grade or feed-grade flour is low and $\delta = 1$ when the demand is high. For Case 3, we set $\alpha = 1$ whenever the remaining bananas from the contractual and spot markets are processed into food-grade or feed-grade flour, and $\alpha = 0$ when no Cavendish bananas are processed into banana flour.

RESULTS

Mathematical Model

We describe the dynamics of Cavendish banana production as a differential equation given by:

$$B'(t) = \Lambda - \varepsilon B(t)$$

with $B(0) = B_0$. Solving the initial value problem for Λ yields:

$$B(t) = (\Lambda/\varepsilon) + \{B_0 - (\Lambda/\varepsilon)\}e^{-\varepsilon t} \quad (5)$$

Taking the limit of $B(t)$ as t approaches infinity to obtain the theoretical long-term harvested bananas, we obtain:

$$B_\infty = \Lambda_0/\varepsilon \quad (6)$$

From Equation 6, we see that the steady-state number of harvested bananas is inversely proportional to the loss rate. The smaller the loss rate, the larger harvested bananas are produced.

We have then derived the long-term total profit of the model farmer by substituting Equation 6 to Equation 4 and obtain:

$$P_\infty = [\sigma_1\rho_1 + \sigma_2\rho_2 + \alpha(1 - \sigma_1 - \sigma_2)\eta\rho_3\delta\ ]\Lambda_0/\varepsilon \quad (7)$$

The three cases stated above are then explored using this formula.

Simulated Long-term Profit for Each Scenario

For each scenario case, color maps representing long-term profits for several parameter combinations are generated from model simulations. The colors from blue to red spectrum indicate low to high values of long-term profit, respectively. Note that ρ_2 here is assumed to take the average profit per kilogram of Cavendish bananas sold.

Figure 3 presents the results for Case 1. In this figure, the maps (A) and (B) both present the long-term monthly profit (on average) of the model farmer for allocating a specific percentage of bananas into the contractual market while venturing on the different types of banana flour products, food-grade, and feed-grade flour when the demand for banana flour is low ($\delta = 0.05$). Similarly, maps (C) and (D) are for the case when the demand for banana flour is high ($\delta = 1.0$).

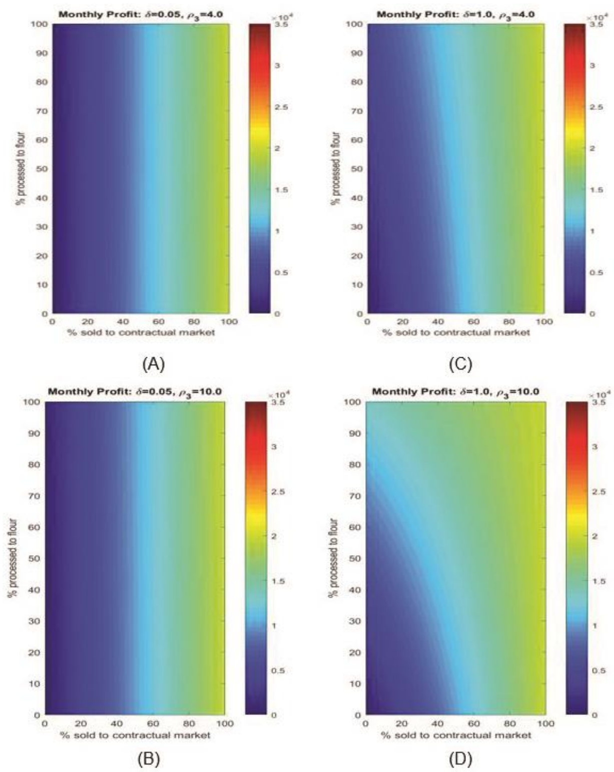

Figure 3. Mean monthly profit as a function of the percentages of bananas processed to flour and sold to contractual market in the absence of spot market for various demands of banana flour: low demand of (A) feed-grade flour and (B) food-grade flour, and high demand of (C) feed-grade and (D) food-grade flour.

Figure 4 presents the results for Case 2 where the model farmer sells Cavendish bananas to the spot market while venturing on the banana flour market. The color maps (A) and (B) show the long-term monthly profit (on average) of the model farmer with food-grade and feed-grade flour, respectively, when there is low banana flour demand ($\delta = 0.05$), while color maps (C) and (D) show long-term profits for high demand ($\delta = 1.0$) in the banana flour market.

For Case 3, we have Figure 5 which presents the long-term profit (on average) gained by the model farmers when they commit pole-vaulting without allocating bananas ($\alpha = 0$) on either feed-grade or food-grade flour as depicted by color maps (A) and (B), respectively. We also present here in color maps (C) and (D) the profits gained by the model farmers who commit pole-vaulting and also process off-grade bananas ($\alpha = 1$) as feed-grade or food-grade flour, respectively.

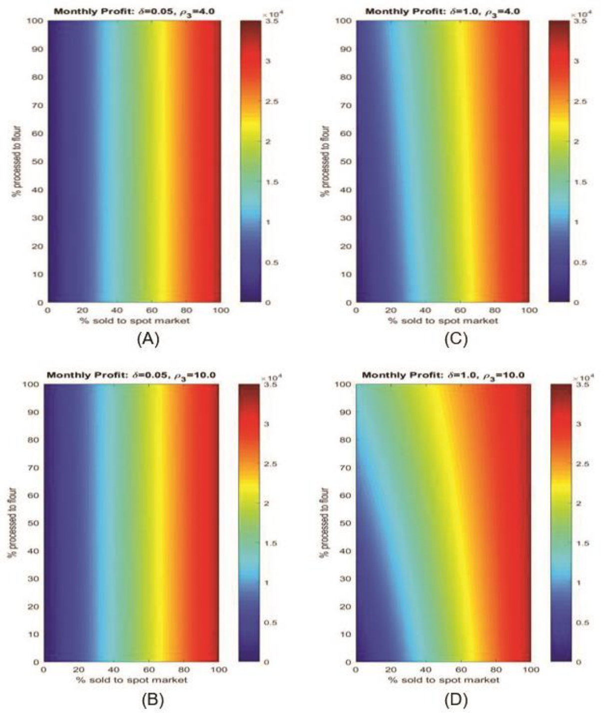

Figure 4. Mean monthly profit as a function of the percentages of bananas processed to flour and sold to the spot market in the absence of a contractual market for various demands of banana flour: low demand of (A) feed-grade flour and (B) food-grade flour, and high demand of (C) feed-grade and (D) food-grade flour.

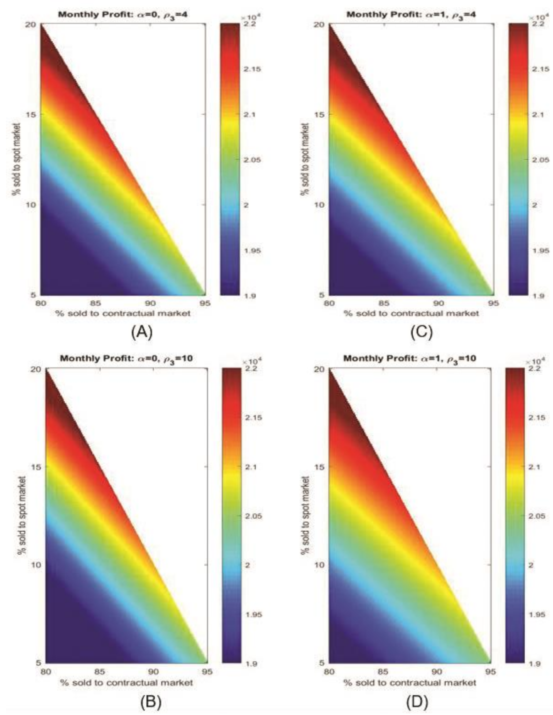

Figure 5. Mean monthly profit as a function of percentages sold to spot market and contractual market for various demands of banana flour: low demand of (A) feed-grade flour and (B) food-grade flour, and high demand of (C) feed-grade and (D) food-grade flour.

Notice that the high-profit (red) spectrum is wider whenever there is an allocation of bananas for banana flour products than without allocation.

We further study the potential of banana flour enterprise for the farmer's profitability in each scenario case by plotting the percentage increase in profit as a function of the percentage of bananas sold to a specific market, as shown in Figures 6 and 7. Note that in Figure 6, the blue and red lines represent profit during low and high demand seasons of banana flour, while these lines in Figure 7 represent the situation wherein 80% and 90% of the bananas are sold to the contractual market, respectively.

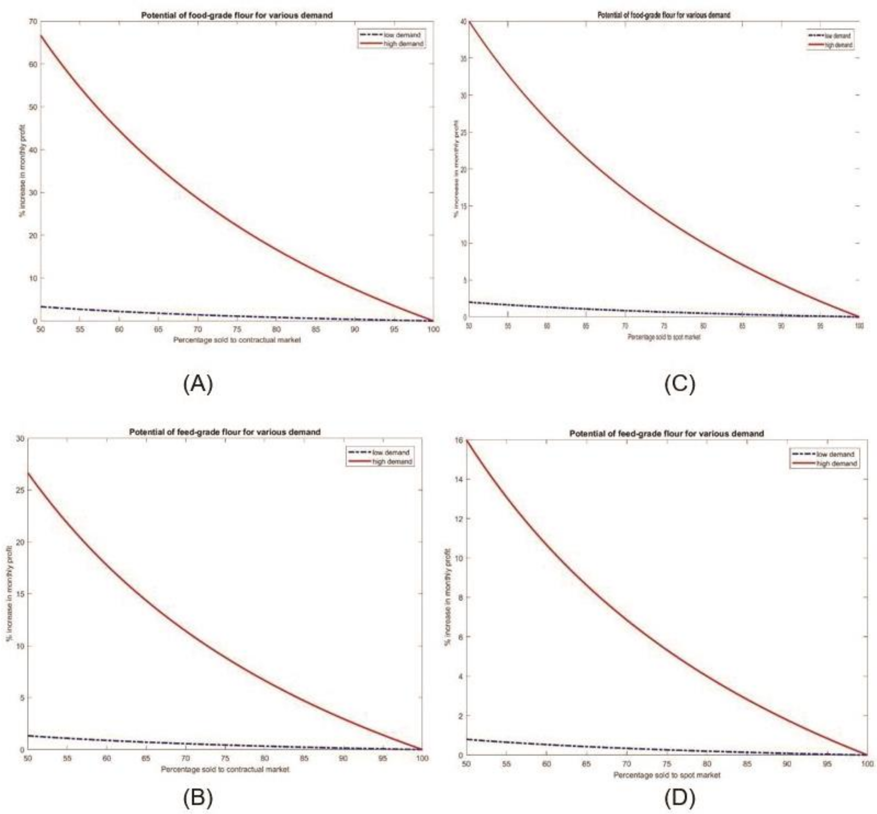

Figure 6. Percentage increase in monthly profit with respect to the percentage sold to contractual market and spot market with the presence of high and low demand in food-grade (A and C) and feed-grade flour (B and D).

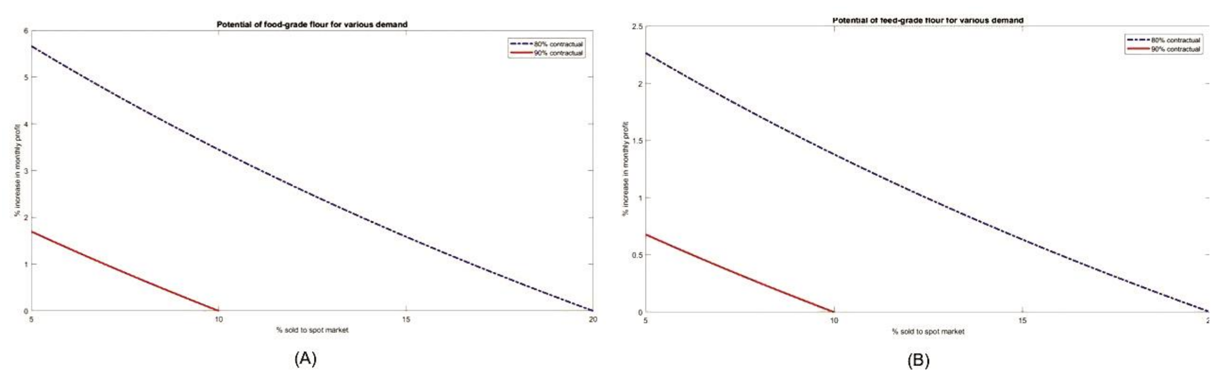

Figure 7. Percentage increase in monthly profit of the model farmers with respect to the percentage of bananas sold to spot market such that 80% and 90% of bananas are sold in the contractual market with the presence of the demand of food-grade (A) and feed-grade (B) flour.

Finally, we observe the volatility of the spot market enterprise by assuming random values for ρ_2 based on an empirical distribution of profit values for the years 2013–2017. Box plots of profit values are drawn, as shown in Figures 8 and 9, using blue and red lines that represent profit during low and high demand seasons of banana flour, respectively. Figure 8 describes the Case 2 scenario whereas Figure 9 describes Case 3. Case 1 is not considered because it does not involve selling to the spot market.

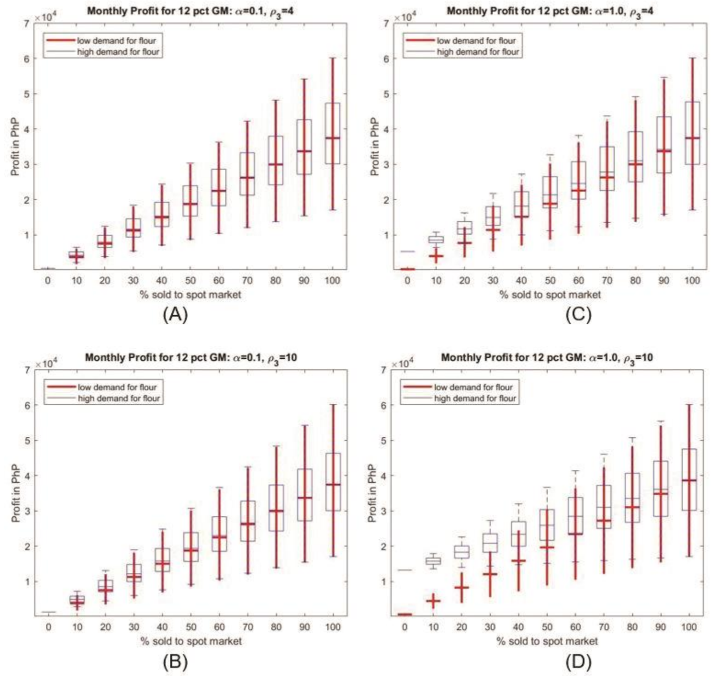

Figure 8. Box plots of monthly profit as a function of the percentages of bananas processed to flour and sold to the spot market in the absence of a contractual market for various demands of banana flour: low demand of (A) feed-grade flour and (B) food-grade flour, and high demand of (C) feed-grade and (D) food-grade flour.

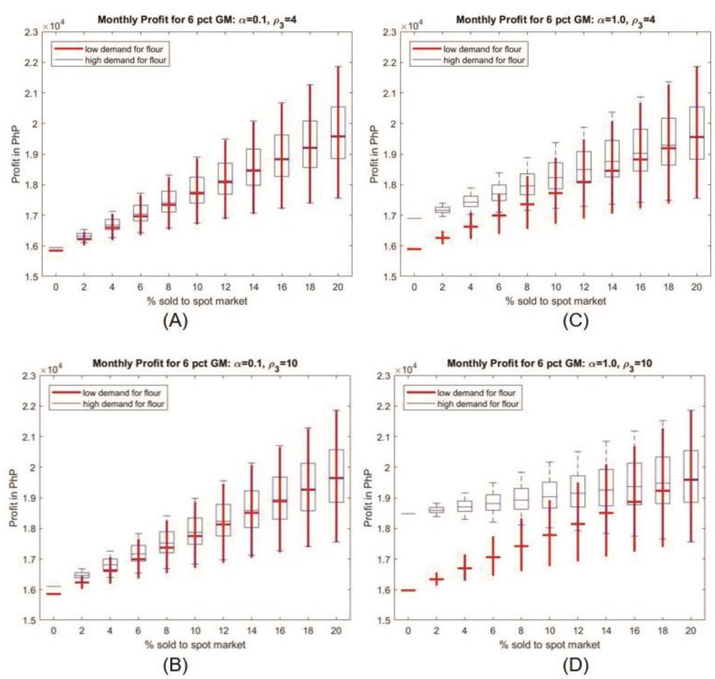

Figure 9. Box plots of monthly profit as a function of percentages sold to spot and contractual markets for various demands of banana flour: low demand of (A) feed-grade flour and (B) food-grade flour, and high demand of (C) feed-grade and (D) food-grade flour.

DISCUSSION

A mathematical model is derived for the long-term monthly profit of a small-scale Cavendish banana farmer based on a simple supply chain network (see Equation 7). The model depends on the allocations of bananas into the contractual market, spot market, and enterprise for banana flour. This is done in order to study how the simulated profit varies for different scenario cases mentioned above.

In Figure 3, observe that whenever the percentage of harvested bananas sold to the contractual market reaches 90%, the color maps turn light green to yellow in the color spectrum. This result shows that within that range of percentage bananas sold to the contractual market, the farmer can obtain a maximum monthly profit (on average) of Php 18,000–20,000.

Moreover, there is no noticeable variation in terms of profitability when the demand for feed-grade and food-grade flour, *i.e.* $\delta = 0.05$, is low (see Figures 3A and 3B). However, when there is a high demand for banana flours, *i.e.*, $\delta = 1.0$, we observe a relatively wider range of high profit in the parameter space (compare Figures 3A and 3B with Figures 3C and 3D). This finding implies that one can allocate less than 90% of bananas to the contractual market and yet still increase the profit by processing the rest of the bananas into either feed-grade or food-grade banana flours.

Comparing Figures 3C and 3D, we can say that it will be more advantageous for a contractual farmer to process the remaining bananas and/or off-grade bananas into food-grade flour than into feed-grade flour as doing so yields a larger profit. For instance, let us consider a model farmer that sells 20% of the harvested bananas to the contractual market and processes all remaining and off-grade bananas into banana flour. A careful inspection of this case in Figures 3C and 3D shows that such a model farmer has simulated profits amounting to approximately Php 8,000 and Php 14,000 for venturing on feed-grade flour and food-grade flour, respectively. This case gives a profit difference of Php 6,000.

Comparing the color maps in Figures 3 and 4, it seems that farmers in the spot market tend to generate larger profits than farmers in the contractual market on average. In Figure 3, we see that a monthly profit of at least Php 20,000 can be achieved by a farmer who sells at least 90% of Cavendish bananas to the contractual market. This same profit can be obtained by a non-contractual farmer by only selling at least 60% of the bananas to the spot market. More so, non-contractual farmers can further increase their profit by venturing into an alternative market, such as the banana flour. It should be noted, however, that the simulated profits for non-contractual farmers should be considered carefully along with the associated risk probabilities. Spot market prices are highly volatile and are driven by the fluctuating market demand. This fact implies that there is no guarantee that a non-contractual farmer can always gain such a high profit. We will further investigate the volatility of profit brought about by the volatility of the spot market prices in the next section.

For scenario Case 3, the model farmer obtains the highest profit when all bananas are allocated to the contractual and spot markets only, *i.e.* it should be that $\sigma_3 = 0$ so that $\sigma_1 + \sigma_2 = 1$. This is observed in Figure 5 that for any given x or y, the highest profit value is found along the diagonal line. This suggests that allocating bananas to be sold to the banana flour market will only result in lower profit. Therefore, the farmers should exert considerable effort to sell all their bananas to the first two markets. Specifically, the color map shows that the highest profit is obtained when all of the bananas the farmers are not obligated to sell in the contractual market (the other 20%) are sold to the spot market.

However, this is not easily attainable as is expected with the volatility of the spot market so considering the allocation of bananas to the alternative markets may provide an opportunity for a higher profit. Based on observations by comparing the color maps in Figures 5A and 5B with color maps in Figures 5C and 5D, choosing to process the bananas into food-grade flour is more profitable than with feed-grade flour should the farmer consider allocating its remaining bananas into the banana flour market.

Overall, we have seen from the simulated profits for the three scenarios that the farmers could venture on producing food-grade flour to increase their profitability.

Exploring the Potential of Banana Flour in Increasing Profit

Figures 6 and 7 specifically reflect the potential of banana flour in increasing the profit of a small-scale farmer. From Figures 6A and 6B, the highest possible percentage increase in monthly profit of a contractual farmer is approximately 67% and 26.5% with a high demand for food-grade and feed-grade flour, respectively. Meanwhile, the highest possible percentage increase in monthly profit is around 4% and 1.5% for low demand for food-grade and feed-grade flour, respectively.

On the other hand, as seen in Figures 6C and 6D, the highest possible percentage increase in monthly profit of a non-contractual farmer is approximately 40% and 16% with a high demand of food-grade and feed-grade flour, respectively, while around 1.5% and 0.9% for low demand of food-grade and feed-grade flour, respectively.

In the case when a farmer pole-vaults, plots in Figure 7 show that the percentage increase in monthly profit is greater whenever 80% of the bananas are sold to contractual market than 90% of the bananas allocated to contractual market, and off-grade / remaining bananas are processed into food-grade (see Figure 7A) or feed-grade flour (see Figure 7B).

Based on these results, it is apparent that a model farmer gains more with the alternative markets – such as feed-grade and food-grade banana flour – while selling in the contractual market, spot market, or to both contractual and spot markets.

Exploring the Volatility of the Spot Market

Figure 8 shows the volatility of the spot market in the Case 2 scenario, which explores the profit values in the absence of the contractual market. Here, the profit per kg of Cavendish banana sold assumes random values derived from the empirical distribution of historical profit values in the spot market for the years 2013–2017.

When the farmers opt to sell less than 80% of their bananas to the spot market and all other bananas including off-grade have been processed to food-grade flour (*i.e.* $\alpha = 1$), there is an obvious difference between profits generated from selling flour during low demand season and high demand season (see Figures 8C and 8D). This means that if all remaining bananas are converted to banana flour, it is more beneficial for the model farmers to sell their banana flour products – especially the food-grade – during high demand than during low demand.

A further note in Figure 8D that the median profit of a model farmer during low demand season is higher than the minimum profit during high demand season when 40% of the bananas are sold to the spot market and all the remaining bananas are converted to food-grade banana flour. This implies a potential “safe zone” for farmers who do not control the demand for banana flour.

Consider the case when the model farmer sells all bananas to the spot market. The lowest monthly profit this farmer gets is around Php 15,000, the median profit is around Php 38,000, and the highest possible profit is around Php 60,000. This occasion displays the box plot with the largest range implying the highest variability in profit values. This represents a high-risk high-reward scenario. Nevertheless, the box plots show that in the event of the worst-case scenario, this occasion still results in the highest profit among the lowest possible profit obtained for all occasions. However, we note that the case where a farmer is able to sell all bananas to the spot market is an impossible scenario since there will always be some waste.

In the case where the farmer sells a small portion of the bananas to the spot market (10% sold), the profit can reach up to Php 18,000 if the rest of the bananas are processed to food-grade flour and sold during high demand season, as seen in Figure 8D. The profit values can reach up to Php 11,000 if the bananas are processed to feed-grade flour and sold during high demand season as shown in Figure 8C. This value increases as a larger portion of the bananas are sold to the spot market.

However, it might be interesting to note that the lowest possible profit value the farmers can get remains steady at about Php 14,000–15,000 when the demand for food-grade flour is high, as seen in Figure 8D. This could suggest the potential of considering the food-grade banana flour markets as an alternative strategy in scenarios where the selling price in the spot market proves less desirable.

Figure 9 shows the volatility of the spot market for Case 3 where the farmers commit pole-vaulting. The same trend is observed as in Figure 8 only that the profit values attained are lower. Most of the profits in Figure 9 comes from the allocation of bananas in the contractual market, which has a lesser average profit compared to the spot market.

By pole-vaulting all 20% of the bananas free for allocation, the profit can range roughly from Php 17,500–22,000 only. This highest possible profit is about three times smaller than the values obtained in Case 2. If the farmers do not pole-vault and only convert a small portion of the bananas to flour (see Figures 9A and 9B), then they will gain a profit of no more than Php 16,000.

Profit variability in selling food-grade flour is higher than with selling feed-grade flour when comparing Figures 9A and 9C with Figures 9B and 9D. Farmers may opt to pole-vault than sell flour. Besides they still get a minimum profit of Php 17,000 with pole-vaulting at least 14% of their bananas.

In both cases considered, there is less difference in variability between low-demand and high-demand season when only 10% of the wastes are converted to flour ($\alpha = 0.1$) compared to when all banana wastes are converted ($\alpha = 1$).

Also, notice the potential of venturing into food-grade flour during high demand if the model farmers can convert all remaining bananas (Figure 9D). The slight decrease in the minimum profit as more and more bananas are sold to the spot market, as opposed to converting it to food-grade banana flour, is an indicator that the conversion gives a slight increase in the overall profit during pole-vaulting.

We note here that barriers to selling in the spot market are not a major concern. In fact, this is an option that is open to farmers or farmer groups particularly those with expired contracts. They can now opt to supply entirely to the spot market or to both spot and contract markets without being accused of side-selling (or pole-vaulting, *i.e.*, selling outside contract) or reneging their contracts. There are many buyers in the spot market and some of these buyers assist in terms of capital required for both production and packing.

CONCLUSION

This paper highlights the behavior of the profit model derived from this simple supply chain as a result of allocating the bananas into three different enterprises: contractual market, spot market, and an enterprise for banana flour. From our model analysis and simulation, the best scenario when farmers sell their bananas in the contractual market is when 100% of the unsold bananas are processed into food-grade flour. This is only achieved if the facilities for banana flour production are highly efficient. The same best scenario applies to model farmers who sell bananas in the spot market. Although we saw that the model farmer may achieve a higher profit with the spot market than with the contractual market, we cannot suggest that all small-scale Cavendish farmers should become non-contractual farmers. We can, on the other hand, use the analysis made here for non-contractual farmers assuming that it is linked by a careful analysis of risk probabilities from historical knowledge of spot market prices and demands.

Moreover, our simulations reveal that the best scenario to allocate bananas in both contractual and spot market is when there is a high demand for food-grade flour, which abides with common intuition. Although there are barriers to entry in flour processing – namely, the capital investment required for the building, drying facility, and processing and other equipment – government agencies such as the Department of Science and Technology and the Department of Trade and Industry have been supportive to promote this enterprise by providing equipment for processing and facilities for drying including support for technical assistance to eventually comply with the Food and Drug Administration (FDA) certification. Technical assistance includes training on good manufacturing and product development to comply not only in terms of FDA standards but also to meet quality standards required by the market. Generally, we conclude that allocating remaining bananas into an alternative product such as banana flour can, indeed, increase the profit of the model farmers.

It is important to analyze the best scenario where model farmers must allocate their harvest to a certain enterprise. This way, farmers can make optimal decisions in order to maximize their profit. The current practice of small-scale Cavendish farmers in the Davao region is to allocate their harvest in either the contractual market or the spot market alone. In relation to our study, such a practice is not optimal. Our study offers farmers strategies as they plan to allocate their bananas into enterprises. The model can also be used to give rough estimates of expected profits in the set allocation strategy.

Aside from motivating small-scale Cavendish banana farmers to explore banana flour production as means to increase their profit, the insights derived from our study can also aid in justifying the need for creating programs that will promote sustainable livelihood for small-scale Cavendish farmers. The program can include further support to an integrated program that addresses the gaps in meeting market requirements for specific cooperatives (particularly those who have started venturing into the processing of bananas). This includes further product development, credit and market facilitation, and technical assistance for FDA accreditation.

The novel approach of analysis in this study is simple and only requires minimal sets of data – in fact, crude estimates of the parameters – as compared with existing simulation approaches. Despite these properties, our approach has provided useful insights whether it is more profitable to venture into the banana flour market or not. The approach can be adopted to compare and simulate a banana farmer's profit among enterprises not discussed here (*e.g.*, banana chips, pectin, *etc.*). It can also be readily modified so that it can be used to study profits for other types of commodities and markets. Models in this study are simple enough to apply and can easily be fine-tuned with respect to empirical data in order to be used for predictive purposes. For instance, the model for banana flour production can further be improved by considering better statistical estimates for harvest rate and loss rate (due to disease and other climatic conditions) on a farm.

We further note here that our approach is more useful if the system under study has little information and in analyzing unexplored scenarios. It can be used as an initial diagnostic tool for assessing profitability as it only uses rough parameter estimates. However, we do not recommend this approach if a high level of precision on profitability analysis is required for forecasting purposes. For such a type of profitability research, data-driven approaches for profitability assessment are suggested, *e.g.* cost and return analysis (Rayburn 2009).

In our study, the average prices of bananas for each enterprise are used. For further research, one can extend the model to take into consideration the dynamics in the prices of bananas in the contractual market or the alternative market enterprise as well as the stochastic market demand. This recommendation is based on the fact that the current prices of bananas change all throughout the year where fluctuations of prices often happen. Furthermore, alluding to the possibility of achieving economies of scale through clustering where unit cost can be lowered and reliability to supply is enhanced, it is suggested for further research to consider the same analysis where the model farmer is a group of farmers rather than an individual.

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