Available online at www.centmapress.org

INTERNATIONAL JOURNAL ON FOOD SYSTEM DYNAMICS

Int. J. Food System Dynamics 14 (4), 2023, 419-430

DOI: https://dx.doi.org/10.18461/ijfsd.v14i4.H5

Exploring Product Diversification: the Case of Contract and Non-contract Farmers in the Philippine Cavendish Banana Value Chain

Marie Analiz April A. Limpoco[1] and Larry N. Digal[2]

[1]Department of Mathematics, Physics and Computer Science, University of the Philippines Mindanao, Mintal, Davao City, Philippines
[2]School of Management, University of the Philippines Mindanao, Mintal, Davao City, Philippines
malimpoco@up.edu.ph; lndigal@up.edu.ph

Received February 2023, accepted September 2023, available online November 2023

ABSTRACT

Uncertainties arising from market fluctuations limit choices of banana famers under contracts. However, they can opt not to renew their contracts with multi-national firms to sell to spot market or diversify. This paper examines optimal portfolio of Cavendish banana products of contract and non-contract farmers under uncertainty. We explore the effect of diversification by including banana flour from rejects aside from fresh banana. Constrained M-estimation of parameters and robust portfolio optimization results show that (1) non-contract farms benefit more from diversifying compared to contract farms; and (2) prices are higher for non-contract farms but profits are lower compared to contract farms.

***Keywords**: contract farming; product diversification; optimization.*

1 Introduction

There have been various strategies to improve participation of small-scale producers in the global agribusiness value chains. These include product development and improving the enabling environment so that these small-scale producers are able to link in more profitable value chains to uplift their living conditions. In some countries, part of this is to promote contractual arrangements between these small producers and large agribusiness companies.

Contract farming is seen to be beneficial for farmers particularly in improving profitability (Briones 2015; Ray et al., 2021), minimizing risks (Digal 2007; Suyo et al., 2021), accelerating technology transfer (Eaton and Shepherd, 2001; da Silva and Rankin, 2013), household food security (Bellemare and Novak, 2017; Bellemare and Bloem, 2018; Ton et al., 2017; Otsuka et al., 2016) and enhancing productivity and participation in global value chains (Murray-Prior, 2005; Proctor and Digal, (2008). Others however argue, that contract farming can be detrimental to the environment (Singh, 2002) as they usually operate in plantation agriculture and to laborers who work long hours (Porter and Phillips Howard, 1997). In some cases, it may even lead to income inequality (Isager, et al., 2018). A critical requirement to contract farming is collective action among small farmers. Organizing themselves to producer organizations increases their bargaining power (World Bank, 2007; D'Haese et al., 2005), lowers transaction costs (Grosh, 1994; Key and Rusten, 1999; Sgroi and Sciancarapore, 2022) and improves supply chain coordination (Anderson and Monjardino, 2019) and access to high value markets (Soullier and Moustier, 2018).

In the Philippines, one of the top three exporters of cavendish banana in the world, contract farming has been mainstreamed especially for export-oriented agricultural industries such as cavendish banana and pineapple where multinational companies dominate. In 1998, when the comprehensive agrarian reform law was implemented for commercial farms mainly operated by multinational and large domestic companies, these companies ventured into contractual arrangements with small farmers who were beneficiaries of the agrarian reform program. More recently, many of these contracts have expired and some farmers including farmer cooperatives did not renew their contracts. Those who opted for non-renewal now sell in spot or non-contract market where prices can be higher but variable. Others venture into value added products using banana rejects such as feed, flour and ketchup. The government, on the other hand, as part of implementing the agrarian reform law, provided support service programs that include product diversification, value adding and processed products and provision of common service facilities such as equipment and dryers.

This paper examines decisions of farmers to maximize profitability under uncertainty particularly those farmers under contract and selling to spot market with the option to diversify into value added products in Davao region which is the top cavendish banana-producing region in the Philippines. The region contributes around 40,percent to the total national production. Some Cavendish banana farms in this region have forged contracts with exporting multinational companies at a fixed selling price while other farms have no contracts and are thus participating in the spot market.

The paper is organized as follows. The section that follows elaborates on the portfolio optimization model. Section 3 discusses how the model was estimated followed by the discussion of the results in section 4. Finally, concluding comments are presented in section 5.

2 Diversification and Portfolio Optimization

The idea of diversification as a means of protecting against potential losses due to uncertainties has long been conceived in the field of finance, but it was Harry Markowitz who formalized this into a form that can be defined and solved using mathematical optimization. This theory, known as the Modern Portfolio Theory (MPT), allows investors to allocate their wealth across varying assets instead of exclusively selecting one among the existing options. Moreover, the investor's attitude in allocating capital among the assets involves not only inclination towards large returns but also aversion from uncertainties. This concept of managing risks through diversification has also been applied in agriculture particularly to cope with risks and uncertainties (Paut et al., 2019, 2020; Akhtar et al., 2019) and improve profitability (Barnes et al., 2015; Burbano-Figueroa, 2022).

The aim of MPT is to select a portfolio with the maximum expected return given a specified level of risk, or a portfolio with the minimum risk given a target return. This is expressed through a mathematical optimization model with three variants (1) Minimum risk given a specified return (2) Maximum expected return given a specified risk level (3) Risk-aversion model. All three variants are commonly called mean-variance optimization models.

2.1 Mean-variance optimization model

The mean-variance optimization model, although widely known in the finance sector and applied to forestry, fisheries, electricity supply, crop, land-use, and many other strategic planning that involves diversification, has some limitations.

These include the assumption that returns are normally distributed, use of variance as measure of risks and that the parameters are deterministic and accurate.

To circumvent the issues in the parameter estimation using sample mean and sample covariance, several robust estimators have been proposed in the literature. Two of the standard classes of robust estimators are the M-estimates and the S-estimates.

2.2 Robust optimization

Deterministic optimization models involving an objective function to optimize (maximize or minimize) subject to at least one constraint assumes that parameters are known, fixed, and accurate. This assumption is violated in most, if not all, real-world applications since uncertainties are inexorable. Some of the sources of uncertainties include forecasting errors, measurement errors, implementation errors, and estimation errors. Ignoring this fact usually results in suboptimal and/or infeasible solutions when actual values of the parameters are revealed and applied, sometimes rendering the solution trivial, if not useless. To address this problem, a class of optimization models called stochastic optimization models assume that parameters are random variables following known probability distributions. The downside of stochastic optimization though is that in reality, probability distributions are not exactly known, and the computational cost of solving the associated model is high.

The application of the robust framework in the area of portfolio optimization is usually limited by the complexity of converting the deterministic model into its robust counterpart and by the level of conservatism of the solution produced such that suboptimal solutions are accepted to guarantee feasibility. Bertsimas, D. & Sim, M. (2004) proposed a robust counterpart model that can be solved by linear programming methods but with less conservatism, enabling more optimal solutions. The uncertainty set considered was a polyhedral uncertainty set with a protection level guaranteeing feasibility or a high probability of feasibility even under uncertainties.

For a portfolio with a set N of n assets (|N| = n) to choose from such that **μ** is the vector of asset-returns and **w** is the vector of portfolio weights, the robust linear optimization model will be

$$\text{maximize } \sum_{i=1}^{n} \mu_i \mathrm{w}_i - \beta(\mathbf{w}, \Gamma) \quad (1)$$

subject to

$$\sum_{i=1}^{n} \mathrm{w}_i = 1$$

$$\mathrm{w}_i \geq 0, i = 1, 2, \ldots, n$$

where

$$\beta(\mathbf{w}, \Gamma) = \max_{\{S \cup \{t\} | S \subseteq N, |S| = \lfloor \Gamma \rfloor, t \in N \setminus S\}} \{ \sum_{j \in S} \sigma_j w_j + (\Gamma - \lfloor \Gamma \rfloor)\, \sigma_t w_t \}$$

Here, the set of assets N is partitioned into S and {t} based on the value of Γ such that S is a proper subset of N containing the coefficients (or in this case, expected returns μ) whose actual values are allowed to deviate from the estimated with deterministic guarantee of feasibility while {t} is the set whose elements are not expected to deviate from the estimate. Note that $|S| = \lfloor \Gamma \rfloor$ and Γ can take real number values between [0,|N|] or [0,n] such that Γ = 0 implies no difference is allowed between the estimated parameters and the actual values while Γ = n means all parameter estimates will be different from the actual. In addition, the model is protected such that if $\lfloor \Gamma \rfloor$ or less estimated coefficients deviate from the actual values, the solution will still be feasible and if more than $\lfloor \Gamma \rfloor$ will differ, there is a high probability that the solution will still be feasible. This robust formulation has an equivalent linear programming form

$$\text{maximize } \sum_{i=1}^{n} \mu_i \mathrm{w}_i - \Gamma \mathrm{p} - \sum_{i=1}^{n} \mathrm{q}_i \quad (2)$$

subject to

$$\sum_{i=1}^{n} \mathrm{w}_i$$

$$\mathrm{p} + \mathrm{q}_i \geq \sigma_i \mathrm{w}_i \qquad \forall \mathrm{i}$$

$$\mathrm{p}, \mathrm{q}_i, \mathrm{w}_i \geq 0 \qquad \forall \mathrm{i}$$

which can be solved using linear optimization methods. We use this formulation in determining the optimal proportion of Cavendish banana products given uncertainties in the estimated net profit per product.

3 Methods

3.1 Data

A total of 356 Cavendish banana farms with land areas ranging from 0.10 ha to 20 ha were randomly sampled from the list of farms situated in the largest Cavendish-banana producing region in the Philippines – Davao region, particularly in Davao del Norte. Of these, 167 are contract farms while 189 are non-contract farms who participate in the spot market to sell their produce. The data collected from each farm consists of the monthly volume (in boxes) and price (in pesos) of class A, class B, and cluster bananas, as well as the volume of banana rejects, from January to December 2018. Farm costs were also gathered, particularly the input cost (fertilizer, sigatoka control, pesticide/herbicide, and maintenance and material cost), labor cost, depreciation cost, transportation cost, land rental, and postharvest cost. However, the available data on cost is the total for the entire year. Monthly cost was computed by allocating cost based on the sales of the product. In particular, let C be the total cost for the whole year, R_i be the monthly sales of product i, and R be the sales of all products for the entire year. The monthly cost per product i is computed using the formula

$$C_i = C\left(\frac{R_i}{R}\right) \tag{3}$$

For computing the monthly sales and cost for processing banana rejects into flour, the optimal profit per batch of 1000 kg of flour processed from 4000 kg of banana rejects by the AMS Employees Fresh Fruits Producers Cooperative (AMSEFFPCO) located in Davao del Norte, Philippines, was used as the price per box, while the volume sold and cost incurred were computed similarly with the other products. Overall, the monthly net profit per box per product served as the inputs to the robust portfolio optimization model.

3.2 Robust estimation and portfolio optimization framework

The framework used for generating robust optimal proportion of Cavendish banana products for contract and non-contract farms consists of (1) estimating the parameters in the robust portfolio model using constrained M-estimation; and (2) running the robust portfolio model with a polyhedral uncertainty set through linear optimization.

3.2.1 Constrained M-estimation of multivariate location and scatter.

For each month from January to December 2018, the net profit per box of class A, class B, cluster, and flour from rejects per farm was computed. The 167 observations from contract farms and 189 from non-contract farms served as inputs to obtain the expected return (in terms of net profit per box) per product per month using constrained M-estimation. The loss function ρ(r) used is the translated biweight function with breakdown point set at 45%.

3.2.2 Robust portfolio optimization with polyhedral uncertainty set.

The portfolio management problem for Cavendish banana products of contract and non-contract farms can be represented by the following robust model with polyhedral uncertainty set:

$$\text{maximize } \sum_{i=1}^{4} \mu_i w_i - \Gamma p - \sum_{i=1}^{4} q_i \tag{4}$$

subject to

$$\sum_{i=1}^{4} w_i$$

$$p + q_i \geq \sigma_i w_i \qquad \forall i$$

$$w_1 = \pi$$

$$p, q_i, w_i \geq 0 \qquad \forall i$$

where i = class A, class B, cluster, and flour from rejects; μ_i and σ_i are the monthly mean and standard deviation of net profit per box of product i estimated using constrained M-estimation; Γ is the protection level against infeasibility such that Γ ϵ [0,4]; w_i is the optimal proportion of Cavendish bananas to be sold as product i; π is the class A production capacity; and p and q are decision variables arising from the conversion of the robust counterpart into a linear formulation through duality theorems. Note that the proportion of class A w_1 is set equal to the capability of the farm to produce class A Cavendish bananas. This is due to the fact that the maximum profitability of a farm is achieved by maximizing the production of class A Cavendish bananas. Hence the product portfolio model aims to provide guidance as to how Cavendish bananas must be diversified into other products in case the farm cannot produce 100% class A Cavendish bananas. This model and all other computations were performed using R programming language.

3.3 Rolling horizon

To assess the performance of the model, we adopt a modified version of the rolling horizon method of DeMiguel & Nogales (2009). In particular, to recommend portfolio weights for month t, parameter estimation and portfolio optimization were performed using the data from month t-1. The generated portfolio weights were then multiplied to the actual net profit per box per product of each farm and then to the total number of boxes produced for month t to determine the total net profit for month t per farm based on the model. This was then compared with the actual net profit for month t. The net profit per hectare for the portfolio and the actual values was computed and used in comparing them through a paired t-test. The stability of portfolio weights was computed as the standard deviation of monthly portfolio weights.

4 Results and Discussion

4.1 Profitability of contract and non-contract farms

Table 1 shows the profitability of sampled farms in the region, comparing the contract and non-contract farms. It is noteworthy that although non-contract farms have higher sales per hectare with PhP 403,797.30 per ha compared to the PhP 355,775.90 per ha of contract farms, net profit per hectare is higher for contract farms (PhP 69,858.00/ha) than for non-contract farms (PhP 12,761.90/ha). The larger sales of non-contract farms owes to the fact that the spot market can offer higher selling prices depending on the market situation. In contrast, contract farmers must stick to the fixed selling price stipulated in their contracts throughout the term of the agreement. The drawback, however, of having no contract with large banana-exporting companies is that the entire cost is typically shouldered by the farmer, unlike in the case of contract farms where access to financial and facility support is available. This is the reason why non-contract farms incur greater costs, resulting in a lower net profit, as compared to contract farms.

Due to the variability of Cavendish bananas in terms of quality and market specifications, a grading system is used to classify them into class A, class B, cluster or reject. Class A bananas are those with 0 to 2 surface defects or blemishes with finger circumference ranging from 39-47 mm and finger length of at least 7.5 inches for big-hand and 6.5-7.4 inches for small-hand. Class B bananas are those with more surface defects than class A bananas but not more than 10% of the total surface area, or those bananas that do not reach the finger circumference requirement for class A bananas. Cluster bananas have the same quality requirements as those of class A or class B but consists of only part of the hand, usually with only 5 to 11 fingers. Lastly, those bananas that do not pass the quality requirements for class A, class B, or cluster are considered rejects. Among these classes, class A has the highest selling price with the greatest market demand.

Table 1.

Comparison of profitability between contract and non-contract farms from January to December 2018.

	Contract farms	Non-contract farm
Number	167	189
Ave. Land area (ha)	1.64	1.86
Sales per ha (PhP/ha)	355,775.90	403,797.30
Cost per ha (PhP/ha)	285,917.90	391,035.40
Net Profit per ha (PhP)	69,858.00	12,761.90

4.2 Quality grade variation between contract and non-contract farms

The percentage distribution of Cavendish bananas vary across farms. As presented in Table 2, class A production is higher in contract farms (89.7%) than in non-contract farms (81.56%). Furthermore, rejection rate is higher in non-contract farms (1.48%) than in contract farms (0.05%), while the difference between class B and cluster production is wider for non-contract farms (13.18%) than in contract farms (5.84%).

The potential for greater income for farms participating in the spot market is constrained by the costs associated with Cavendish banana production as well as by the quality of produce. Farmers have to pay for all costs incurred such as fertilizing, disease management, labor, and postharvest. Also, the quality of banana products tend to be better for contract farms perhaps because of better disease management and access to postharvest facilities. Interventions such as better access to loans or establishment of cooperatives that have better access to such, increased education and skills in disease management, and shared postharvest facility will definitely augment the chances of realizing this great income potential for non-contract farms.

The major weakness of the classical estimators of center (sample mean) and scatter (sample standard deviation) is its sensitivity to extremely low or high values, otherwise known as outliers. In practice, these outliers are inevitable, making the sample mean and sample standard deviation poor estimates of the central tendency and variability, respectively, of real-world data sets. Robust estimators like the constrained M-estimate of multivariate location and scatter have been developed to address this weakness.

Table 2.
Average percentage distribution of Cavendish banana products for contract and non-contract farms.

	Percentage distribution (%)	
	Contract farms	Non-contract farms
Class A	89.77	81.56
Class B	8.01	15.07
Cluster	2.17	1.89
Rejects	0.05	1.48

4.3 Constrained M-estimate of location and scatter for between contract and non-contract farms

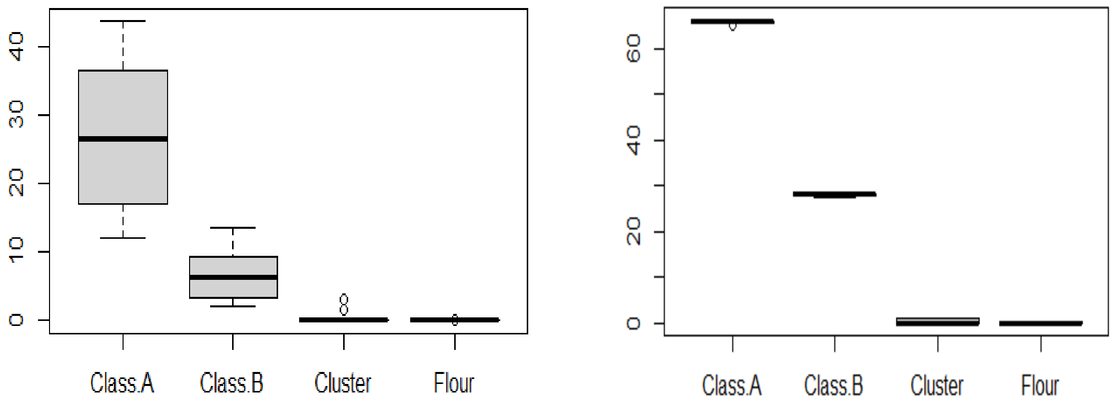
Tables 3 presents the constrained M-estimates of location and scatter for the net profit per box per Cavendish banana product of contract and non-contract farms. Among the products, class A consistently generates the most profit, followed by class B bananas. Specifically, contract farms can achieve around PhP 65 to 66 of net profit for class A while for non-contract farms, the monthly net profit per box is from PhP 12.08 to PhP 43.73. Both the monthly variability and the spatial variability represented by the standard deviation across farms are wider for non-contract farms unlike in contract farms. Overall, contract farms have higher and less variable net profits per box of products as compared to non-contract farms.

Table 3.
Constrained M-estimates of location and scatter for the monthly net profit per box of Cavendish banana products in non-contract and contract farms.

Month	Mean (± std. dev) Net profit per box (PhP/box)							
	Non-Contract				Contract			
	Class A	Class B	Cluster	Flour	Class A	Class B	Cluster	Flour
January	29.81 (±181.81)	6.21 (±73.51)	0.01 (±0.78)	0.004 (±0.164)	65.98 (±24.48)	28.30 (±10.50)	0.00 (±0.00)	0.00 (±0.00)
February	43.08 (±130.97)	13.66 (±51.23)	3.01 (±25.09)	0.11 (±4.36)	65.18 (±20.06)	27.59 (±8.93)	0.93 (±9.41)	0.13 (±2.21)
March	31.82 (±227.95)	6.45 (±75.92)	0.00 (±0.00)	0.00 (±0.00)	65.81 (±24.96)	28.14 (±10.63)	0.00 (±0.00)	0.00 (±0.00)
April	22.63 (±247.14)	6.78 (±71.73)	0.00 (±0.00)	0.00 (±0.00)	66.31 (±22.84)	27.95 (±10.87)	1.10 (±10.51)	0.00 (±0.00)
May	12.08 (±282.76)	2.30 (±82.01)	-0.02 (±0.26)	0.00 (±0.00)	66.30 (±22.84)	27.96 (±10.89)	1.14 (±10.94)	0.13 (±2.12)
June	17.22 (±272.61)	3.78 (±77.41)	0.00 (±0.00)	0.00 (±0.00)	65.67 (±24.69)	28.13 (±10.58)	0.12 (±2.23)	0.00 (±0.00)
July	16.46 (±227.32)	3.16 (±72.39)	0.00 (±0.00)	0.00 (±0.00)	65.84 (±24.60)	28.15 (±10.50)	0.00 (±0.00)	0.00 (±0.00)
August	17.14 (±222.56)	2.13 (±69.90)	0.04 (±0.63)	0.003 (±0.16)	65.84 (±21.56)	27.84 (±9.85)	1.02 (±11.00)	0.13 (±2.20)
September	23.12 (±213.91)	4.93 (±65.05)	0.00 (±0.00)	0.00 (±0.00)	65.98 (±25.16)	28.17 (±10.63)	0.00 (±0.00)	0.00 (±0.00)
October	36.97 (±147.62)	9.97 (±43.80)	1.63 (±13.24)	0.10 (±2.85)	65.96 (±25.12)	28.27 (±10.77)	0.00 (±0.00)	0.00 (±0.00)
November	36.15 (±195.07)	9.27 (±56.76)	0.002 (±1.86)	0.01 (±0.49)	65.73 (±22.27)	27.75 (±10.53)	0.00 (±0.00)	0.00 (±0.00)
December	43.73 (±202.70)	9.28 (±60.68)	0.05 (±0.70)	0.003 (±0.16)	66.14 (±24.71)	28.30 (±10.51)	0.00 (±0.00)	0.00 (±0.00)

4.3.1 Robust portfolio for contract farms

The constrained M-estimates of location and scatter served as input data for the robust portfolio model with a polyhedral uncertainty set. The recommended portfolio of Cavendish banana products for month t is obtained by solving the model with input data from month t-1. For instance, the recommended product diversification for February was determined from the results of the model that utilizes the estimates from January. Fig. 1 depicts the recommended proportion of products for all months and for all values of the protection level $\Gamma = 0,1,2,3,4$.



(1a) (1b)

Figure 1. Monthly net profit per box of Cavendish banana products in (a) contract farms and (b) non-contract farms.

Results of the robust portfolio for contract farms suggest that producing class A and class B Cavendish bananas will maximize profitability regardless of whether the parameter estimates, which are the net profit per box of product, change. For example, if a farm that has a contract arrangement with an exporting company can only produce 90% class A Cavendish banana boxes, then the remaining 10% should be sold as class B boxes rather than distributing them into clusters or flour. This portfolio is feasible since the average percentage of class A Cavendish bananas among contract farms is 89.77% while the average class B percentage is 8.01%. Additionally, the recommended portfolio is the same for all months and for all levels of uncertainties. This reflects the relatively little variability in net profit associated with contract farms. Since the selling price is fixed for the entire year as stipulated in the contract, the only sources of variation for the net profit are the cost incurred and the volume produced, which is also affected by the quality of bananas.

To determine whether the recommended portfolio produces significantly higher net profit per hectare in relation to the actual net profit per hectare of the sampled contract farms, paired t-test was performed (Table 4). As shown, the recommended portfolio generated significantly higher net profit per hectare for all months at 5% significance level except for April for which, although the difference is not statistically significant, the portfolio still resulted in a higher net profit per hectare. This is largely due to the fact that on April of 2018, the product percentage distribution is concentrated on class A and class B Cavendish bananas, which is similar to the portfolio recommendation. On another note, since the portfolio weights are the same for all months, that is, the proportion of Cavendish bananas should be distributed between class A and class B only, the variability across time is zero, implying stability in the portfolio weights produced.

Table 4.

Difference between the resulting portfolio's net profit per hectare and the actual net profit per hectare for contract farms when Γ = 0, 1, 2, 3, 4.

Month	Portfolio's net profit per ha (PhP/ha)	Actual net profit per ha (PhP/ha)	Difference (PhP/ha)
February	4,792.83	4,668.09	124.74**
March	5,595.30	5,482.37	112.92**
April	6,086.65	6,022.35	64.30^{ns}
May	6,002.91	5,830.67	172.24**
June	7,069.97	6,911.58	158.39**
July	7,062.60	6,907.16	155.44**
August	6,626.56	6,494.26	132.30**
September	6,952.83	6,809.39	143.44**
October	5,786.97	5,675.34	111.63*
November	5,481.86	5,343.10	138.75**
December	5,430.38	5,301.45	128.93**

*statistically significant at α=10%; **statistically significant at α=5%; ^{ns}not statistically significant

The recommended portfolio for contract farms poses great potential for maximizing the income of Cavendish banana farmers. Evidently, the model offers significantly higher monthly net profit per hectare, with additional increase of at least PhP 111.63/ha, implying that the existing percentage distribution of products for contract farms can still be augmented by using the model results. Hence, although contract farmers are tied with the fixed selling price in accordance to the contract agreement they have with the exporting company, they can still take advantage of the additional income the portfolio model provides. Meanwhile, the stability of the model's portfolio weights guarantees no drastic changes in their diversification policies even when uncertainties arise. Ultimately, the robustness of the model as well as its higher expected income should be appealing to the farmers and to the industry as well.

4.3.2 Robust portfolio for non-contract farms

The model recommended robust portfolios generated for non-contract farms are more varied in contrast to those generated for contract farms. When Γ = 0 wherein no allowable deviations among all parameter estimates are expected, the model recommends the production of only class A and class B Cavendish bananas (Fig. 2).

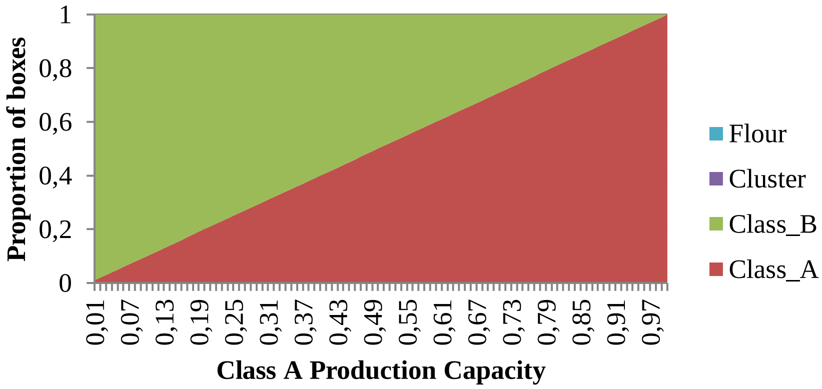


Figure 2. Recommended Cavendish banana product diversification for contract farms when Γ = 0,1,2,3,4.

If one of the net profit per box parameter estimates is expected to differ from the actual value (Γ = 1), it is recommended that non-contract farms diversify into the four Cavendish banana products namely class A, class B, cluster, and flour especially when their class A production capacity is only at most 23% (Fig. 3). However, if the farm is capable of producing more class A Cavendish bananas, the model recommends allotting the rest of the bananas into class B only. Lastly, whenever Γ is 2 to 4 (Figures 4 to 6, respectively), diversifying into class A, cluster, and flour is recommended to maximize net profit per hectare while protecting against risk.

The variability in recommended portfolios for non-contract farms indicates the volatile nature of returns because of the spot market. Particularly, price fluctuations as dictated by the spot market add to the other sources of variation namely the cost, volume produced, and quality. Because of the inherent risks associated in entering the spot market, the robust portfolio is a reasonable strategy to mitigate potential negative impacts of such uncertainties. Here, we find that the model generally suggests diversification whenever it is expected that at least one of the net profit per box estimates turns out to be different from the actual value. Moreover, if the capacity to produce the most profitable product which is class A Cavendish banana is low, diversification should be implemented. This strategy provides immunity against risks.

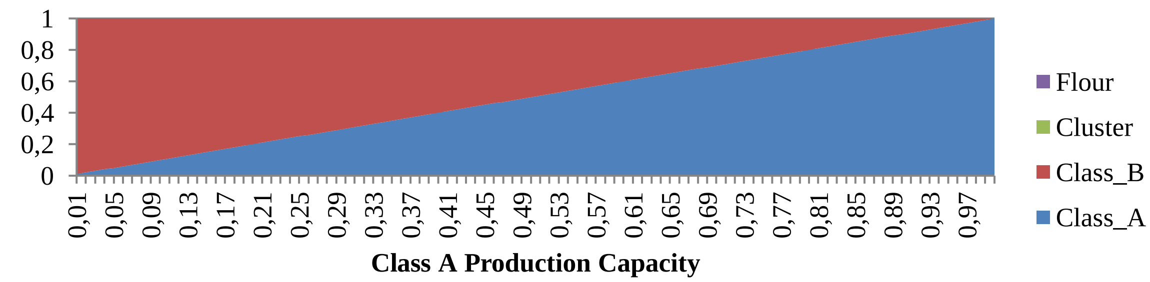


Figure 3. Recommended Cavendish banana product diversification for non-contract farms when Γ = 0.

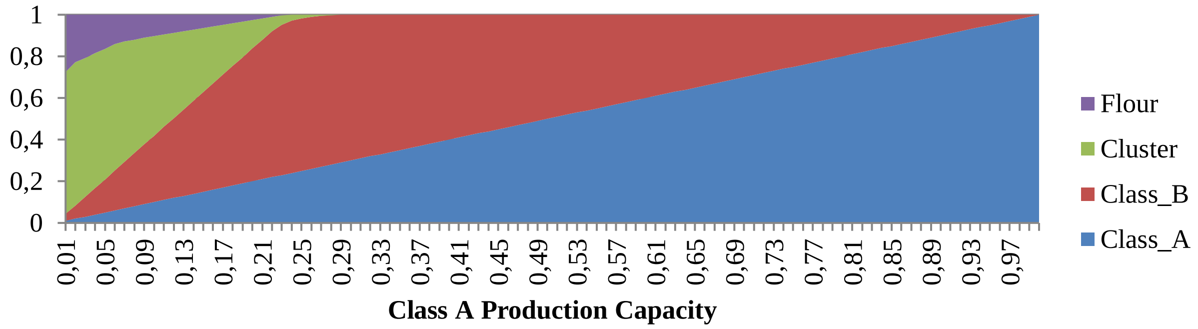


Figure 4. Recommended Cavendish banana product diversification for non-contract farms when Γ = 1.

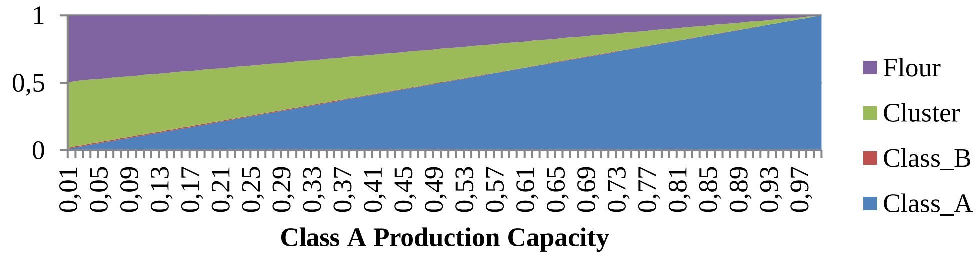


Figure 5. Recommended Cavendish banana product diversification for non-contract farms when Γ = 2.

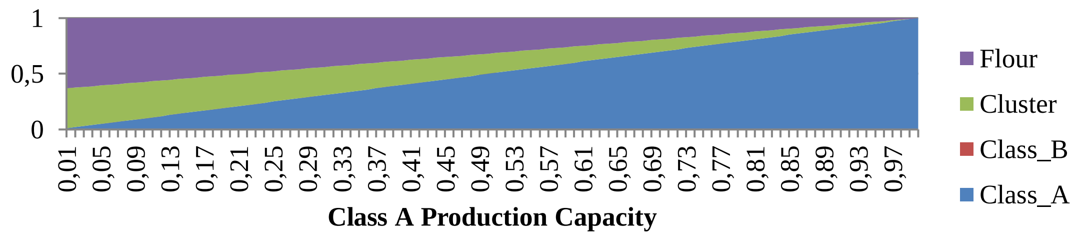


Figure 6. Recommended Cavendish banana product diversification for non-contract farms when Γ = 3.

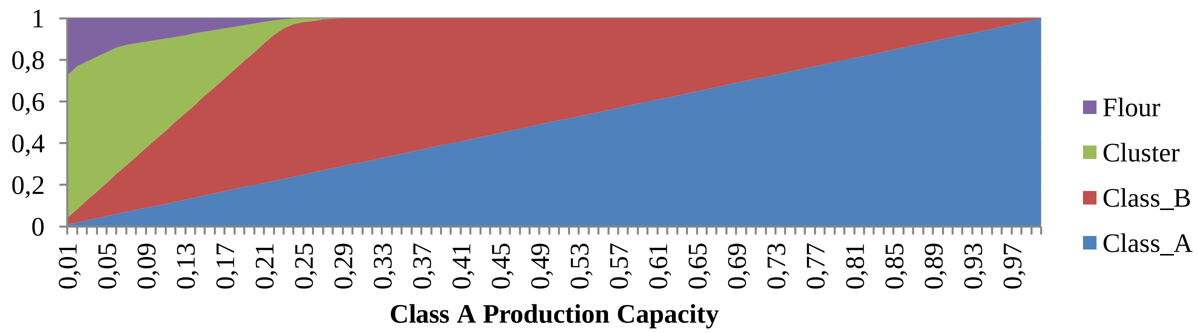


Figure 7. Recommended Cavendish banana product diversification for non-contract farms when Γ = 4.

Table 5 provides details on the net profit per hectare resulting from the model recommended portfolios as compared to the actual net profit per hectare of non-contract farms. Among the protection levels Γ, significantly higher net profit per hectare is achieved when at least two (2) parameter estimates are expected to deviate from their actual values. As high as PhP 386.85/ha and as low as PhP 179.03/ha can be significantly added to the income of non-contract farmers using the recommended portfolios.

Table 5.

Portfolio's net profit per hectare and the actual net profit per hectare for non-contract farms when Γ = 0, 1, 2, 3, 4.

Month	Net profit per hectare (PhP/ha)					
	Actual	Γ = 0	Γ = 1	Γ = 2	Γ = 3	Γ = 4
Feb	186.96	209.13^{ns}	209.16^{ns}	471.77**	479.53**	479.53**
Mar	1,114.88	1,104.24^{ns}	1,104.24^{ns}	1,485.60**	1,485.60**	1,485.60**
Apr	801.28	760.70^{ns}	760.28^{ns}	1,168.10**	1,188.13**	1,188.13**
May	1,219.54	1,168.65^{ns}	1,170.03^{ns}	1,398.57*	1,398.57*	1,398.57*
Jun	2,129.91	2,073.82^{ns}	2,073.82^{ns}	2,368.34**	2,410.68**	2,410.68**
Jul	1,543.95	1,512.73^{ns}	1,512.73^{ns}	1,849.61***	1,862.48***	1,862.48***
Aug	1,514.13	1,437.79^{ns}	1,437.79^{ns}	1,719.46**	1,719.46**	1,719.46**
Sep	1,052.28	1,013.67^{ns}	1,013.67^{ns}	1,345.29***	1,377.05***	1,377.05***
Oct	830.74	769.36^{ns}	769.36^{ns}	991.73^{ns}	991.73^{ns}	991.73^{ns}
Nov	449.92	440.07^{ns}	441.92^{ns}	723.77***	747.25***	747.25***
Dec	1,546.29	1,493.07^{ns}	1,576.33^{ns}	1,804.99**	1,812.18**	1,812.18**

*statistically significant and greater than actual at α=10%

**statistically significant and greater than actual at α=5%

***statistically significant and greater than actual at α=1%

^{ns}not statistically significant

For non-contract farms, the model is able to generate significantly higher returns whenever greater parameter uncertainties are expected. This confirms the appropriateness of the robust portfolio model's objective of finding the best solution among the possible worst-case realizations of the input data to the inherent volatility of non-contract farm income, thereby immunizing the portfolio from the unwanted effects of uncertainties. With this model, farmers are guaranteed that the impact of risk arising from several sources of variation will be lessened while maintaining profitability.

5 Conclusion

Results of the model estimated show how small farmers can take advantage of opportunities under uncertain conditions. Particularly for farmers with no contracts and supplying to spot markets, profitability can be improved through product diversification.

A number of strategies have been implemented to improve income particularly of smallholder farmers. Improving income of farmers in the cavendish banana industry is quite different compared to most agricultural industries because of the presence of contractual arrangements and the perceived imbalanced of power between farmers and multinational companies. There are allegations that multinational companies exercise buying power that leads to contractual arrangements that disadvantage farmers (Dalabajan and Dinglasan, 2018).

This paper shows that farmers who opt to disengage from contracts have the opportunity to earn better incomes despite the risks through product diversification. The case analyzed shows the need to improve support service programs such as product diversification through the development of value-added products from cavendish banana. Increased access to financial and facility support for farmers participating in the spot market in addition to promoting diversification is necessary to mitigate associated risks. This will expand options for farmers to improve their income and livelihoods.

The robust portfolio framework used in this study has not been applied to product portfolio management in the past for agricultural products under contract and non-contract farms. Future studies for other product portfolios can be explored.

Acknowledgement

This research was supported by the Commission on Higher Education and the University of the Philippines Mindanao and the Agri-aqua value chain laboratory funded by the DOST-PCAARRD.

References

Akhtar, S., Gu-cheng, L., Nazir, A., Razzaq, A., Ullah, R., Faisal, M., Naseer, M.A.U.R., and Raza, M.H. (2019). Maize production under risk: The simultaneous adoption of off-farm income diversification and agricultural credit to manage risk. *Journal of Integrative Agriculture*, **18**(2): 460-470.

Anderson, E. and Monjardino, M. (2019). Contract design in agriculture supply chains with random yield. *European Journal of Operational Research*, **277**: 1072-1082.

Bellemare, M.F. and Bloem, J.R. (2018). Does contract farming improve welfare? A review. *World Development*, **112**:259-271.

Bellemare, M.F. and Novak, L. (2017). Contract farming and food security. *American Journal of Agricultural Economics*, **99**(2): 357-378.

Bertsimas, D. and Sim, M. (2004). The Price of Robustness. *Operations Research*, **52**(1): 35-53.

Briones, R.M. (2015). Small farmers in high-values chains: Binding or relaxing constraints to inclusive growth? *World Development*, **72**:43-52.

Da Silva, C.A. and Rankin, M. (2013). Contract farming for inclusive market access. Food Agricultural Organization, Rome.

Dalabajan, D. and Dinglasan, A.K. (2018). Land but no freedom: Debt, poverty and human suffering in the Philippine banana trade. Oxfam International.

DeMiguel, V. and Nogales, F. (2009). Portfolio Selection with Robust Estimation. *Operations Research*, **57**(3): 560-577.

D'Haese, M., Verbeke, W., Van Huylenbroeck, G., et al. (2005). New institutional arrangements for rural development: The case of local woolgrowers' associations in the Transkei Area, South Africa. *Journal of Development Studies,* **41** (8): 1444-1466.

Digal, L.N. (2007).Agricultural Contracts in Mindanao: the Case of Banana and Pineapple, PIDS Discussion Paper Series, No. 2007-24. Philippine Institute for Development Studies (PIDS), Makati City, Philippines.

Grosh, B. (1994). Contract farming in Africa: An application of the new institutional economics. *Journal of African Economies*, **3**(2): 231-261.

Isager, L., Fold, N., and Nsindagi (2018). The post-privatization role of out-growers' Associations in Rural Capital Accumulation: Contract farming of sugar cane in Kilombero, Tanzania. *Journal of Agrarian Change*, **18**(1): 196-213.

Key, N. and Runsten, D. (1999). Contract farming, smallholders and rural development in Latin America: the organization of agroprocessing firms and the scale of outgrower production. *World Development*, **27**(2): 381-401.

Murrray-Prior, R., Batt, P., Conception, S., Digal, L., Hualda, L., and Montiflor, M. (2006). *Global Value Chains: A Place for Mindanao Producers?* Acta Hoticulturae Number 699: Proceedings of the First International Symposium on Improving the Performance in the Transitional Economies. Acta Horticulturae.

Otsuka, K., Nakano, Y., and Takahashi, K. (2016). Contract farming in developed and developing countries. *Annual Review of Resource Economics*, **8**:353-276.

Paut, R., Sabatier, R., Tchamitchian, M. (2019). Reducing risk through crop diversification: an application of portfolio theory to diversified horticultural systems. *Agricultural Systems*, **168**: 123–130. https://doi.org/10.1016/j.agsy.2018.11.002.

Paut, R., Sabatier, R., Tchamitchian, M. (2020). Modelling crop diversification and association effects in agricultural systems. *Agriculture, Ecosystems and Environment*, **288**. https://doi.org/10.1016/j.agee.2019.106711.

Porter, G. and Philips-Howard, K. (1995). Farmers, labourers and the company: Exploring relationships on a Transkei contract farming scheme. *Journal of Development Studies*, **32**(1): 55-73.

Proctor, F. and Digal, L. (2008). Opportunities for small-scale producers' inclusion in dynamic markets in developing countries and transition economies: A synthesis of findings from eight country level chain-wide learning workshops. Working Paper. www.regoverningmarkets.org.

Ray, N., Clarke, G., and Waley, P. (2021). The impact of contract farming on the welfare and livelihoods of farmers: A village case study from West Bengal. *Journal of Rural Studies*, **86**: 127-135.

Sgroi, F. and Sciancalepore, V.D. (2022). Dynamics of structural change in agriculture, transaction cost theory and market efficiency: The case of cultivation contracts between agricultural enterprises and the food industry. *Journal of Agriculture Food Research*, **10**: 100396

Singh, S. (2002). Multi-national corporations and agricultural development: A study of contract farming in the Indian Punjab. *Journal of International Development*, **14**(2): 181-194.

Soullier, G. and Moustier, P. (2018). Impacts of contract farming in domestic grain chains on farmer income and food insecurity. Contrasted evidence from Senegal. *Food Policy*, **79**: 179-198.

Suyo, J.G.B., Le Masson, V., Luhan, M.R.J, and Hurtado, A.Q. (2021). Navigating risks and uncertainties: Risk perceptions and risk management strategies in the Philippine seaweed industry. *Marine Policy*, **126**: 104408.

World Bank (2007). World Development Report 2008: Agriculture for Development. The World Bank, Washington, DC.

Ton, G., Vellema, W., Desiere, S., Weituschat, S., and D'Haese, M. (2018). Contract farming for improving smallholder incomes: What can we learn from effectiveness studies? *World Development*, **104**:46-64.