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The Price Risk Management Trough Crop Diversification: The Portfolio Theory Can Be Extended To Cash Crops?

La gestion du risque de prix par la diversification des cultures: la théorie du portefeuille peut-elle être étendue aux produits de rente ?

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Abstract
The objective of this article is to show that the cultural diversification practiced by farmers organizations producing cocoa and coffee is a price risk management strategy for these products from a portfolio theory perspective. Secondary price data from UNCTAD and FAO have been used to calculate correlations and to identify crop combinations that maximize income and minimize risk. The combinations of cocoa - palm oil - tubers, cereals - bananas - coffee ... are optimal. Farmers organizations can adopt a combination of two or three crops, as the results show, to manage the price risk of cash crops. They can orient their cultivation activities by combining cash crops (with highly fluctuating and uncontrollable prices) with food crops (sometimes with stable and controllable prices). These associations must take into account the negative correlations of prices and yields between crops. The study showed that it is not the combination of many crops that minimizes price risk and maximizes the income of farmers organizations, but the choice of a limited number of crops that makes it possible to achieve this objective. These results corroborate those achieved with financial assets combining assets with negative correlations in portfolios. Thus, the portfolio theory can be extended to cash crops.
Keywords: *Diversification, price risk, portfolio, farmers organizations, correlation.*

Résumé
L'objectif de cet article est de montrer que la diversification culturelle pratiquée par les organisations paysannes produisant du cacao et du café est une stratégie de gestion des risques de prix pour ces produits dans une perspective théorique de portefeuille. Les données secondaires sur les prix de la CNUCED et de la FAO ont été utilisées pour calculer les corrélations et identifier les combinaisons de cultures qui maximisent les revenus et minimisent les risques. Les combinaisons de cacao - huile de palme - tubercules, céréales - banane - café ... sont optimales. Les organisations paysannes peuvent adopter une combinaison de deux ou trois cultures, comme le montrent les résultats, pour gérer le risque de prix des cultures de rente. Ils peuvent orienter leurs activités culturales en combinant les cultures de rente (avec des prix très fluctuants et incontrôlables) aux cultures vivrières (parfois avec des prix stables et contrôlables). Ces associations doivent tenir compte des corrélations négatives des prix et des rendements entre les cultures. L'étude a montré que ce n'est pas la combinaison de nombreuses cultures qui minimise le risque de prix et maximise les revenus des organisations paysannes, mais le choix d'un nombre limité de cultures qui permet d'atteindre cet objectif. Ces résultats corroborent ceux obtenus avec des actifs financiers combinant des actifs avec des corrélations négatives dans les portefeuilles. Ainsi, la théorie du portefeuille peut être étendue aux cultures de rente.
Mots-clés*: Diversification, risque de prix, portefeuille, organisations paysannes, corrélation.*

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I. Introduction

The management of price volatility of raw materials, especially agricultural commodities, has been an international concern since the United Nations Conference on Trade and Development (UNCTAD) held in the 1950s. Under the leadership of national and international organizations, several mechanisms and strategies have been proposed, such as product agreements, market instruments and national and international stabilization systems. The persistence of price volatility, and particularly the fall of prices in the mid-1980s, made both national and international hedging instruments obsolete. Moreover, market instruments in some countries,

particularly in Developing Countries where liberalization was rushed, became inoperative and commodity futures markets proved to be incomplete or non-existent,

Farmers Organizations (FOs) producing cocoa and coffee, which benefited from the support of the States at several levels, were left out in the face of the vagaries of the markets. Price fluctuations combined with their downward trend resulted in a decrease and uncertainty of their income. As a result, poverty in rural areas has increased. Among the income support strategies set up by these farmers' organizations are: crop associations, crop diversification abandonment of cash crops in favor of other crops... In this respect, FAO statistics (2019) reveal that the cultivated areas and the quantities harvested, excluding cash crops, are increasing significantly. If the large multinational groups are at the root of this reorientation of agriculture in these countries, the Farmers' Organizations that were once specialized in cash crops have now embarked on this diversification. According to the UNCTAD report (2018), the diversification index calculated from the Herfindal Diversication Index (HDI) is 0.66 in Central Africa, reflecting the high degree of diversification at both the commodity chain and farm levels. Moreover, the volatility indices for cash products such as cocoa, coffee, rubber and palm oil are 3.81, 5.19, 5.61 and 4.86 respectively, thus showing the degree of price instability of these different products and the need to find mitigation strategies (UNCTAD, 2019).

The initial objectives of this diversification were income support and food self-sufficiency. Today, the increase in area and quantity has already exceeded these initial objectives. The products can be found in national, sub-regional and international markets where the problem of prices and their fluctuations is still acute. This problem is aggravated when the prices of the various products follow a downward trend and /or maintain a perfectly positive correlation.

The question of price risk management through crop diversification is becoming urgent and is posed in the same terms as in modern portfolio theory. Indeed, diversification provides information on the importance of holding portfolios that are sufficiently diversified to achieve the minimum risk objective. The exposure of agricultural activity to numerous risks, including that of fluctuations in the selling prices of products, leads the cocoa and coffee producing Farmers' Organizations of Developing Countries to adopt cultivation practices that can be assumed to be aimed at minimizing the price risk of cash crops. What is the crop mix that maximizes the income of farmers' organizations and minimizes price risk?

The answer to this question is based on Markowitz's (1952) portfolio theory with its extensions such as Roy's (1952) concept of safety first and the behavioural portfolio theories of Statmann and Shefrin (2000). Empirically, it is observed that farmers' organizations engage in various crop associations (Cordier et al., 2018). :- cocoa - plantain - oil palm - tubers - bananas ; - coffee - banana - rubber tree - cereals - market garden crops; - cocoa - tubers - oil palm - plantains - cereals ; - etc.

However, these practices, far from being spontaneous generation, do not seem to be in line with the models deduced from portfolio theory. It is therefore necessary to apply the principle of the portfolio theory to cash crops and other crops (tubers, cereals, oil palm, etc.) which form the basis of the economies of Developing Countries and on which most of their income and export earnings depend. Moreover, while some works (Ibrahim, 2016 and UNCTAD, 2018) have described crop diversification practices in certain countries, they have not proposed crop combinations that would maximize the income of Farmers' Organizations and minimize the price risk.

The objective of this paper is to show that crop diversification, through a judicious combination of cash and food crops, is a price risk management strategy. The continuation of this work is organized as follows: the Theoretical Background of portfolio theory and the crop diversification (2), the Material and Methods (3), the Empirical Results (4) and the managerial implications (5).

1. The Theoretical Background of portfolio theory and the crop diversification

The prices of raw materials such as cocoa and coffee fluctuate. These are random variables that lead to price risk. Therefore, maximizing expected gains is insufficient to make rational decisions (Simon, 2015). A solution to this problem can be found in the work of Von Neumann and Morgenstern in 1923, who proposed an axiom linked to the theory of utility functions that describes the behavior of economic agents in the face of risk. It emerges that the selection criterion is the maximization of the expected utility. Since Markowitz's article (1952), several studies have been conducted. In this section, we present the diversification through the prism of portfolio theory and then the crop diversification.

1.1. The Markowitz diversification

The choice between achieving a certain but low profitability, or taking a risk offset by a higher expected return, is a fundamental dilemma in finance (Aftalion and Poncet, 2016). Markowitz (1952) formalized and quantified the effect of diversification, according to which a judicious combination of many assets in a portfolio reduces the total risk for a given rate of return. We will discuss portfolio diversification on the one hand and alternative portfolio management on the other.

1.1.1. The portfolio diversification

The major lesson of modern portfolio theory is the concept of diversification, which provides information on the importance of holding portfolios that are sufficiently diversified to achieve the objective of risk minimization. The larger the size of these portfolios, the more risk is minimized (Esran, Harb, verzhenko; 2017).

This result is justifiable through a simple naïve diversification strategy suggesting the construction of a sufficiently large, equally weighted portfolio. There is then a relationship between diversification and risk reduction. This is the key lesson of Markowitz's theory (Cobbaut and Bernard, 2017). However, this conclusion comes up against a completely contradictory empirical finding. Indeed, many studies have been able to verify the under-diversification or concentration of portfolios. Barbier and Odean (2000), report that, a typical individual investor tends to hold a portfolio of only four stocks. This result is confirmed by Polkovnichenko (2005) using data from SCF (the Survey of Consumer Finances), where a diversification effect was detected among portfolios held by United State of America households. Goetzmann and Kumar (2008) also defend the concentration effect at the level of individual investors' portfolios. The concentration effect is greater among younger, less educated, and lower-income investors. The authors explain these results primarily by the informational quality associated with holding concentrated portfolios.

One of the motivations for crop diversification is certainly the lack of information on the evolution of variables affecting the prices of exportable products. For Farmers' Organizations, information on products such as cocoa and coffee in terms of prices, marketing channels, supply and demand... is almost unavailable in real time. They therefore choose the crops where they have the most information. We are faced with a diversification of crops combining cash crops and food crops (Mandeng, 2013).

However, the decisions of farmers' organizations to diversify seem to have a twofold objective: to preserve a minimum level of wealth (safety first) and the trade-off between the fear of falling prices of cash crops and the hope of seeing these prices take off again (behavioral portfolio theory). These two decisions constitute alternative portfolio management.

1.1.2. The alternative portfolio management.

The ambiguities of Markowitz-style diversification have led Statman (2004) to describe them as a "puzzle". The reduction of this puzzle can only be achieved through portfolio management approaches that challenge the reductive assumptions of the Markowitz approach.

- **The "safety first" models**

Roy (1952) developed the concept of "safety first". Unlike Markowitz's (1952) idea, which links risk to the deviation of the investor's wealth from its average value, thus weighting probable gains and losses in the same way and suggesting variance as a sufficient measure of risk; Roy (1952) translates risk rather in terms of the losses borne by the investor. Thus, according to this concept, the investor wants to preserve a minimum level of wealth, often called the subsistence level. A realization of wealth below this threshold will be considered a loss. Thus, Roy (1952) proposes to use this threshold as a portfolio selection criterion in the sense that the investor's objective is to minimize the probability that wealth will fall below the subsistence threshold. A limitation of Roy (1952)'s model is that it does not provide information on what the investor is supposed to do with the excess wealth. It is at this limit that Arzac and Bawa (1977) attempt to provide solutions by adding an additional choice criterion, which is the final wealth expectation or also the portfolio, return expectation (Abdallah, 2014).

Farmers' organizations producing cocoa and/or coffee taken as investors and after the fall in commodity prices in the mid-1980s followed by the liberalization of trade in these products, face two situations: the decline and fluctuation of income. The immediate consequence is poverty in rural areas specializing in these crops. By adopting the safety first model, they have combined cash crops with other crops that are marketed nationally and sub-regionally and are also used for consumption. They have been able to maintain their subsistence level through this diversification (Mandeng, 2016).

- **The behavioural portfolio theory**

The inability of utility expectation theory to describe the behaviours observed in individuals is demonstrated in numerous empirical or experimental economics works and has led to the development of alternative theories such as perspective theory (Kalmann and Tversky, 1979), rank dependent utility models (Quiggin, 1982) or cumulative perspective theory (Tversky and Kalmann, 1992). On the other hand, the advances of Thaler (1999) through the theory of mental accounting, which refers to the way in which individuals perceive, classify and organize financial flows and their investments, have led to the development of the idea of prioritizing investment flows into categories or accounts linked to their degree of liquidity. Shefrin and Statman (2000) drew on this framework to develop their so-called "behavioural" portfolio theory, with the

aim of providing some answers to controversial investor behaviour that escaped the conclusions of Markowitz's standard theory. This theory offers two versions. One is called the "single mental account version", in which the authors combine the concept of safety first with the conclusions of psychology (Lopes, 1987). According to this version, individuals decisions are governed by two feelings: fear and hope. Adaptation to investment choices for each of these two feelings results in a distortion of the distribution of the probability of final wealth. The second called "Multiple mental account", where the authors introduce another psychological bias emanating from the work of Thaler (1999), is known as mental accounting. In this version, which is an extension of the first one, several mental accounts are considered at the same time.

Thus, on the behavioural level, farmers' organizations producing cocoa and/or coffee, like all other investors, play between fear and hope. This is justified by the presence on the same spaces of cash crops and food crops. They have not removed all the cash crops in the hope that their prices will stabilize and rise. But the fear of a perpetual slump and erratic fluctuations in the prices of these products led them to opt for a combination of crops.

1.2. The crop diversification

Crop diversification refers to the production of several crops on the same farm and/or plot of land (Ibrahim, 2016). Crop diversification is considered an agricultural risk management strategy around the world (Ramaswani et al., 2003). Indeed, this strategy appears to be effective in reducing overall agricultural risk (Mandeng, 2016). This is because each crop variety is exposed to risk to different degrees. With regard to the price risk of exportable products such as cocoa and coffee, crop diversification not only mitigates its impact on household income through the multiplication of sources of income, but also reduces the dependence of these households on imported products. This diversification can be observed at the level of commodity chains and at the farm level.

1.2.1. The diversification of sectors

The perverse effects of an economy's dependence on one sector of the economy have been described as dutch disease, referring to North Sea gas production in Holland. This term has been applied to the economies of Nigeria (oil), Cameroon (coffee, oil) and Colombia (coffee) (Cuddington (1989) cited by Malezieux and Moustier, 2015).

In the central-eastern part of Cote d'Ivoire, for example, the development of market gardening corresponds to the drop in cocoa prices associated with the ageing of plantations from the 1990s onwards. The development of market gardening in the French Overseas Departments corresponds to the difficulties in marketing banana and sugar cane, the pivotal crops of these islands (Temple, 1997). However, while the financial instability of markets is one of the determinants of diversification, its success and sustainability depend on many other factors such as: infrastructure, processing units, proximity to the city, packaging, demand, etc., which determine the economic conditions of agricultural production (Malezieux and Moustier, 2015). Thus, diversification is emblematic of two parallel evolutions of agricultural markets: instability and segmentation (IRAD, 2018). However, some authors wonder whether diversification crops are not condemned to play a residual role, or even a "hiding place" compared to pivot crops in crisis. Indeed, niche markets are narrow and the areas devoted to diversification crops are often scattered. Diversification may correspond to the logic of uncoordinated entrepreneurs competing in narrow niche markets. This reinforces market instability (Papy, 2017). However, policies to support diversification chains, through support in terms of technical training, producer organization and access to market infrastructure, can stabilize markets or even transform diversification crops into pivot crops. This is the case of horticulture in Réunion, which has surpassed sugar cane in value (Malezieux and Moustier 2015). But, what about the farms diversification?

1.2.2. The diversification of farms

The agricultural holding, the basic economic and social entity in most situations, is the privileged management place where diversification takes its economic, social and environmental coherence.

The process of diversification can be seen as the response of an actor-farmer to a new economic situation: adapting to new markets and thus seizing new opportunities, optimizing the family labour force, minimizing or limiting risks (Mandeng, 2018). It is the combination of the multiple action strategy that will have to be considered. The farmer's objectives, the strategies for dealing with agricultural risk and the trajectories of parcel development are essential analytical factors for understanding the logic and forms taken by diversification. Rather than maximizing income expectations, the poor farmer seeks to ensure a minimum income that allows him to reach the subsistence threshold, i.e. the reproduction of the farm and the family's basic needs (food, housing, clothing, schooling for children) (IRAD, 2018). This "risk-averse" attitude will lead to anti-risk strategies (which can be described as defensive strategies), including diversification of production. While a european farmer may borrow from the bank to cope with a bad year, the west african farmer may not

survive (Papy, 2017). In the work carried out in the 2000s in West Africa, cassava/sweet potato, or cassava/corn/sweet potato, or cassava/bean combinations give coefficients of variation in income that are almost half those of pure crops. The diversification of farm activities towards non-agricultural work, such as trade or handicrafts, follows the same risk reduction logic (Meynard et al., 2018). The farmer seeks to build up a portfolio of activities with as few correlations as possible between the risk level of each component. The combination of several crops on a farm also allows transfers of financial resources from one crop to another, depending on their degree of success. This is the case for market gardening farms in the Abengourou region of Côte d'Ivoire, for which the benefits of tomatoes make it possible to replant perennial crops, and which reciprocally use the products of coffee and cocoa plots to reinvest in tomatoes (Cordier et *al*., 2018).

The analysis of vegetable cropping systems in Brazzaville illustrates strategies for combining vegetables on the farm. Peri-urban market gardeners derive most of their consumption needs from the sale of vegetables. They therefore adopt strategies to obtain regular income all year round (Gafsi, 2017).

Ultimately, the question of managing the price risk of agricultural products involves various techniques (coverage, insurance, diversification and other public or private contributions). Table above, presents the practical actions to be implemented in the face of the vulnerability caused by agricultural risks. This table shows, among other things, that diversification is an opportunity in the face of risk. Farmers' Organizations have seized this opportunity and have embarked on the diversification of their agricultural production in such a way that today, on farms, several crops coexist (cocoa tubers-banana-cereals-oil palm, etc.), and there is diversification of the commodity chains (oil palm, coffee, cocoa, cereals, etc.). This work aims to optimize this diversification by testing crop associations that minimize the price risk and maximize the income of farmers' organizations. The following methodology allows us to demonstrate this.

Table 1: Facing risk, a typology based on vulnerability

Practical action	Ex ante	Ex post
Capital endowment Lallau(2005) Cordier et al (2018)	Insurance and savings -precautionary savings (money, livestock, stocks) Setting up informal insurance (tontine, community)	Decapitalization and indebtedness -use of precautionary savings -reduction in current consumption, health, and school expenditures -use of informal insurance -Increased exploitation of natural resources -resale of equipment and inventory
Opportunities IRAD (2018) Gafsi(2017)	Diversification, Specialization and Status Quo -pluriactivity, crop association, plot dispersal, technical status quo -specialization in counter-hazardous crops or activities	Compensation -diversification of activities - retrenchment
Price risk Simon and Lauthier (2010), Mandeng (2018 and 2016)	Avoid -investment in inputs hydraulic, anti-erosion and agroforestry installations -occupation of space	Rupture -change of activities -temporary or permanent rural exodus -lending -productive investments

Source: Author from the literature review

II. Material and Methods

The objective of this paper is to show that crop diversification or the association between cash crops (cocoa and/or coffee) and other food crops (rice, maize, plantain, banana, oil palm...) is a price risk management strategy. The methodology consists of two steps: the first one consists in presenting the underlying assumptions of crop diversification and their adaptation to crop diversification and the second one, presents the data and the correlation test.

2.1 The diversification hypothesis and their extension

This sub-section takes the general assumptions of portfolio diversification and seeks to adapt them within a specific framework which is crop diversification.

The diversification assumptions (Markowitz, 1952)

Markowitz's various works that have led to the theorization of optimal stock portfolio diversification are based on a number of assumptions, including the following:

- H1: Risk aversion. Markowitz explains the difference in risk perception that exists between investors by the degree of risk aversion;
- H2: The mean-variance approach. In building the portfolio, investors seek to maximize the average of the portfolio's returns while minimizing its variance;
- H3: The decision horizon. It is the same for all investors and for a period;

- H4: The normality of returns. Markowitz assumes that the evolution of prices on the financial market is a random phenomenon described by a Laplace-Gauss probability law;
- H5: Covariance of assets. The returns on different assets are not independent of each other, i.e., their covariances are not zero;
- H6: Market efficiency. For Fama (1965), the market is informatively efficient if prices fully and instantaneously reveal all available information, and for Jensen (1978), there should be no profit or special advantage in having information;
- H7: The absence of transaction costs;
- H8: Any investment is a decision taken in a situation of risk, the return on a financial asset for any future period is therefore a random variable that is assumed to be distributed according to the normal distribution.

The different assumptions made by Markowitz for assets trading on financial markets seem to be well adapted for some, in the context of crop diversification in cocoa and coffee producing countries (H1, H2, H3, H4, H5, H8). But other hypotheses do not correspond to the reality of this context because of the non-existence or embryonic state of commodity futures markets (H6 and H7). Moreover, climatic and production conditions impact on the quality and quantity of these products, hence other hypotheses, namely:

- H9: Only price volatility is a source of risk on the income of farmers' organizations;
- H10: The income of farmers' organizations is the average sales of all cash and food crops over a period of time.

2.2. The data and the statistical test

The sub-section presents the data used for analysis and the statistical test needed to identify crop combinations that maximize the income of farmers' organizations and minimize price risk.

2.2.1. The data

Table 2 above shows the price data for the different products (cocoa, coffee, banana, plantain, rice, tubers, palm oil, and maize) used. They come from the UNCTAD and FAO databases. The observation period is from 2000 to 2018. These prices are expressed in United State Dollars (USD) per ton or per 60 kg bag.

Table 2: Price data for different types of products

Elements	*Products*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
Producer Price (USD/tonne)	Cocoa	632	903,2	1102,8	1556,4	1129.6	1122	1335.4	1732.5	1888.4	2340.4	2300,9	2220,9	2390,5	1998,5	2540,6	2320,9	2490,5	2098,5	2540,6
	Coffee	491.6	621,4	700,9	763,5	763.1	590.9	824.2	869.1	893	920.4	920,4	952,1	879,6	951,2	865,9	922,1	899,6	981,2	875,9
	Palm oil	476.4	472	496.4	739.8	800,2	752,6	987,5	1438.8	1348.7	1280.3	1209.6	1106.7	1982,9	1250,7	1400,2	1406.7	2082,9	1450,7	1400,2
	Tuber (Cassava)	110	88.7	93.3	120.4	116,2	155,2	168,3	268.9	316	418.5	333.8	286.1	362,1	321,2	395,4	386.1	392,1	301,2	399,4
	Cereals (corn)	217	177.3	186.5	238.3	196,2	175,9	214,9	472.4	373.3	315.5	407.2	418.9	423,9	412	398,6	418.9	411,9	412	388,6
	Plantains and others	90	124	91.3	142.8	111,2	145,3	300,1	352.8	337.5	371.8	363.1	306.1	310,2	300,2	350,2	366.1	340,2	320,2	390,2
	Rice	214	204.9	215.5	210,3	199,8	230,1	459,5	567.6	263.5	246.9	357.4	404.6	399,2	405,2	375,2	394.6	399,2	415,2	395,2
	Bananas	80,8	78,1	78.9	80,9	81,6	79,8	86	89,1	78,9	92,3	85,1	90,2	98,2	96,7	102,3	103,1	104,2	105,2	111,7

Source: FAOSTAT and UNCTAD

2.2.2. The correlation test

The statistical test is the Pearson price correlation. In terms of diversification, only products with a negative correlation are of interest in the demonstration. The calculations consist, on the one hand, in finding the coefficient of variation:

$$V = \frac{\sigma}{E}, \qquad (1)$$

and on the other hand to calculate the variance:

$$\sigma_p{}^2 \quad = \sigma^2{}_x + \sigma^2{}_y \qquad (2)$$

Thus, if the products in terms of price are negatively correlated, i.e. if *Rho* is equal to -1 ($\rho_{x\,y} = -1$) so, (3)

$$\sigma_p{}^2 = a^2\sigma_x{}^2{}_x + b^2\sigma_y{}^2 \; - \; 2\,a.\,b\sigma_x\sigma_y$$

$$\sigma_p{}^2 \quad = \left(a\sigma_x - b\sigma_y\right)^2 \qquad (4)$$

Equation (4) shows us that the risk of X cancels or reduces the risk of Y. Diversification is used to reduce the overall risk of the portfolio. In practice when an event lowers X,Y increases and vice versa. In order to eliminate the risk completely, we will build the portfolio so that it equals, and the portfolio of activities will then be risk-free.

III. Empirical Results

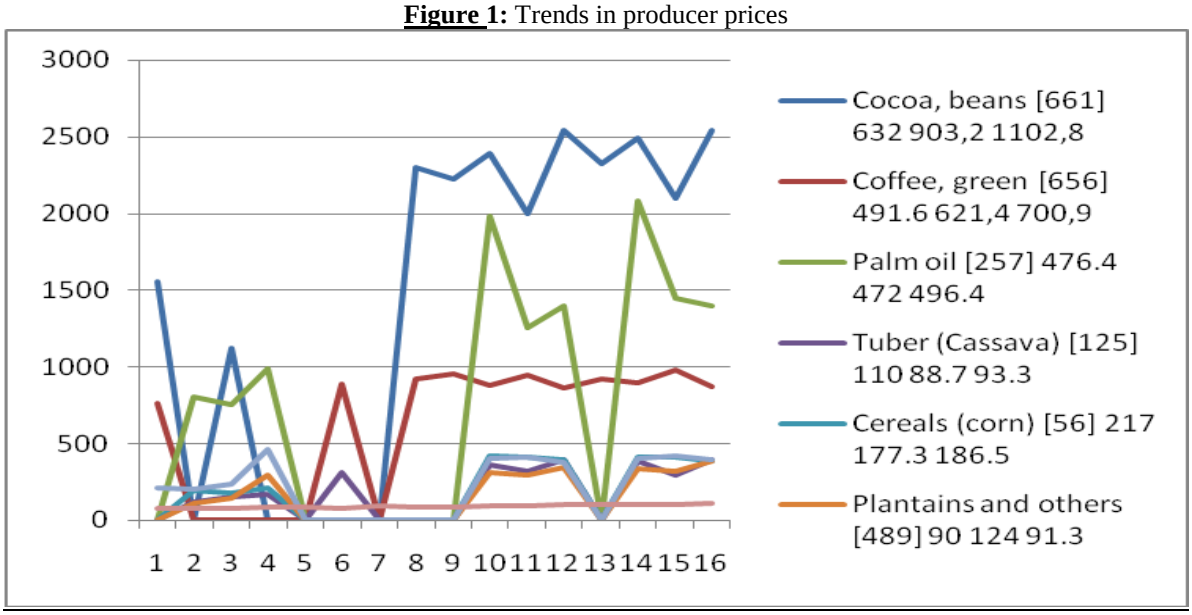
The exploitation of the data in Table 4, through the analysis of price trends for different products and the application of the correlation test, leads us first to present the results and secondly, the managerial implications.

This study is based on certain agricultural products. The objective being to find a link between these different products, we are interested here in their trends and their correlations in relation to their prices. Based on data collected over a nineteen-year period (2000 to 2018), we have eight products for this study. Using the SPSS software, we extracted the graph and correlations.

3.1 The analysis of price trends.

Price is the most important element of this study. Starting from figure 1 above, we analyze the trend in the prices of the different products at the producer level. Apart from bananas, which have an almost constant price curve, all other products have highly fluctuating prices. These erratic fluctuations appear to be cyclical and are characterized by sharp rises and falls. The analysis of the trends on this graph illustrates the effect of diversification for some years. For example, in 2002, 2004 and 2007, the collapse of cocoa and coffee prices was supported by the rise in palm oil, tuber and cereal prices. Similarly, in 2009, 2011 and 2015 the fall in prices of some products is supported by stable prices of food crops such as tubers, seedlings and cereals. All these trends lead us to test the correlation between products.

Figure 1: Trends in producer prices



Source: Analysis in SPSS of Table 3

3.2 The correlation analysis

Table 3 above, presents the results of the analysis of the correlations between the different prices of our products. It shows that there are correlations between cocoa and palm oil, cocoa and banana; between coffee and palm oil, coffee and banana and between banana and palm oil. The resulting matrix shows: the correlation

coefficients, the degree of significance of the relationship and the number (N) of observations. We are interested in negative correlation coefficients because they allow us to construct portfolios in such a way that when the price of one product decreases, the price(s) of another increases.

Table 3: Producer price correlations

		P. banana	P. cocoa	P. coffee	P. palm oil	P. cassava	P. plantains	P. rice
P. banana	Pearson Correlation	1	,174	-,014	,388	,382	,399	,380
	Sig. (bilateral)		,535	,961	,153	,160	,141	,163
	N	15	15	15	15	15	15	15
P. cocoa	Pearson Correlation	,174	1	,750**	,389	,279	,334	,263
	Sig. (bilateral)	,535		,001	,152	,314	,223	,343
	N	15	15	15	15	15	15	15
P. coffee	Pearson Correlation	-,014	,750**	1	,149	,296	,082	-,030
	Sig. (bilateral)	,961	,001		,596	,285	,771	,915
	N	15	15	15	15	15	15	15
P. palm oil	Sig. (bilateral)	.	.	.	.	.	.	.
	N	0	0	0	0	0	0	0
	Pearson Correlation	,388	,389	,149	1	,770**	,932**	,823**
	Sig. (bilateral)	,153	,152	,596		,001	,000	,000
	N	15	15	15	15	15	15	15
P. cassava (tuber)	Sig. (bilatérale)	.	.	.	.	.	.	.
	N	0	0	0	0	0	0	0
	Pearson Correlation	,382	,279	,296	,770**	1	,768**	,693**
	Sig. (bilateral)	,160	,314	,285	,001		,001	,004
	N	15	15	15	15	15	15	15
P. cereals (corn)	Pearson Correlation	,404	,389	,082	,898**	,819**	,916**	,889**
	Sig. (bilateral)	,136	,152	,770	,000	,000	,000	,000
	N	15	15	15	15	15	15	15
	Sig. (bilateral)	.	.	.	.	.	.	.
	N	0	0	0	0	0	0	0
P. plantains	Pearson Correlation	,399	,334	,082	,932**	,768**	1	,895**
	Sig. (bilateral)	,141	,223	,771	,000	,001		,000
	N	15	15	15	15	15	15	15
P. cereals (rice)	Pearson Correlation	,380	,263	-,030	,823**	,693**	,895**	1
	Sig. (bilateral)	,163	,343	,915	,000	,004	,000	
	N	15	15	15	15	15	15	15

Source: Analysis in SPSS

3.3 The building of optimal portfolios

Table 3 above, taken from the matrix of price correlation coefficients, shows that there is a possibility of combining crops in an optimal way. In this table, it is the "Yes" answers that are interesting because they provide information on the possibility of building portfolios. In this table, we can see that rice and palm oil are almost correlated with all other products except in some cases with maize. On the other hand, by focusing on the combination of annuity products such as cocoa and coffee, some associations revealed by the analysis appear relevant. Thus, one can propose the combinations that constitute the following optimal portfolios or crop mixes:

- Cocoa - palm oil - cereals;
- Coffee - palm oil - cereals;
- Rice - banana - tubers;
- Cereals - banana - coffee.

Tableau 3 : Crop association

	R. bananas	R. cocoa	R. coffee	R. cassava	R. corn	R. plantains	R. rice
R. bananas	1	No (,838**)	No (,483)	No (,686**)	Yes (-,554*)	No (,907**)	Yes (-,288)
R. cocoa	No (,838**)	1	No (,516*)	No (,701**)	Yes (-,609*)	No (,898**)	Yes (-,387)
R. coffee	No (,483)	No (,516*)	1	No (,347)	Yes (-,494)	No (,556*)	Yes (-,492)
R. palm oil	Yes (-,475)	Yes (-,508)	Yes (-,043)	Yes (-,586*)	No (,154)	Yes (-,539*)	Yes (-,319)
R. Tubers(cassava)	No (,686**)	No (,701**)	No (,347)	1	Yes (-,131)	No (,883**)	Yes (-,051)
R. cereals (corn)	Yes (-,554*)	Yes (-,609*)	Yes (-,494)	Yes i (-,131)	1	Yes (-,469)	No (,646**)
R. plantains	No (,907**)	No (,898**)	No (,556*)	No (,883**)	Yes (-,469)	1	Yes (-,274)
R. cereals (rice)	Yes (-,288)	Yes (-,387)	Yes (-,492)	Yes (-,051)	No (,646**)	Yes (-,274)	1

Source: Analysis in SPSS of Table 2

These results are consistent with empirical field observations in the different crop areas. In reality, these are the crop associations that are practiced in many countries where cacao et coffee are produced (Cameroon, Ivory Cost, Ghana Colombia, Malaysia...). It is relevant that Farmers' Organizations can adopt crop diversification in the face of erratic fluctuations in the prices of their commodities, namely cocoa and coffee. For this seems to minimize the price risk and maximize their income. These results do not deviate from the reality of financial market actors. Because they faced the price risk, they diversify their portfolios by associating negatively correlated assets. These results correspond to the findings of Goetzmann and Kumar (2008) and Keynes (1923)[1].

IV. The managerial implications.

Erratic fluctuations in the prices of commodities such as cocoa and coffee pose a real management problem in producing countries whose incomes are highly dependent. The problem is that of net losses due to the fall in the selling price, with the corollary of lower incomes. Several attempts are being made to minimize the impact of price risk on the income of farmers' organizations:

- At the level of commodity futures markets, hedging techniques are proposed such as futures contracts, options, forwards and futures contracts, income insurance contracts... (Simon and Lauthier, 2010);
- The proposals of researchers interested in this issue, especially in developing countries, are price risk management techniques and models for coffee and cocoa farmers. This is the case of the price risk management strategies proposed by the Kamdem two sequence model in 1990, the World Bank's model in Burundi in 2005, or the Mandeng (2016) income model for Cameroon (Mandeng, 2018) ;
- Crop diversification practiced by the Farmers' Organizations themselves, etc.

Thus, in a context of liberalization, price fluctuations, rising prices of agricultural inputs, incomplete information and the absence of Commodity Term Markets (TMM); Far from diversifying products without taking into account their yield and risk, farmers organizations can adopt a combination of two or three crops, as our results show, to manage the price risk of cash crops. In other words, they can orient their cultivation activities by combining cash crops (with highly fluctuating and uncontrollable prices) with food crops (sometimes with stable and controllable prices). These associations must take into account the negative correlations of prices and yields between crops. All of the above should lead to minimizing price risk and maximizing income. Thus, this study aims at a twofold contribution:

- on the one hand, the extension of portfolio theory to cash crops. In the sense that the portfolio theory with its principle of diversification can enable Farmers' Organizations to become aware of the danger that the price risk has on their income and the possibilities offered by crop diversification to manage it. Given the incompleteness of the markets in this context, the possibilities of practicing Markowitz-style diversification are limited. These

organizations, by adapting this theory and applying the combinations found in this work, show that diversification is not only applicable to financial assets and in contexts defined by the theory; but that certain managerial practices are well suited to diversification. In other words, in addition to the classical diversification enunciated by Harry Markowitz, farmers' organizations producing cash crops, in their strategies to minimize price risk, propose a diversification that is specific to them: crop diversification;

- on the other hand, the proposal of optimal crop portfolios or optimal crop mixes allowing for efficient crop combinations, despite the lack of certain information such as the degree of volatility (variance and standard deviation) and the expected return on these products. The study showed that it is not the combination of many crops that minimizes price risk and maximizes the income of farmers' organizations, but the choice of a limited number of crops that makes it possible to achieve this objective.

V. Conclusion

Field observations of cultivation practices in cocoa and coffee producing countries, in general, and in Cameroon, in particular, form the basis of this article. At the end of this reflection, the results show that the crop combinations that can reduce the price risk or even stabilize the income of Farmers' Organizations are: cocoa - palm oil – cereals, coffee - palm oil – cereals, tubers - banana – cocoa and tubers - banana - coffee. These results are not that far from those of assets on the financial markets. This confirms that the portfolio theory can be extended to cash crops. But this crop diversification pursues a double interest: - "safety first" which allows farmers' organizations to secure a minimum subsistence income from the various sources of sale. This subsistence income enables these organizations to be resilient to the vagaries of international markets; - "food self-sufficiency" in the sense that diversified production makes it possible to meet the nutritional needs of households and allows them to be less dependent on imported products. Farmers' organizations must integrate the results of this study in order to carry out their farming associations properly. It is up to support organizations at the national and international level to orient agricultural policies for better results in the face of the risk of price risks, especially for cash crops.

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