Economies of Diversification and Stochastic Dominance Analysis in French Mixed Sheep Farms

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Abstract
Farm diversification is mainly driven by risk mitigation effects and economic gains related to complementarities between production activities. By combining these two aspects, we aim to investigate economies of diversification in a sample of French mixed sheep farms, and to identify stochastic dominant mixtures of sheep farming activities. Partially diversified systems (Sheep-Grass, Sheep-Crop, and Sheep-Landless) and fully diversified systems (Sheep-Grass-Crop-Landless) were evaluated. Our analysis relies on Certainty Equivalent (risk-adjusted return) values estimated using the method of Stochastic Efficiency with Respect to a Function (SERF). We find a relatively high degree of diseconomies of diversification in the sheep farming systems considered. The results also indicate that the fully diversified system considered is driven by its risk-reducing effects. Stochastic dominance analyses indicate that the dominant system in terms of risk-adjusted returns is the Sheep-Crop one. Our results meet the need for economic references to support the development of mixed sheep production systems.

Keywords: Economies of diversification, Stochastic dominance, Mixed sheep farms, Massif Central.

1. Introduction

The main objective of the present paper is to investigate the existence and the degree of economies of diversification in French mixed sheep farms, and to identify mixtures of sheep farming activities that provide greater risk-adjusted return to farmers. Such an analysis may be useful for producers who think about changing their production-mix. In fact, we are interested in two standard economic rationales for diversification strategies. Indeed, in economics, it is usually argued that, production diversification can have (or can be driven by) two effects: a risk reducing effect and a scope economies effect (Chavas and Di Falco, 2012). Under uncertainty, risk-averse producers have incentives to diversify their production activities (Heady, 1952). This could be explained by the fact that production diversification can be seen as a strategy used by farmers to protect themselves against production or market risk. Since farmers are typically risk-averse (they aware about variability in their productions and their related prices), they may respond to risks in diversifying their production activities. As stated by Chavas and Di Falco (2012), this could be illustrated by the rule of thumb: 'Don't put all your eggs in one basket'. Diversification can thus help farmers to be more resilient (i.e., with low variability in their income) in case of crisis in at least one of their production activities.

Besides risk management, another possible motivation for diversification is the presence of economies of scope (Chavas and Di Falco, 2012). Scope economies exist if the cost of joint production of a set of outputs in a diversified firm is lower than the cost of their disjoint production in several specialized firms. The concept of economies of scope focuses on measuring economic gains (in terms of cost reduction) associated with diversified firms in comparison with specialized firms. Analysis of scope economies requires either data on completely specialized firms (or stand-alone production) or partitions of the outputs of the firms in mutually exclusive categories (see, Panzar, and Willig, 1981; Grosskopf et al., 1992; Ferrier et al., 1993). Since such data are not always available, the classic definition of economies of scope has been generalized to economies of diversification (Grosskopf et al., 1992; Ferrier et al., 1993; Chavas and Kim, 2010; Chavas and Di Falco, 2012; Malikov et al., 2017). Economies of diversification measures economic gains (in terms of cost reduction or certainty equivalent) associated with fully diversified firms in comparison with partially specialized firms. Thus, economies of scope are a special case of the more general measure of economies of diversification (Eder, 2018).

Empirically, these two effects are usually investigated separately (e.g., Smale et al., 1998; Di Falco and Chavas, 2009). Recently, Chavas and Di Falco (2012) introduced a unified framework where both rationales for production diversification are integrated in an applied microeconomics setting using the concept of certainty equivalent (CE). Our paper uses their approach but it departs from Chavas and Di Falco (2012) in three ways. First, in contrast to Chavas and Di Falco (2012), our analysis is based on observed partial specialized farms (see also, Malikov et al., 2017). Second, while Chavas and Di Falco (2012) consider only production risk, we consider both yield and price risk. Third, we apply the Stochastic Efficiency with respect to a Function (SERF) method (Hardaker et al. 2004), which is widely used to estimate CE values and to compare risky alternatives. As such, our framework has two important features. First, it allows investigating the existence and the degree of economies of diversification. Second, it allows ranking mixture of farming activities in terms of stochastic dominance. The SERF method has previously been used to rank crop production systems (e.g., Pendell et al., 2007; Watkins et al., 2008 ; Bryant et al., 2008; Archer and Reicosky, 2009; Williams et al., 2009; Hignight et al., 2010; Barham et al., 2011, Williams et al., 2012; Boyer et al., 2018; Adusumilli et al., 2020). However, to our best knowledge, our paper provides the first application of the SERF method in economics of diversification.

Our framework is applied to a sample of sheep farming systems in an area in the Center of France, namely the "Massif Central". Under the European terminology, the Massif Central is classified as a Less Favored Agricultural Area. In these areas, farmers operate under more difficult production conditions, such as a steep land, a high altitude, unfavorable climate (e.g., short growing season and long wintering period) and isolated location. The Massif Central includes mountain areas (60% of the territory); but also areas immediately adjacent to them, which are known as simple less favored areas (foothills, plains) (SIDAM, 2020). 85% of the territory of the Massif Central is devoted to grazing livestock, including 60% of permanent grassland (SIDAM, 2020). In the Massif Central, sheep represents the third production (15% of livestock unit), after the beef cattle (38%) and dairy cattle (20%) (SIDAM, 2014) (See also appendix A). An advantage of sheep farming is that sheep are well suited to valorize Less Favored Agricultural Areas, such as the Massif Central (Benoit and Laignel, 2009). However, the sheep farms in the Massif Central are exposed to hazards (climate, health, etc.), but also to seasonal and annual price volatilities (see appendix B). In this context, our analysis may provide relevant information for designing/selecting mixture of farming activities that allows farmers to have greater risk-adjusted return, to reduce their economic risk or to valorize territorial potentialities (including touristic activities) of the Massif Central.

The remainder of the paper is organized as follows. Section 2 describes our analytical approach. Section 3 presents the data used. Results are presented and discussed in Section 4, and Section 5 provides concluding remarks.

2.- Theoretical, Conceptual and Empirical Considerations

2.1.- Theoretical and Conceptual Considerations

Our analysis is based on the concept of Certainty Equivalent (CE), which is derived from the Expected Utility Theory (EUT). The EUT postulates that when faced with risky prospects, an individual chooses the alternative that offers the maximum expected utility. Under this theory, the preferences of economic agents are represented by a utility function U (.), and the consequences of their decisions by random variables π associated with probabilities p. The EUT assumes that agents make their decisions as if they were maximizing the expected utility of their random earnings. Thus, they prefer a random gain π_1 to a random gain π_2, $\pi_1 \gtrsim \pi_2$, if and only if $EU(\pi_1) \geq EU(\pi_2)$.

More formally, denoting by $U(\pi)$ the utility function of a producer with respect to performance criteria π (random net returns). The probability density functions (PDF) that represent the outcomes for n risky alternatives are noted by $f_1(\pi), f_2(\pi), \ldots, f_n(\pi)$, and their corresponding cumulative distribution functions (CDF) are $F_1(\pi), F_2(\pi), \ldots, F_n(\pi)$. The utility of these alternatives can be expressed as follows:

$$U(\pi) = EU(\pi) = \int U(\pi) f(\pi) d\pi = \int U(\pi) dF(\pi) \quad (1)$$

From the CDF, it is possible to determine which alternative is stochastically dominant. For instance, given two alternatives A and B, with CDFs over outcomes π defined by $F_a(\pi)$ and $F_b(\pi)$, alternative A will dominate alternative B if $F_a(\pi) \leq F_b(\pi)$. Graphically, this means that $F_b(\pi)$ is closest to the origin of the axes. However, for more discriminating power, we will rank our mixed sheep farms by converting their utilities into certainty equivalents (CE) as follows (Hardaker, 2000; Hardaker et al., 2004):

$$CE(\pi, \phi) = U^{-1}(\pi, \phi) \quad (2)$$

where U^{-1} is the reciprocal of the utility function U and ϕ is the risk-aversion coefficient of the producer. For a stochastic outcome, π, Pratt (1964) has shown that the CE can be approximated by:

$$CE[\pi] = E[\pi] - \frac{1}{2}\phi V[\pi] \quad (3)$$

where $E[\pi]$ denotes the expected value of π and $V[\pi]$ its variance. Thus, the certainty equivalent of a random outcome, π, $CE[\pi]$, is the difference between its expected value ($E[\pi]$) and a risk premium ($R \approx 0.5\phi V\,[\pi]$). The risk premium (R) is the maximum amount that a risk-averse individual is willing to pay to avoid facing a risk. From the equation (3), the CE can be seen as the risk-adjusted value of the expected net return.

<u>Existence of diversification economies</u>

Following Chavas and Di Falco (2012), economies of diversification (diseconomies of diversification) exist if:

$$ED = CE(\pi) - \sum_{k=1}^{K} CE(\pi_k) > 0(< 0) \quad (4)$$

where $CE(\pi)$ is the certainty equivalent value of the net return of the fully diversified farms and $CE(\pi_k)$ is the certainty equivalent value of the net return of the k-th type of partially specialized farms. As aforementioned, in contrast to Chavas and Di Falco, our counterfactual $CE(\pi_k)$ is defined on observed partial specialized farms (see also, Malikov et al., 2017).

Equation (4) indicates that economies of diversification exist (ED > 0) when the certainty equivalent of the fully diversified farms is higher than the one of K partially specialized farms. This may allow us to identify the presence of positive externalities across production activities. Alternatively, diseconomies of diversification exist if ED < 0.

Degree of diversification economies

Assuming that $CE(\pi) > 0$, the degree of diversification economies can be investigated using the following expression:

$$DED = \frac{CE(\pi) - \sum_{k=1}^{K} CE(\pi_k)}{CE(\pi)} \quad (5)$$

The components of diversification economies

As previously stated, the standard decomposition of the certainty equivalent is given by:

$$CE[\pi] = E[\pi] - R(\pi) \quad (6)$$

Economies of diversification (diseconomies of diversification) exist if

$$ED = ED_{\pi} + ED_{R} > 0(< 0) \quad (7)$$

Where

$$ED_{\pi} = E[\pi] - \sum_{k=1}^{K} E[\pi_k]$$

$$ED_{R} = -\left[R(\pi) - \sum_{k=1}^{K} R(\pi_k)\right]$$

Equation (7) identifies two additive components of the benefits of diversification: the expected income component ED_{π}, and the risk component ED_{R}.

2.2.- Empirical considerations

The SERF method has been developed to estimate the certainty equivalent (CE) of the return of a set of risky alternatives in order to rank them over a range of risk aversion coefficients. In the present study, we also used the CE values estimated with the SERF method to investigate the existence and the degree of economies of diversification for our sample of mixed sheep farms.

The SERF method estimates the CE values using equations (1) and (2).Thus it requires the specification of a utility function. Schumann et al. (2004) showed that the use of different types of utility functions, such as the power or negative exponential utility functions is unlikely to affect the results of the SERF method. In this study, we use the power utility function to estimate the CE values. This utility function exhibits a decreasing absolute risk aversion, namely individuals are willing to take more risks when their wealth increases. In the implementation of the SERF method, we do not need to know the decision-maker's risk aversion coefficient ϕ (Richardson and Outlaw 2008). It requires only to set a lower and a upper value for ϕ (e.g., $\phi = 0$, for risk neutral producers and $\phi = 4$, for an extremely risk averse producers) (see Anderson and Dillon, 1992). This enables the SERF method to rank risky alternatives upon a plausible range of risk aversion coefficients (Schumann et al. 2004). This an important point because producers with different degrees of risk-aversion are likely to have different preferences among risky alternatives (Hardaker et al., 1997).

The SERF method has many advantages over other methods usually used for comparing risky alternatives. For instance, the direct implementation of the expected utility approach requires consistent specification of the utility function of the decision-maker (Anderson et al., 1977). However, it has been shown that accurate elicitation of the utility function of the decision-makers is not a clear-cut issue (King and Robison 1984). First-order and second-order stochastic dominance overcome the need to define a utility function, but they often lead to meaningless results (Schumann et al. 2004). Another approach, called stochastic dominance with respect to a function (SDRF) could be used to compare risky alternatives (Meyer, 1977). The SDRF method does not require explicit definition of a utility function, but only a lower and an upper absolute risk aversion coefficient. However, the SDRF method performs only pairwise comparisons (Hardaker et al., 2004; Allison 2010). The mean-variance (MV) method could also be used to compare risky alternatives. However, the MV approach often leads to inconclusive results (Hardaker et al., 2004). The SERF method enables overcoming the limitations of the previous methods. Although the SERF method requires the specification of a utility function, as previously stated, Schumann et al. (2004) showed that the choice of the utility function is unlikely to affect the results of the SERF method. In addition, unlike the SDRF, the SERF method compares simultaneously many risky alternatives (Hardaker and Lien, 2003). Another advantage of the SERF method is that it considers the entire net return distribution, but not only one point of measurement, as does the MV method.

In SERF analysis, the term stochastic efficiency is usually used to interpret the results. However, in the present study, to avoid any confusion with the term stochastic frontier analysis (SFA) commonly used in efficiency analysis, we use the term stochastic dominance. Indeed, we acknowledge that SERF is a variant (an improved method or a generalized form) of stochastic dominance analysis (see also, Schenk et al., 2014).

3.- Data description

The data used in this study come from surveys carried out by the Joint Research Unit Herbivores (UMRH), of the French National Research Institute for Agriculture, Food and the Environment (INRAE). These data were collected in a network of suckler sheep production monitored annually over the period 1987 to 2017. During these successive surveys, many variables were collected on the structure and management of the flock, as well as the technical and economic results of the farms. More precisely, our dataset includes information on (i) the workforce (family, salaried, temporary), (ii) the flock (lambings, animal movements, and weights of animals sold), (iii) areas (crops, grassland), (iv) equipment (exhaustive list and costs), (v) buildings and installations, (vi) intermediate consumption (quantities and prices), (vii) sales (types of animals and crops, quantities, prices), (viii) subsidies (coupled, decoupled, unit amounts), and (ix) investments and loans. The farms are mainly located in the north of the Massif Central and its periphery, and they are distributed between plain areas with grassland breeds and a mountain and foothills areas with rustic breeds. As previously stated, the Massif Central is classified in the so-called Less Favored Agricultural Area (LFA).

Our empirical analysis is undertaken on an unbalanced panel of 1,139 farm-year observations from 134 mixed sheep farms over the period 1987 to 2017. Over this period, we keep farms that were surveyed for at least three years in order to have a certain level of variability in the data. Based on the strategies used by farmers to mitigate economic risks, the following sheep farming systems are examined in the present study:

- **Sheep-Grass:** This system consists of farms that have neither annual crops nor other livestock. These are farmers whose 100% of their land is dedicated to grass.
- **Sheep-Crop:** This system concerns farms that have sheep, grass and more than 15% of the usable agricultural area in annual crops such as cereals and oilseeds.
- **Sheep-Landless:** This system refers to sheep-grass farms with off-land activities, such as poultry and agro-tourism.
- **Sheep-Grass.Crop.Landless**: This system consists of sheep farms that have all the previous categories (i.e., Grass, Crop and off-land activities).

This partition of the sheep farms has been done in line with Grosskopf et al. (1992) and Ferrier et al. (1993), in order to investigate the existence of economies of diversification. The main characteristics of the farms operating in these four systems are summarized in Table 1.

Table 1.- Main characteristics of the farms over the entire study period

	Sheep-Grass	Sheep-Crop	Sheep-Landless	Sheep-Grass.Crop.Landless
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Usable agricultural area (ha)	89.55 (50.01)	111.71 (57.63)	82.69 (32.07)	90.54 (36.81)
Main fodder area (ha)	89.54 (50.03)	89.38 (45.38)	74.97 (29.84)	78.13 (32.05)
Permanent grassland (ha)	16.05 (23.19)	7.74 (17.57)	3.56 (5.47)	5.62 (10.30)
Crop area	0 (0)	20.61 (24.93)	7.52 (5.07)	12.08 (10.02)
Forage autonomy for sheep	79.10 (8.90)	73.68 (9.27)	69.86 (10.58)	71.66 (10.97)
Feed autonomy for sheep	79.14 (8.91)	84.08 (8.18)	79.66 (9.26)	81.35 (10.02)
Ovine Livestock units	78.79 (30.63)	82.99 (34.73)	70.09 (25.24)	75.17 (37.75)
Annual work unit (AWU)	1.52 (0.53)	1.39 (0.47)	1.48 (0.41)	1.66 (0.56)
Gross product	85,169 (33,817)	100,513 (52,949)	103,945 (42,368)	127,182 (71,471)
Operational costs	25,958 (11,085)	33,301 (18,680)	38,063 (15,982)	48,584.39 (36,770.13)
Fixed costs	33,925 (15,293)	41,460 (24,766)	45,111 (22,483)	51,099 (24,553)
Subsidies	16,528 (14,276)	14,129 (15,387)	19,249 (12,243)	25,230 (18,099)
Net return	25,286 (14,559)	25,752 (18,724)	20,772 (15,407)	27,498 (21,478)
Number of observations	215	736	82	106

Notes SD: Std. dev.

4.- Results and discussion

4.1.- Diversification economies

We use the certainty equivalent (CE) values estimated using the SERF method to compute economies of diversification (ED) in the French sheep farms located in the Massif Central using equation (4). Such economies would exist if the CE value of the fully diversified farms is greater than the sum of the CE values of the partially specialized farms. The results concerning the existence of ED are shown in Fig. 1.

Figure 1. Economies (diseconomies) of diversification in French sheep farms

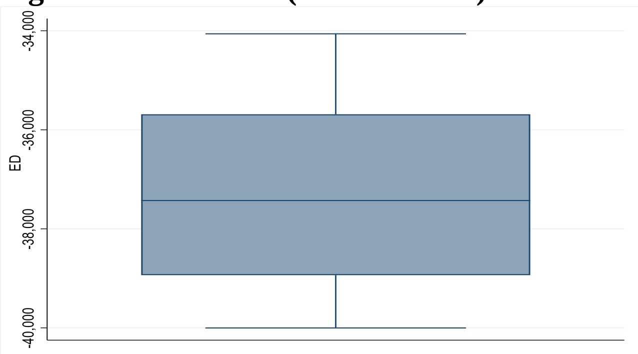


Fig. 1 indicates that all the values of the ED indicator are negative. This suggests that there are no economies of diversification in the sheep farming systems considered. That is, our results evidence the existence of diseconomies of diversification in our sheep farming systems. In order words, our results indicate that the fully diversified system considered does not generate more risk-adjusted return (CE) than the partially specialized systems. To go a step further in our analysis, we also investigate the degree of diversification economies using equation (5), and the results are plotted in Fig. 2.

Figure 2.- Degree of economies (diseconomies) of diversification in French sheep farms

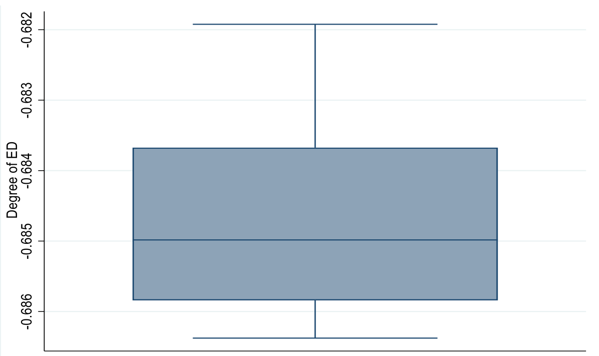
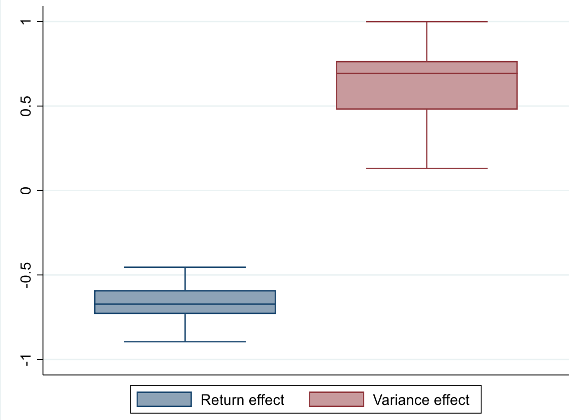


Fig. 2 indicates that there is a relatively high degree of diseconomies of diversification in the sheep farming systems considered. Indeed, all the values of the indicator of the degree of economies of diversification are negative and amount to -0.685 on average. This suggests that the fully diversified sheep system reach only 31.5% of the risk-adjusted return (CE) generated by the partially specialized systems all together. Using a quite different approach from ours, Fleming and Lien (2009) showed that the existence of synergies (i.e., output complementarities) does not necessarily result in economic gains from diversification. Indeed, despite the existence of synergies, they found significant diseconomies for small scale farming operations. Using the same approach as Fleming and Lien (2009), Coelli and Fleming (2004) found weak evidence for diversification economies between subsistence food production, coffee and cash food production, and diseconomies of diversification between coffee and cash food production.

However, following Hajargasht et al. (2008), Wimmer and Sauer (2019) measure diversification economies as cost complementarities between individual outputs. They found that small dairy farms are more likely to benefit from diversification between milk and livestock production, while larger farms tend to benefit from diversification between milk and crop production. In turn, the existence of economies of diversification in mixed farms remains an open empirical question.

In Fig.3, we shed light on the sources of the observed diseconomies of diversification. This Figure shows that the mean return effect is negative while the risk effect is positive. The negative value for the mean return effect highlights that the average net return per family labor unit generated by the fully diversified system is lower than the one generated by the partially specialized systems all together. The positive value of the risk effect indicates that the variance of the completely diversified system is lower than the one of the partially specialized systems all together. Overall, the results from Fig. 3 indicate that although the diversified system does not generate more return than the partially specialized systems, it ensures more stable net returns. This suggests that farmers could considered the diversified system as a safer option for their farms (Sarwosri and Mußhoff, 2020) in the sense that it allows farmers to spread production and market risk (Villano et al., 2019). These results are also in line with the portfolio theory, which suggests that diversified producers should face lower risk (Markowitz, 1952, 1990; Paut et al., 2019). They are also in line with the idea that classical concepts (such as income maximization) that are often used to guide farm management are increasingly replaced by other concepts such as stability (Darnhofer et al. 2010; Astigarraga and Ingrand, 2011).

Figure 3. Sources of Diversification Economies

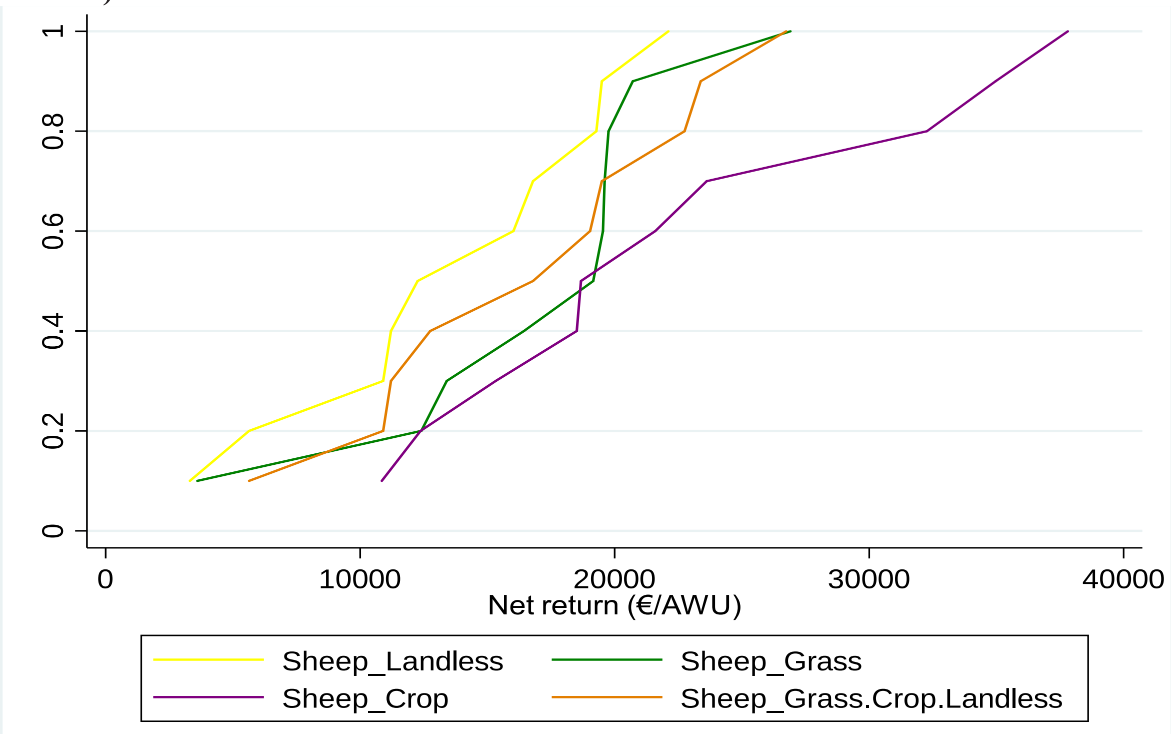


4.2.- Stochastic dominance analysis

This section presents the ranking of our sheep farming systems using the SERF method. The SERF method is known as a more discriminating form of the (or a generalized) stochastic dominance analytical framework (Schenk et al., 2014). However, for comparison purposes, CDF curves and the mean-standard deviation ranking for our sheep farming systems are depicted in Fig. 4 and 5, respectively. Indeed, some general conclusion can be drawn from each of the methods.

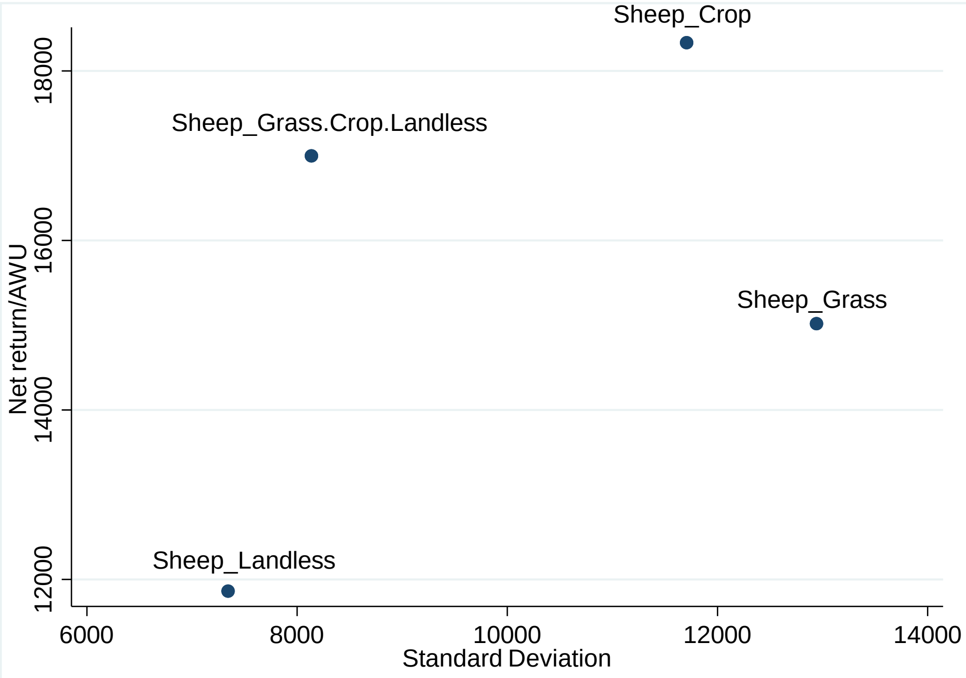
The CDF curves show that the Sheep-Landless system is closest to the origin of the axes and does not intersect with the other sheep farming systems. This suggests that the Sheep-Landless system is dominated by the other ones. However, it is not feasible to rank the other systems using their CDFs since they intersect each other.

Figure 4.- Cumulative distribution functions (CDFs) of the different sheep farming system (€/AWU)



A general conclusion that can be drawn from Fig. 5 is that the Sheep-Landless system has the lowest standard deviation for the net return per family labor unit. This suggests that this system could be a good strategy to mitigate economic risks. This could be explained by the off-land activities, which may be less sensitive to climatic context. In addition, in the Sheep-Landless system, the breeders work along integrated lines, mainly for poultry, i.e., as subcontractors for agribusiness companies. In this system, the production is paid at a remunerative price even if the market conditions are unfavorable. Therefore, the market risk is shared between the breeders and the integrator. However, the Sheep-Landless system has also a disadvantage compared to the other systems: it has the lowest average net return per family labor unit. Among the farms studied, these farms have developed off-ground activities generally because they have a lack of land in relation to the available labor force; and sometimes because sheep profitability is too low. As our results show, this did not upset their economic results. This result is in line with Ripoll-Bosch et al. (2014) who found that production diversification might enhance farm flexibility, but is not necessarily related to economic performance. Similarly, Villagra et al. (2015) found that sheep represented the main source of income across different diversification schemes, but it was not the most profitable livestock activity.

Figure 5.- Mean-standard deviation plot of the four sheep farming systems

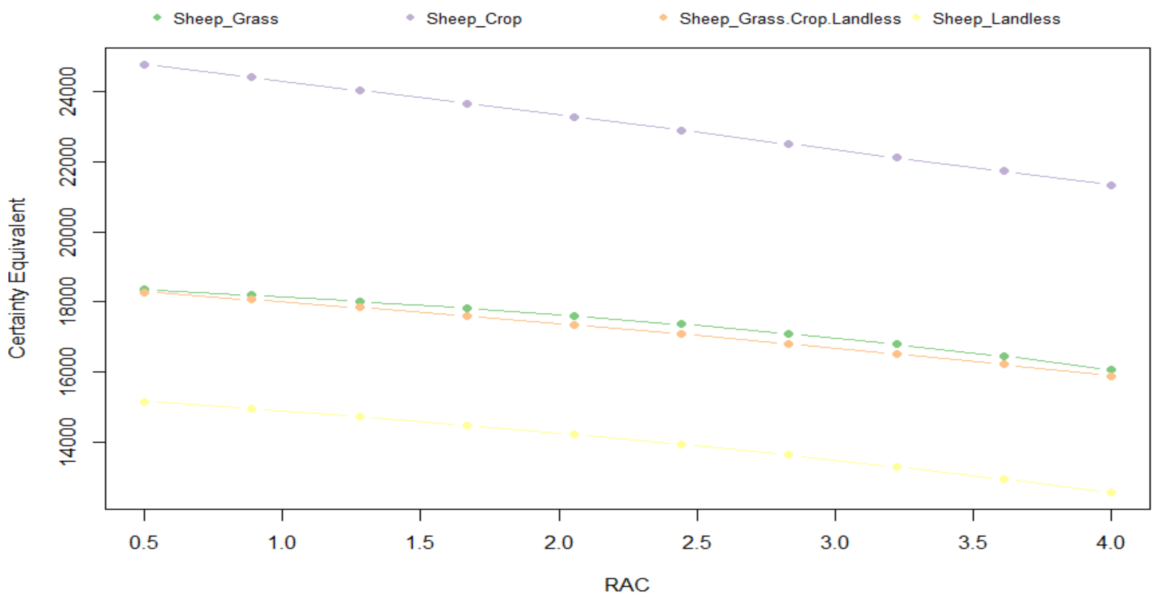


Note that Fig. 5 also indicates that the Sheep-Grass (i.e., completely specialized) system exhibits the highest variability in the net return per family labor unit. This result highlights an interest for farms' diversification (Chavas and Di Falco, 2012). By considering relatively similar systems to ours, Prache et al. (2018) found that the system that exhibits the highest variability in terms of net returns over the past 10 years is the Sheep-Crop system. They argued that Sheep-Crop system was very impacted by the climatic context and the fall in cereal prices. Our result is slightly different from the one of Prache et al. (2018) maybe because we consider the net return per family labor unit instead of the absolute value of the net return.

Nevertheless, from Fig. 5, it appears that it is not feasible to rank our farming systems using the mean-standard deviation criterion. Indeed, while Sheep-Landless system has the lowest mean and the lowest standard deviation, we cannot classify the other systems using both their means and their standard deviation. For instance, the Sheep-Crop system has the largest mean net return while the Sheep-Grass system has the largest standard deviation. Thus, with the mean–standard deviation criterion, none of the sheep farming systems has the largest mean net return and smallest standard deviation. In addition, none of them has lowest average net return and the highest standard deviation. That is why their ranking under the mean–standard deviation criterion is impossible.

Fig. 6 reports the results of the SERF method. These results are obtained by estimating the CE values by including the total subsidies received by farmers. Fig. 7 reports the same results but without including the subsidies in the estimations. This may be useful for investigating the role of the subsidies in the ranking of the different systems.

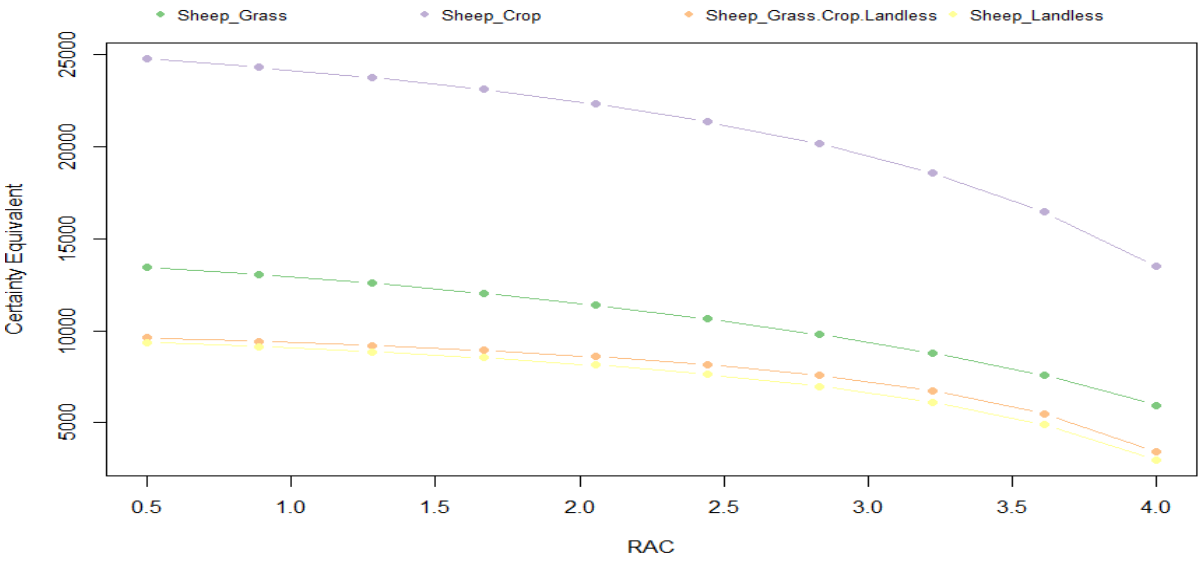
Figure 6.- Certainty equivalent (CE) curves of net return (€/AWU) for the different sheep farming systems



The SERF analysis (Fig.6) confirms the fact that the Sheep-Landless system is dominated by the other ones in terms of risk-adjusted net return per family labor unit, as shown in the CDF curves (see Fig. 4). Interestingly, the SERF analysis clarifies the rank of the other systems. Indeed, the SERF analysis (Fig.6) indicates that Sheep-Crop system is the dominant alternative across all levels of risk aversion coefficient (RAC). This means that the Sheep-Crop system exhibits the highest risk-adjusted return per family labor unit. In other words, the Sheep-Crop system provides the best compromise between the net return and its variability. This could be explained by the fact that this system benefit from larger structures (see table 1) and that it is located in areas with relatively good agricultural potential (Benoit and Laignel, 2009; Venineaux-Delvalle et al., 2017). Indeed, as industrial crops are more frequent in the rotations in the Sheep-Crop system, they provide access to various co-products to feed the sheep and the highest sheep feed autonomy (see Table 1). Another possible explanation is that as the Sheep-Crop system offers the possibility of feeding animals from co-products and crops produced on the farm, it facilitates off-season lamb production (see Prache et al., 2018), which may be valued by the market. Indeed, it is well known that from the economic law (supply and demand), off-season products can be better valued by the market. That is, they can be sold at more attractive prices, compensating higher production costs.

The SERF analysis conducted without considering the subsidies received par farmers (Fig. 7) provides a similar pattern. However, note that when the subsidies are taking into account (Fig. 6), the Sheep-Grass and the completely diversified systems perform similarly; while without accounting for the subsidies (Fig. 7), the Sheep-Landless and the completely diversified systems perform similarly. This may be understood in the sense that the performance of our completely diversified sheep systems relies mainly on the subsidies received by the farmers.

Figure 7.- Certainty equivalent (CE) curves of net return (€/AWU) for the different sheep farming system (without subsidies)



5.- Concluding remarks

This study investigates the existence and the degree of economies of diversification in sheep farming systems in France. It also identifies stochastic dominant mixtures of sheep farming activities in terms of risk-adjusted net returns. To examine the economies of diversification, we compare specialized and partially diversified systems (Sheep-Grass, Sheep-Crop, and Sheep-Landless) with fully diversified systems (Sheep-Grass-Crop-Landless) in terms of certainty equivalents of their net returns per family labor unit. The certainty equivalent of the net return is a risk-adjusted measure that allows integrating two economic rationales for production diversification: risk reducing effect and scope economies effect. To identify the stochastic dominant mixtures of sheep farming activities, we use the stochastic efficiency with respect to a function (SERF) analysis, which is also known as a generalized method of stochastic dominance analysis.

Our empirical analysis is undertaken on an unbalanced panel of 1,139 farm-year observations from 134 mixed sheep farms located in an area of the Center of France, namely the Massif Central, over the period 1987 to 2017. The Massif Central is classified in the so-called Less Favored Agricultural Area (LFA). An advantage of sheep farming is that sheep are well suited to valorize LFA. In spite of that, sheep farmers in the Massif Central have to face with risk and uncertainty due to unforeseen climate conditions, sanitary issues sues and price volatility. In this context, our analysis may provide relevant information for designing/selecting mixture of farming activities that allows farmers to have greater risk-adjusted returns, or to reduce their economic risk. This may be insightful for producers who think about changing their production-mix in order to continue to valorize territorial potentialities.

The results indicate that there are no economies of diversification in the sheep farming systems considered. That is, we find that the fully diversified system considered does not generate more risk-adjusted returns (CE) per family labor unit than the partially specialized systems. In addition, we find that all the values of the indicator of the degree of economies of diversification are negative and amount to -0.685 on average. This suggests a relatively high degree of diseconomies of diversification in the sense that the completely diversified sheep system reaches only 31.5% of the risk-adjusted returns (CE) generated by the partially specialized systems all together. We also investigate the sources of the observed diseconomies of diversification. We find that the average net return per family labor unit generated by the completely diversified system is lower than the one generated by the partially specialized systems all together, while the variance of the net return of the completely diversified system is lower than the one of the partially specialized systems. This suggests that the observed diseconomies of diversification are mainly due to the mean return effect. That is, the diversified system does not generate more return than the partially specialized systems, but it ensures more stable returns.

The dominance stochastic analysis conducted using the SERF method reveals that the dominant system in terms of risk-adjusted returns is the Sheep-Crop one. That is, the Sheep-Crop system provides the best compromise between the net return per family labor unit and its variability. This may be due to the fact that these systems (i) benefit from more attractive prices (for off-season products), and (ii) concern large farms located in areas favorable to cash crops. We also find that the returns of the Sheep-Landless system exhibit the lowest variability, while the one of the fully specialized (Sheep-Grass) system exhibits the largest variability. Note also that the variability of the returns of the fully specialized (Sheep-Grass) system is rather close to that of the Sheep-Crop system (Fig. 5). We recognize these differences may reflect the heterogeneity of the diversification strategies of farmers. For instance, we admit that each farmer trades off risk and return at a personal (or individual) rate. In addition, diversification decision could also be related, among other things, to soil quality, microclimate, historical context, territorial norms and constraints, and soil conservation strategies. It also depends on (a) individual circumstance, (b) resource availability (e.g., workforce, land, fixed capital), (c) farmers' skills, (d) farmers'desire to contribute to social and environmental objectives, (e) abilities, (f) incentives and existence of marketing channels (or market opportunity), and (g) extension service for a given production (see also, McNally, 2001; Meert et al., 2005; Leck et al., 2014; McFadden and Gorman, 2016; Suess-Reyes and Fuetsch, 2016; Moris et al., 2017). For instance, soil quality, land fragmentation and the lack of land in relation to the available labor force may encourage farmers to diversify their production systems so as not to disappear. It is also recognized that larger farms and farms with greater assets are more likely to diversify their production activities (McInerney and Turner, 1991; Ilbery, 1991; McNally, 2001).

In the same vein, the different systems could co-exist given specific farm characteristics and many contextual drivers. In this line, Villano et al. (2010) argued that the choice of diversification may be a function of a number of factors outside the farmer's control. In addition, previous studious studies (e.g., McNally, 2001; Pardos et al., 2008; Maye et al., 2009; Hansson et al., 2013; Moris et al., 2017) found significant heterogeneity amongst farmers in their motives for diversifying their production activities. Therefore, further research on the production capacities of the farms, their characteristics and their contextual drivers could provide additional information on their diversification strategies. As such, it could be difficult to prescribe a specific sheep farming system to farmers from our results.

However, from an economic standpoint, an important goal of farm diversification is to find combinations of farming activities that provide the best compromise between the farm return and its variability. In this light, we believe that, in addition to producers who think about changing their production-mix, our results could provide insights to policy-makers and extension professionals. They can inform policy-makers' decisions on the components of the observed diseconomies of diversifications in the Massif Central sheep farms. Extension professionals can distribute the information from our results to help farmers to make better diversification decisions.

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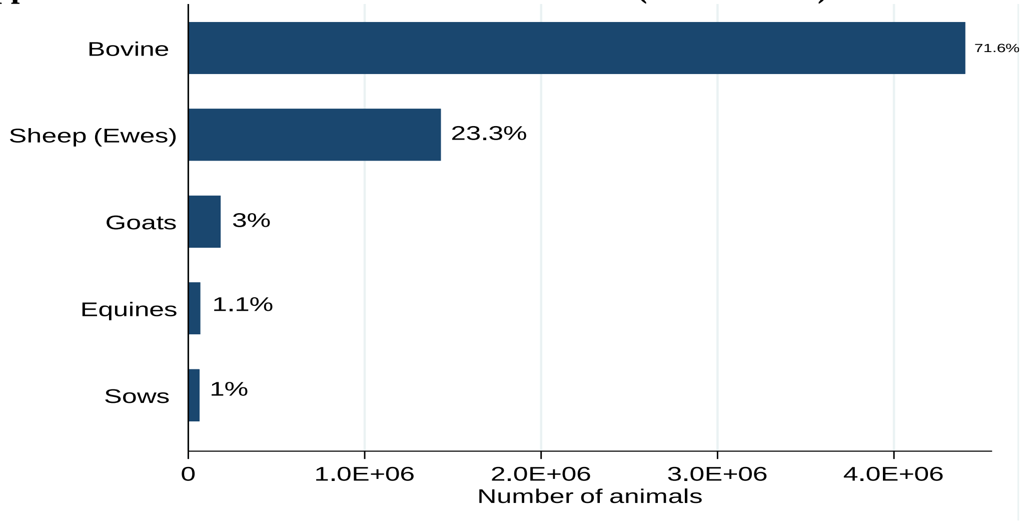
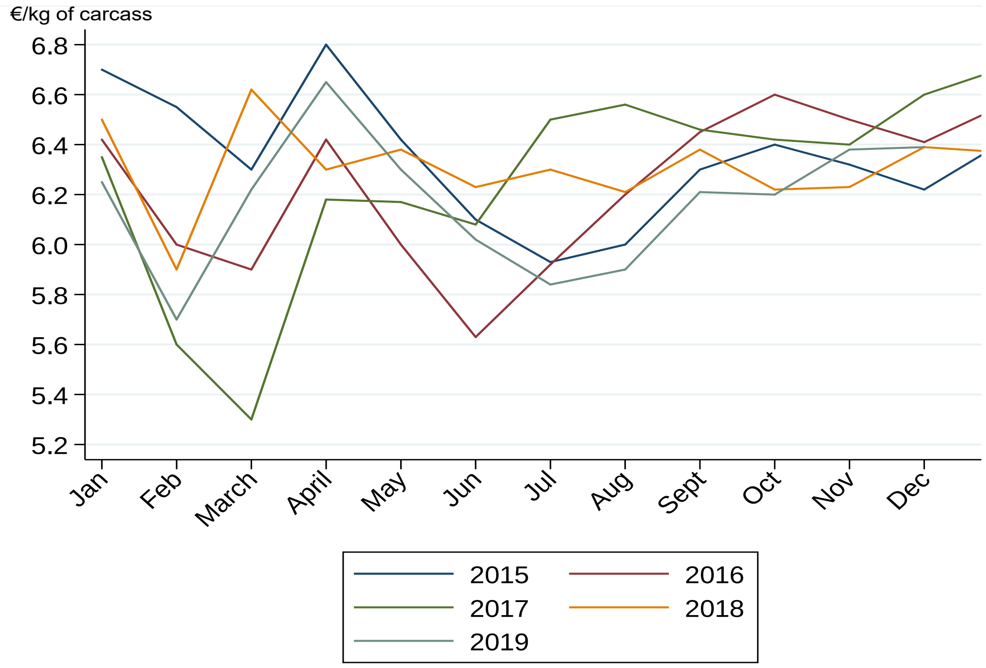
Appendix

Appendix A. The livestock of the Massif Central (for all farms)



Sources: Own elaboration with data from SIDAM (2020)

Appendix B: Average price (weighted by regions) of French sheep (lamb).



Sources: Own elaboration with data from FranceAgriMer