Potential gains from specialization and diversification further to the reorganization of farming systems

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Abstract: In economic activities, two main forces guide firm and market structures namely specialization and diversification. This paper provides new insights on this topic in the agricultural sector. We propose to measure potential gains due to specialization and diversification in farms further to a reorganization of activities (division and merger) and to highlight what prevails. An activity analysis model is developed in order to detect potential gains from specialization and/or diversification. A 2003 database of French farms is used as an application. Our findings show that even if both processes are beneficial for farming systems, the division gains outweigh the gains obtained by merger at the industry level.

Keywords: specialization; diversification; division; merger; free coordination hull; free disposal hull; agriculture.

JEL Classification: D24, L25, Q12

1. Introduction

Since decades, the agricultural sector experiments deep mutations and structural changes driven by the presence of new production technologies, new market conditions, rural depopulation and agricultural policy reforms. Among these changes are the number of farms in each type (crops, livestock, mixed...) and the average farm size.

In economics, it is well-known that the market structure and the number of firms in the industry are directly linked to specialization and/or diversification phenomena. While labour division and specialization of units facilitate technical progress and productivity enhancements, diversification is recognized as factor of scope economy linked to environmental synergies between different firm's activities and risk management strategies. Economies of scope are defined as cost reductions made possible by joint production instead of separate production (Panzar and Willig, 1981 and Baumol *et al*, 1982). They can come to the cost complementarity between two productions and/or the sharing or joint utilization of quasi-fixed inputs.

In farming systems, specialization and diversification processes coexist and must collide. Therefore, the challenge consists in providing methodological tools in order to disentangling them and to assess in which case specialization dominates diversification or inversely from an economic viewpoint. Several papers deal with diversification in agricultural literature. Fernandez-Cornejo *et al* (1992) identified substantial dynamic scope economies between cattle and others products (crops, hogs and milk) in German agriculture. Chavas and Aliber (1993) highlighted important economies of scope of farms in Wisconsin which produce crops and/or livestock. For Morrison Paul and Nehring (2005), product diversification contributes to US farm's economic performance. Finally, on a sample of farms in Missouri, Wu and Prato (2006) shown that the cost of joint production of crops and livestock is less than the cost of separate production. Recently, Chavas and Di Falco (2012) investigated farm diversification linked to economies of scope and risk management. In an empirical application on Ethiopian farms, they demonstrate that there exists a significant incentive for farmers to diversify.

Contrary to these studies, Blancard *et al* (2011) were interested in the potential specialization gains in agricultural activities. From a sample of farms located in the northeast of France, the authors revealed that the main way to reduce the costs production is indeed an increase in the specialization of farms in terms of crops or livestock. This could partly explain the increasing shift to more specialization observed in the French agricultural sector over the last few decades. A few years earlier, Chavas (2001, 2008) suggested that the benefits of specialization and the enhancement of productivity could explain the trend toward more specialized farms. However, as stated by this author, this does not imply necessarily the absence of economies of scope.

Thus, a relevant question is suggested by all these studies: between specialization and diversification what is the process generating the most gains for farms and thus the most economically justifiable? Therefore, this paper provides new insights on the processes of diversification and specialization. More precisely, we measure and compare the gains in terms of cost reduction that farmers could get with a higher degree of specialization or diversification. We further decompose the potential gains obtained from the two types of reorganization – division and merger – into technical, size and mix gains. Decomposing the gains is important to estimate until where the reorganization should go (e.g. a division or a merger with or without mix changes). Moreover, by the examination of the output mix effect, we can determine whether the farm should go toward more specialized or mixed activities and compute the potential gains from specialization and diversification process.

To measure the potential gains *a priori* due to merger, our approach is quite similar to the way adopted by Bogetoft and Wang (2005) or Kristensen *et al* (2010). Following these authors, we also use the same concept of mix to capture the effect of this reorganization. However, our study differs from the above papers and others (e.g. Färe 1986; Grosskopf and Yaisawarng 1990) in two important respects. First, besides the merger, we also consider division process by relying on the methodology developed by Blancard *et al* (2011) to quantify the potential gains. Second, we estimate these two kinds of gains with the use of non-convex technologies. As mentioned by Farrell (1959) and rephrased by Cherchye and Post (2003), the convexity assumption precludes the possibility of detecting potential gains from specialization and can only reveal economies of scope. This second point allows us to deviate from Ray (2004) in particular.

From the methodological viewpoint, we use an activity analysis framework (Koopmans 1951 and Baumol 1958) where the Free Coordination Hull (FCH) approach developed by Green and Cook (2004) is combined with the Free Disposal Hull (FDH) model proposed by Deprins *et al* (1984) to detect both potential gains from specialization and diversification. As a non-convex approach that allows both directly observed and summed Decision Making Units (DMUs) to define the production technology, FCH is the relevant model for analyzing optimal reallocation of large farm activities among smaller units (division process) and alternatively optimal reallocation of small farms activities among a larger farm (merger process).

The usefulness of this methodology is demonstrated with an application to a sample of 608 French farms specialized in crop or livestock and diversified during 2003.

The structure of this paper is as follows. The next section relates our alternative approach to compute potential gains from mix, size and technical gains. The data used in our empirical analysis and the results are briefly discussed in next to last section. Some concluding comments will be presented in final section.

2. Methodology

The analysis of production structure and gains due to activities reorganization requires representing the underlying production technologies. These latter can be modelled thanks to an Activity Analysis Model (AAM) introduced by Koopmans (1951) and Baumol (1958). AAM is a mathematical programming based technique with the presence of multiple inputs and multiple outputs. The main advantage of AAM is to allow technology estimation without specifying any functional form between inputs and outputs. We use the general framework developed by Shephard (1953) in order to model the technology by production possibility set.

Let us consider that K Decision Making Units (DMUs) are observed and we denote $\mathfrak{K} = \{1,\ldots,K\}$ as the associated index set. We also assume that DMUs face a production process with M outputs and N inputs where $y = \left(y^1,\ldots,y^M\right) \in R_+^M$ is the vector of outputs and $x = \left(x^1,\ldots,x^N\right) \in R_+^N$ is the vector of inputs. We also define the respective index sets of outputs and inputs as $\mathfrak{M} = \{1,\ldots,M\}$ and $\mathfrak{N} = \{1,\ldots,N\}$.

Following Green and Cook (2004) and Blancard *et al* (2011), we have considered different types of technologies by either considering or not the additivity assumption (FCH or FDH technologies). Furthermore, we also consider varying the types of DMUs entering into the production possibility set (all DMUs or some subset of DMUs identical in terms of output mix). By denoting $s = \text{FDH or FCH}$ and $r =$ all or the same output mix (after denoted smix), the production possibility set $T(s,r)$ is defined by:

$$T(s,r) = \left\{ (x,y) : \sum_{k\in\mathfrak{K}(r)} \lambda_k y_k^m \geq y^m, \forall m \in \mathfrak{M}, \sum_{k\in\mathfrak{K}(r)} \lambda_k x_k^n \leq x^n, \forall\ n \in \mathfrak{N}, \lambda_k \in \Lambda(s)\ \forall k \in \mathfrak{K}(r) \right\} \tag{1}$$

In (1), $\lambda_k \in \Lambda(s) := \begin{cases} \lambda_k \in \{0,1\}; \sum \lambda_k = 1\ \forall k \in \mathfrak{K}(r)\ \left(\text{for } s = \text{FDH}\right) \\ \lambda_k \in \{0,1\}\ \ \forall k \in \mathfrak{K}(r) \left(\text{for } s = \text{FCH}\right) \end{cases}$ (2)

In FDH and FCH, λ is a binary variable leading to Mix Integer Program (MIP). Formally, the difference between FDH and FCH concerns the presence or not of $\sum \lambda_k = 1$. Contrary to FDH, FCH allows one to sum DMUs activities.

In order to define DMUs subsets given their mix of activities, we introduce $H(k,o)$ as an indicator of difference in terms of output shares between two DMUs k and o:

$$\mathfrak{K}(r) := \begin{cases} k \in \mathfrak{K} : H(k,o) \geq 0\ \left(\text{for } r = \text{all}\right) \\ k \in \mathfrak{K} : H(k,o) = 0\ \left(\text{for } r = \text{smix}\right) \end{cases} \tag{3}$$

Thus, by taking a specific DMU o, $\mathfrak{K}(\text{all})$ contains all observed DMUs in the data set while $\mathfrak{K}(\text{smix})$ contains only the observed DMUs that are identical in terms of output mix than DMU o.

In this paper, we retain the Hamming distance[1] denoted H to determine the DMUs with the same output mix. It is measured by the sum of absolute deviations between two DMUs in terms of structure of output. Formally, for DMUs k and o, we have:

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[1] The Hamming distance was proposed by Hamming (1950) and initially developed in information theory.

$$H(k,o) = \sum_{m=1}^{M} \left| (f_o^m - f_k^m) \right| \Big/ 2 \qquad (4)$$

where $f^m = \dfrac{p^m y^m}{\sum\limits_m p^m y^m}$ is the share of output m in total output value with p as the output price. The maximum value of Hamming distance is 1 when the two DMUs under comparison are each one fully specialized into different output and the minimum value is 0 when all output shares are equal[2].

2.1. The potential gains from division and merger

In this section, we propose two models to estimate the potential gains from both division and merger. The ultimate purpose is to determine *i)* whether it is more interesting to break up a large farm into a number of smaller units or *ii)* whether it is more interesting to merge smaller farms into a larger one.

2.1.1. The potential gains from division

To estimate potential gains from division, the cost efficiency score for DMU o (CE_o) is computed as the ratio of minimum cost (C^*) to observed cost for DMU o (C_o) given the definition of the technology in (1). The minimum cost is computed using the following MIP:

$$\begin{aligned}
C^* &= \min_{\lambda_k, \tilde{C}} \tilde{C} \\
\text{s.t.} \quad & \sum_{k \in \mathfrak{K}(r)} \lambda_k y_k^m \geq y_o^m \quad \forall m \in \mathfrak{M} \qquad (5) \\
& \sum_{k \in \mathfrak{K}(r)} \lambda_k C_k \leq \tilde{C} \\
& \lambda_k \in \Lambda(s) \quad \forall k \in \mathfrak{K}(r)
\end{aligned}$$

where C_k measures the total cost of DMU k. Moreover, because we want to examine whether the multiproduct farm would benefit (or lose) from reorganizing production activities into two or more smaller farms, we consider also the constraint $\sum_{k \in \mathfrak{K}(r)} \lambda_k \geq 2$ in model based on the production possibility technology $T(\text{FCH}, r)$. Traditionally, cost efficiency is comprised between 0 and 1 because the evaluated DMU is included in referents and can be compared to itself. Here, by adding $\sum_{k \in \mathfrak{K}(r)} \lambda_k \geq 2$, we have the case where the minimum cost C^* can be smaller, equal or greater than C_o. Then CE_o is not bounded at 1. If CE_o exceeds unity, the division is costly i.e. the evaluated DMU o loses in terms of cost by reorganizing its

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[2] We assume the DMUs as being comparable in terms of mix output when the Hamming distance is included between [0;0.1].

activities into smaller units. If $0 \le CE_o \le 1$, then the cost efficiency indicates the extent to which the DMU o can decrease its costs by splitting its production among smaller units. Finally, $\sum_{k \in \Re(r)} \lambda_k$ gives information on the number of smaller farms that the observed farm should be broken up. Because the optimization may lead to combinations with a great number of small DMUs, we note that it is possible to limit the split into $R_{\max}$ referents and thus the occurrence of complex reorganization by adding the constraint $2 \le \sum_{k \in \Re(r)} \lambda_k \le R_{\max}$ or by selecting the appropriate reference set constituted of DMUs with the same characteristics than the evaluated DMU.

For each DMU o, by varying r in $\Re(r)$ and s in $\Lambda(s)$, we could solve three programs from model (5) to compute the technical, size and mix effects. This decomposition is developed in subsection 2.2.

2.1.2. The potential gains from merger

To estimate the potential gains from the merger including the evaluated farm o, we need to solve one program for each farm that could be considered as a referent farm denoted ref to which the merger has to be similar. For any referent ref which produces a larger output than the evaluated farm, the maximum cost reduction of the merger is computed by the following program:

$$\begin{aligned} &\max_{\delta,\lambda_l} \delta \\ \text{s.t.}\quad & y_{ref}^m \ge y_o^m + \sum_{l \in \Re(r)} \lambda_l \, y_l^m \quad \forall m \in \mathfrak{M} \\ & C_{ref} \le \Big(C_o + \sum_{l \in \Re(r)} \lambda_l \, C_l \Big) \delta^{-1} \\ & \lambda_l \in \Lambda(FCH) \quad \forall l \in \Re(r) \end{aligned} \qquad (6)$$

where y_{ref}^m is the referent's output and C_{ref} its observed total cost. l is the index relative to farms which can potentially belong to the merger; if $\lambda_l = 1$, farm l enters into the merger. If $\delta^{-1} < 1$, farm ref produces more than the merger at a least-cost. The cost reduction for the merger is equal to $[(\delta - 1) \times 100]\%$. The MIP (6) is nonlinear since λ_l and δ, the two model variables, appear multiplicatively on the right hand side. Fortunately, putting δ on the left hand side allows us to linearize this program which has to be solved for the evaluated DMU o relatively to all referents farms producing more output. Finally, among the set of all referents ref for which (6) is solved, we retain the merger which allows the maximum reduction of cost. Thus, if we assume an equal sharing of gains between the DMUs entering in the merger, we compute the cost efficiency score for DMU o (CE_o) as the ratio of minimum cost $(\delta^{-1} C_o)$ to observed cost for DMU o (C_o).

In the same spirit of division, the optimization may lead to combinations with a great number of small DMUs. However, it is possible to limit the merger to $R_{\max}$ referents or to avoid unsuitable DMUs in the merger respectively by adding the following constraint $1 \leq \sum_{l \in \Re(r)} \lambda_l \leq R_{\max}$ or by selecting the appropriate reference set constituted of DMUs with the same characteristics than the evaluated DMU. In their example, Bogetoft and Wang (2005) propose to restrict the merger to the only units which are geographically close.

For each DMU o, by varying r in $\Re(r)$, we could solve two programs from model (6) to compute the mix effect. Moreover, by imposing $\lambda_l = 0 \; \forall l,$ we could also compute the FDH model which is equivalent to those computed in (5). The next subsection presents the decomposition.

2.2. The decomposition of gains from division and merger

In programs (5) and (6), when based on the most general production possibility set (where $s = \text{FCH}$ and $r = \text{all}$), the inefficiency scores include several components, namely: technical, size and mix gains. Before to go further, let us denote each score following the production possibility set $T(s,r)$ as $S_{T(s,r)}$.

Indeed, an inefficient DMU could be compared to one (or several) that is more efficient but in all cases with the same size and output mix. The inefficiency score could then be interpreted as only consisting of technical inefficiency. Thus, imitating the best performers could be sufficient (Bogetoft and Wang, 2005). Next, it could also be the case that the evaluated DMU is inefficient when compared to a sum of smaller DMUs with the same output mix and/or when it may profit from merger with one or several DMUs having the same output mix. In this case, the inefficiency would be the result of a size effect[3]. Finally, if the reference set of the evaluated DMU is solely composed of DMUs that differ in output mix then the inefficiency can be viewed as a potential gains obtained by a change in output mix.

Since one, two, or even three of these components can coexist in the overall efficiency score, it therefore seems useful to decompose it into its technical, size, and mix components. This can be done by both selecting the appropriate technology and exploiting the link between the FDH and FCH models.

Firstly, the technical inefficiency of DMU o is obtained by only solving programs (5) with $s = \text{FDH}$ and $r = \text{smix}$ or (6) indifferently with $\lambda_l = 0 \; \forall l.$ This score can be denoted $S_{T(\text{FDH,smix})}$. By avoiding the additivity assumption and by restricting the production possibility set to only DMUs with the same output mix, neither size effect nor mix effect can be the

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[3] It is important to note that we consider size inefficiency in the context of Maindiratta (1990) rather than as the traditional measure of scale inefficiency. The assumption of divisibility is not considered in our approach, thus excluding any measure of scale inefficiency based on the most productive scale size (MPSS) concept (Banker, 1984). By contrast, the additivity assumption of FCH allows the comparison of a large DMU to the sum of smaller ones and hence reveals any size inefficiency.

source of inefficiency. Therefore, only the technical inefficiency effect is present in this restricted model.

Secondly, to assess the size effect during the division process, we compare the evaluated DMU to smaller ones with the same output mix. In the merger case, the aggregated costs of the evaluated DMU and the candidates for merging are compared with those of the farms which produce at least as much as all together. Therefore, by considering $s = \text{FCH}$ and $r = \text{smix},$ the size inefficiency of DMU o is added to the FDH score. By comparing the efficiency scores under $T(\text{FCH}, \text{smix})$ and $T(\text{FDH}, \text{smix})$ obtained thanks to models (5) or (6), respectively denoted $S_{T(\text{FDH},\text{smix})}$ and $S_{T(\text{FCH},\text{smix})}$, we can measure the net effect of size inefficiency. As shown by Green and Cook (2004), the inefficiency score obtained under FDH is always less than or equal to the inefficiency score obtained under FCH. Thus:

(i) if $\left(S_{T(\text{FCH},\text{smix})} - S_{T(\text{FDH},\text{smix})}\right) = 0$ then DMU o operates at the most efficient size of production which guarantees the low cost. Here, no gain is possible by varying size.

(ii) if $\left(S_{T(\text{FCH},\text{smix})} - S_{T(\text{FDH},\text{smix})}\right) > 0$ then DMU o can decrease its costs by splitting its production among smaller units when it engages in a division process or alternatively by merging with other farms when it engages in a merger process.

By considering also the constraint $\sum \lambda_k \geq 2$ in model (5) based on the production possibility technology $T(\text{FCH}, r)$, a third case may appear:

(iii) if $\left(S_{T(\text{FCH},\text{smix})} - S_{T(\text{FDH},\text{smix})}\right) < 0$ then DMU o increases its costs by splitting its production among smaller units[4].

Thirdly, gains from output mix change are measured by comparing $S_{T(\text{FCH},\text{all})}$ and $S_{T(\text{FCH},\text{smix})}$. Once again, the same logic is used here. The technologies $T(\text{FCH}, \text{all})$ and $T(\text{FCH}, \text{smix})$ differ only with respect to the output mix of the DMUs included in the production possibility set. By evaluating a DMU relative to DMUs with a different mix and then relative to all DMUs, the potential gains from output mix change are given by the differences in the resulting efficiency scores. Since $T(\text{FCH}, \text{smix}) \subseteq T(\text{FCH}, \text{all})$, two possible cases arise:

(i) if $\left(S_{T(\text{FCH},\text{all})} - S_{T(\text{FCH},\text{smix})}\right) = 0,$ then there is no gain from output mix change.

(ii) if $\left(S_{T(\text{FCH},\text{all})} - S_{T(\text{FCH},\text{smix})}\right) > 0,$ then the difference indicates cost reductions obtained by solely output mix change.

To summarize, Table 1 presents the different cases that may arise in division or merger process by combining size and mix effects. For division process, seven cases are possible (denoted *a* to *g*) but only three cases (*a, b,* and *c*) are revealed for merger process.

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[4] As emphasized by Bogetoft and Wang (2003), a merger leads to operate at a large scale. This may or may not be beneficial, depending on the scale properties.

Table 1 – The different cases

Size effect \ **Mix effect**	**Positive**	**None**
Positive	Case *a*	Case *c*
None	Case *b*	Case *g*
Negative	Case *d*: |Mix effect| > |Size effect| Case *e*: |Mix effect| < |Size effect|	Case *f*

Note: In our study, we interrupt the activities reorganization at the step the more favorable for the farm. Thus, because the mix change is the last step of reorganization, the case of a negative mix effect does not arise.

Finally, we have the following decomposition of the overall efficiency measure into its three components:

$$\begin{aligned}\textbf{Overall gains } \left(S_{T(\mathrm{FCH,all})}\right) = & \\ & \textbf{Technical gains } \left(S_{T(\mathrm{FDH,smix})}\right) \\ + & \textbf{ Size gains } \left(S_{T(\mathrm{FCH,smix})} - S_{T(\mathrm{FDH,smix})}\right) \\ + & \textbf{ Mix gains } \left(S_{T(\mathrm{FCH,all})} - S_{T(\mathrm{FCH,smix})}\right)\end{aligned} \qquad (7)$$

The decomposition (7) offers different ways of reducing inefficiency for unit managers.

Technical inefficiency reflects managerial failures that can be remedied in the short term at the DMU level. In this case, gains are possible by learning the practices of peer or reference units. As pointed out by Bogetoft and Wang (2005), if it is not a problem of skills but rather motivation, incentives should be put in place.

In contrast, size and mix inefficiencies respectively involve operation at another scale and change in output mix in the medium-long run perspective. The reduction of these two inefficiencies may need the intervention of a regulator.

When size inefficiency determined from programs (5) and (6) exists, gains are possible by respectively splitting the production into smaller DMUs (for a detailed description, see Ray, 2004) or by merging the individual units. For a multi-plant firm, the question of closing the large plant and setting up smaller units is being considered. In contrast, for a DMU with one independent manager (e.g. a farm), this strategy is more difficult to follow. In the latter case, policy makers have to establish an incentive scheme in support of small DMUs rather than large DMUs.

In the same perspective, to ensure possibilities in mix gains, a DMU should split into two or more smaller units or merge with farms in both two cases having different output mixes. Within a sector composed of numerous independent firms as is the case in the agricultural sector, an incentive policy that encourages mix change possibilities can be put in place.

2.3. Assessing the magnitude of change for obtaining potential gains

Finally, we attempt to evaluate the magnitude of change in terms of output mix needed to obtain the maximum potential gains from specialization and diversification processes. If mix gain is feasible by division, we compute the *ex post* Hamming between the evaluated DMU and all smaller DMUs in which should reorganize the activity. Thus, the higher is the *ex post* Hamming of the evaluated DMU, the more different in terms of mix are the smaller farms in which the DMU could reorganize its production activities. In the same spirit, if we consider a merger process, we can compute the *ex post* Hamming between the evaluated DMU and each DMU entering in the merger. Thus, the higher is the *ex post* Hamming of the evaluated DMU, the more different are the farms with which it should merge in terms of output mix.

3. Data and Empirical results

In France, since early 1950's, the number of farms has been divided by five going from 2 million to 490,000 in 2010. The rate of decrease is still significant and reaches -26% on the last decade[5]. Furthermore, since five decades and the emergence of the Common Agricultural Policy (CAP) this sector is gradually experiencing specialization in favour of a single type of activity (crops or milk for instance) instead of a larger mix of outputs. In most of French agricultural regions characterized by the trio of activities "crop, mixed, livestock" and in spite of a slowing, the change consists in a decrease of mixes activity mainly in favour of crop specialization and to a lesser extent in favour of specialization livestock. Only between 2000 and 2003, mixed farms are declined to 14% while the farms specialized in crops and livestock are decreased to 5% and 6.4%[6], respectively. Thus, the share of specialized farms and the agricultural area managed by them in total area have increased.

3.1. Data

Our input and output data are provided by *Centre d'Économie Rurale de La Meuse* and financed by *Institut National de la Recherche Agronomique.* Originally, database contains detailed information about farms and notably accounting data on farm structure. The farms are located in the French "département de la Meuse", an area situated in the northeast of France. The sample used in our empirical illustration of the method presented above is composed of 608 farms that were observed in 2003.

Outputs selected in our study consist of the revenues generated by crops (e.g. wheat, barley, peas), livestock (milk and cattle), and other productions (e.g. other agricultural work, annex and residual products). Several reasons motivated the selection of these data. Regarding the first two outputs (crops and livestock), the "département de La Meuse" is among those of which agriculture is characterized by the trio "crop, mixed, livestock".

The total cost of production is used as the input and defined as follows: (i) intermediate consumption included operational expenses (fertilizer, seeds, pesticide) and other costs (fuel, water, etc.); (ii) cost of surface area computed by applying rental rates to both hired and

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[5] Source: Agreste - RA 2000, 2010.

[6] Source: Agreste - Enquêtes Structures 2003 and RA 2000.

owned land; (iii) taxes and salaries of hired labor expressed as full time equivalency farm employees and the cost of family labor; and (iv) cost of capital, including machinery and building expenses. These four inputs contribute in our opinion to a good representation of the agricultural activities in this area and we aggregate them into one global input – the total cost of production - in order to stick to the definition of diseconomies of scope given by Baumol *et al* (1982). In agricultural literature and more particularly those focusing on crops and livestock farms, the inputs chosen by researchers are relatively similar to ours (see e.g., Wu and Prato 2006).

Descriptive statistics of the output and input data appear in Table 2. According to the minimum values observed over the sample, the data contain fully specialized farms in the two main outputs (livestock and crops). In contrast, all farms produce at least some other productions. Therefore the Herfindahl-Hirschman indexes[7] (HHIs) reveal the presence of perfectly diversified farms (HHI = 1/*M* = 0.33) and quasi fully specialized farms (HHI = 0.96 ≈ 1). The data also present some variability in the size of farms, as demonstrated by the large standard deviations (compared to the means). Concerning the other productions, they are generally a heterogeneous mass which have sometimes an importance highly variable between farms.

Table 2 - Descriptive statistics for the 608 farms[8]

	Mean	Standard deviation	Min	Max
Output (in Euros)				
Crops	49 583	44 237	0	331 399
Livestock	106 931	88 075	0	557 360
Other productions	32 336	49 439	1 209	865 200
Input (in Euros)				
Total cost of production	210 143	125 087	40 878	1 061 754
Herfindahl-Hirschman index	0.55	0.14	0.33	0.96

3.2. Results and interpretations

In this section, we present the results obtained from models (5) and (6) when are assumed division process and merge process, respectively (subsections 3.2.1 and 3.2.2). We also emphasise the difference in terms of cost reduction and of change magnitude of these two types of activities reorganization (subsection 3.2.3).

3.2.1. Division process

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[7] We chose to retain the Herfindahl-Hirschman specialization index (Hirschman, 1945 and Herfindahl, 1950) because of its intuitive interpretation. For a firm with multiple outputs and when each output can be expressed in terms of revenue, it is defined as the sum of squares of outputs shares in total production. By considering that it is possible to produce *M* output, the maximum value of HHI index is 1 when the firm is fully specialized into a single output and the minimum value is 1/*M* when all output shares are equal.

[8] Note that the outputs do not include the coupled and decoupled subsidies which represent in average 54 000 euros.

As mentioned above, to reduce their cost, farms have three ways viz. eliminate their technical, size and mix inefficiencies. Table 3 shows the decomposition results. First of all, the potential gains from division are considerable. Hence, the potential overall reduction of cost is to 18.70% of total observed cost thanks to the reduction of technical inefficiency and the activities reorganization into smaller farms. Of course, the division process can make with or without mix change. However, we show that a division associated with a mix change is often suitable. Indeed, the mix change has the effect the more important on cost relatively to size and technical effects. On our sample, 432 farms (i.e. 71% of total sample) benefit from division with output mix change.

Table 3 - Overall, technical, size and mix gains

	Overall	**Technical**	**Size**	**Mix**
Potential gains for all farms (in %[a])	18.70	2.54	7.16	9.01
Share in overall efficiency (in %)	100	13.6	38.3	48.2
Number of farms by the gains origins	492	174	299	432[b]
Percentage in total sample	81%	29%	49%	71%

Note: [a] The percentage of gains is relative to total observed cost. [b] In addition to a positive mix effect, these 432 farms exhibit or not a size effect. If the size effect is negative, we only retain farms where |Mix effect| > |Size effect|.

The seven cases mentioned earlier allow the distribution of own 608 farms (Table 4). The 432 farms which benefited from positive mix effect are ranked in cases *a*, *b* and *d* while the 299 farms (49% of total sample) with a positive size effect are ranked in cases *a* and *c*. Despite a negative size effect for 57 farms (in cases *d* and *e*), 42 out of them compensates through a change in output mix.

Table 4 - Distribution of farms according to the case

Cases	**Size effect / Mix effect**	**Number of farms**	**%[a]**
a	+ / +	256	42
b	no / +	134	22
c	+ / no	43	7
d	– / + (|Size effect| < |Mix effect|)	42	7
e	– / + (|Size effect| > |Mix effect|)	15	3
f	– / no	18	3
g	no / no	100	16

Note: [a] Percentage relative to total sample.

Table 5 presents the cardinality of the reference sets of 475 farms (i.e. 78% of total sample) which would benefit from division (i.e. cases *a*, *b*, *c* and *d*). For these candidates for break up, the reference set comprises 2 to 8 farms. However, 84% of farms have a reference set composed of two or three farms. As mentioned above, we could have easily restricted the number of referents by introducing an additional constraint into program (5) to avoid the too complex reorganizations of activities.

Table 5 - Cardinality of reference sets of farms

# referents	**# Farms**	**%**	**Cumulated in %**
2	247	52.0	
3	151	31.8	83.8
4	49	10.3	94.1
5	19	4.0	98.1
6	6	1.3	99.4
7	1	0.2	99.6
8	2	0.4	100
Total	**475**	**100**	**-**

To better illustrate the insights gained from our approach, we consider farm ***7589*** which can benefit from split in Table 6. Indeed, it exists in our sample two smaller farms which can produce more at a lower aggregated cost. Its cost can be reduced by around 44%.

Table 6 - Illustration with farm ***7589***

	HHI	**Crops**	**Livestock**	**Other productions**	**Total cost of production**
Evaluated farm ***7589***	0.607	17 651	155 934	26 442	228 750
Referents:					
farm ***7507***	0.762	4 484	76 488	7 208	46 666
farm ***7848***	0.452	14 284	81 147	42 393	81 144

Table 7 presents the potential gains obtained from division according to the three types of farming (crops, livestock and mixed). We also report the *ex post* Hamming to appraise the magnitude of mix change. According to intuition, mixed farms are those which more benefit from a division with mix change. However, the *ex post* Hamming reveals an important mix change. In sharp contrast to mixed farms, livestock farms can potentially obtain significant overall gains (in average, 22% of observed cost) with a lesser mix change. Crop farms should also make little effort but the gains are lower.

Table 7 - Division gains according to the type of farming

	Crops	**Livestock**	**Mixed**
Number of farms	80	214	314
Surface area (in hectares)	213	149	206
Observed cost (in €)	182 310	197 092	225 832
Overall gains (in %[a])	12.19	22.00	18.08
Technical gains (in %)	4.49	3.67	1.46
Size gains (in %)	5.61	10.79	5.31
Mix gains (in %)	2.09	7.54	11.31
***Ex post* Hamming Distance**	0.08	0.11	0.27

Note: [a] Percentage relative to total observed cost for all farms of the considered type.

3.2.2. Merger process

Table 8 presents the results of the overall, technical, size and mix gains. By merging, the potential overall reduction of cost is to 7.80% of observed cost. After the elimination of technical inefficiency, the merger leads to a cost reduction to 5.26% mainly due to a size change.

Table 8 - Overall, technical, size and mix gains

	Overall gains	Technical gains	Size gains	Mix gains
Potential reduction (in %[a])	7.80	2.54	3.48	1.78
Share in overall efficiency (in %)	100	32.6	44.6	22.8
Number of farms by to the gains origins	437	174	299	283
Percentage in total sample	72%	29%	49%	47%

Note: [a] Percentage relative to total observed cost.

On our sample, 283 farms (47% of total sample) benefit from merger with output mix change. As presented in Table 9, they are partitioned between the cases *a* and *b*.

Table 9 - Distribution of farms according to the case

Cases	Size effect / Mix effect	Number of farms	% [a]
a	+ / +	212	35
b	no / +	71	12
c	+ / no	87	14

Note: [a] Percentage relative to total sample.

As Table 10 shows, the number of DMUs with which 370 DMUs (i.e. 61% of total sample) should merge is included in 1 to 6 farms. However, 80% of these farms should merge with at the most two farms to obtain cost reduction. Hence, the reorganization of activities seems to be relatively few complex for a large majority of farms.

Table 10 - Cardinality of reference sets of farms

# DMUs	# Farms	%	Cumulated in %
1	134	36.2	
2	163	44.1	80.3
3	59	15.9	96.2
4	9	2.4	98.6
5	2	0.5	99.2
6	3	0.8	100
Total	**370**	**100**	**-**

For example in Table 11, consider again farm ***7589*** presented. It should merge with farm ***7659*** as there exists in the sample a referent farm ***7895*** which produces as more as these two united farms and at a lower cost. This referent farm represents a better resource allocation demonstrating the interest to merger for the two smaller DMUs. Here, the cost reduction represents around 8.6%. However, compared to the potential gain obtained by division (44%), it is in her best interest to split in two smaller farms.

Table 11 - Illustration with farm ***7589***

	HHI	**Crops**	**Livestock**	**Other productions**	**Total cost of production**
Evaluated farm: ***7589***	0.607	17 651	155 934	26 442	228 750
Farm entering to the merger: ***7659***	0.471	57 343	157 584	34 486	243 369
Referent farm: ***7895***	0.502	85 352	318 901	73 211	431 575

To go further, Table 12 presents the percentage of gains obtained by merger according to the type of farming (crops, livestock and mixed farms).

Table 12 - Merger Gains according to the three types of farming

	Crops	**Livestock**	**Mixed**
Number of farms	80	214	314
Surface area (in hectares)	213	149	206
Observed cost (in €)	182 310	197 092	225 832
Overall gains (in %[a])	10.72	8.74	6.64
Technical gains (in %)	4.49	3.67	1.46
Size gains in average (in %)	3.57	3.54	3.43
Mix gains in average (in %)	2.66	1.53	1.74
***Ex post* Hamming Distance**	0.35	0.12	0.16

Note: [a] Percentage relative to total observed cost for all farms of the considered type.

Compared to Table 7, gains due to merger are relatively less important for livestock and mixed farms. In contrast, crops would benefit from the effect of a merger more important than from a division. However, the *ex post* Hamming distance reveals an important mix change for crops relatively to the two other types. It means that gains are possible by merging with very different farms in terms of output mix. Thus, in order to obtain the maximum gains, crop farms need to make a significant change.

3.2.3. Division versus merger

At the sectoral level, after the elimination of technical inefficiency, relatively to division the merger allows a less important reduction of cost respectively 5.26% against 16.16%. Thus, we can conclude that potential division gains outweigh the benefits from merger process.

In order to compare the importance magnitude of output mix change for the farms benefiting from gains after division (i.e. 432 farms) and merger (i.e. 283 farms), Figures 1.a and 1.b present the distribution of farms by the *ex post* Hamming (in %). To obtain maximum mix gains from division, the magnitude of change ranges from 0.00 to 0.43 with a relative equitable distribution (excepted for the last interval [0.40 ; 0.45]).

By contrast, even if output mix varying from 0.00 to 0.70, a majority of farms (i.e. 56.9%) could benefit from mix gains by an output mix change varying from 0.00 to 0.15. The mean is 0.18.

This information about the importance magnitude of mix change can help farmers to make a trade-off between division and merger processes. Nevertheless, it only concerns the farms which can benefit both division and merger gains i.e. 264 farms (43% of our sample) including our illustrative farm ***7589***. In Figure 2, all farms following size and mix gains obtained by division and merger[9] are represented. Our 264 farms are those which are not located on one of the two axes.

Figure 1. Distribution of farms (in %) benefiting from mix gains by the *ex post* Hamming

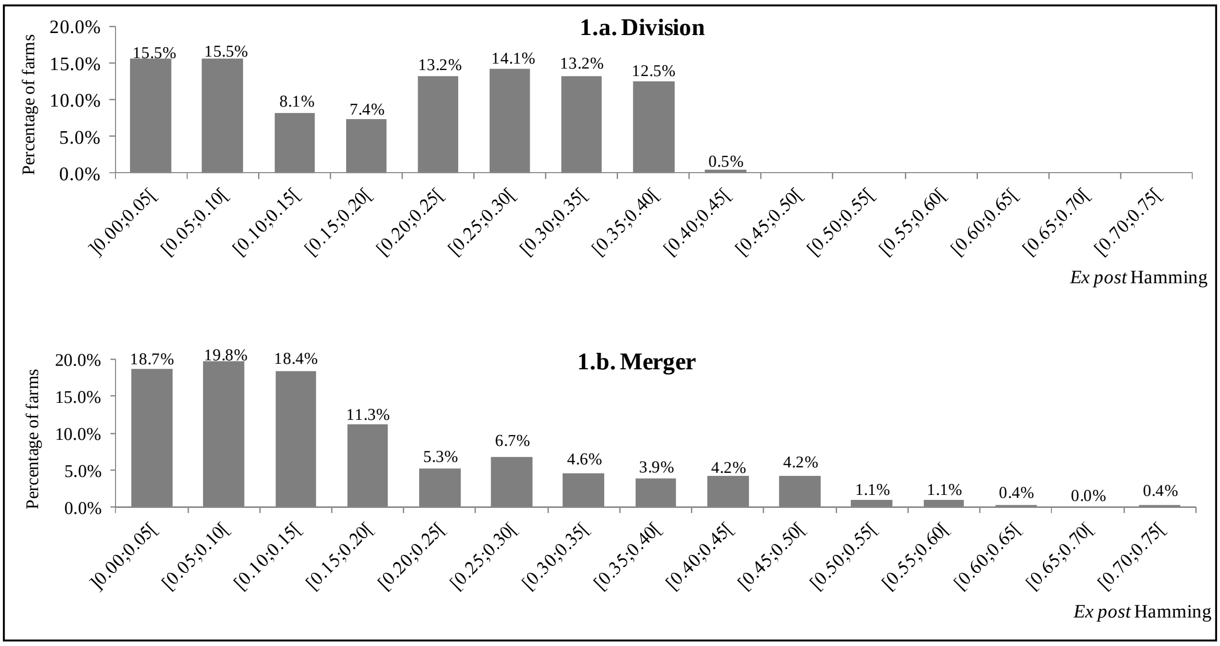
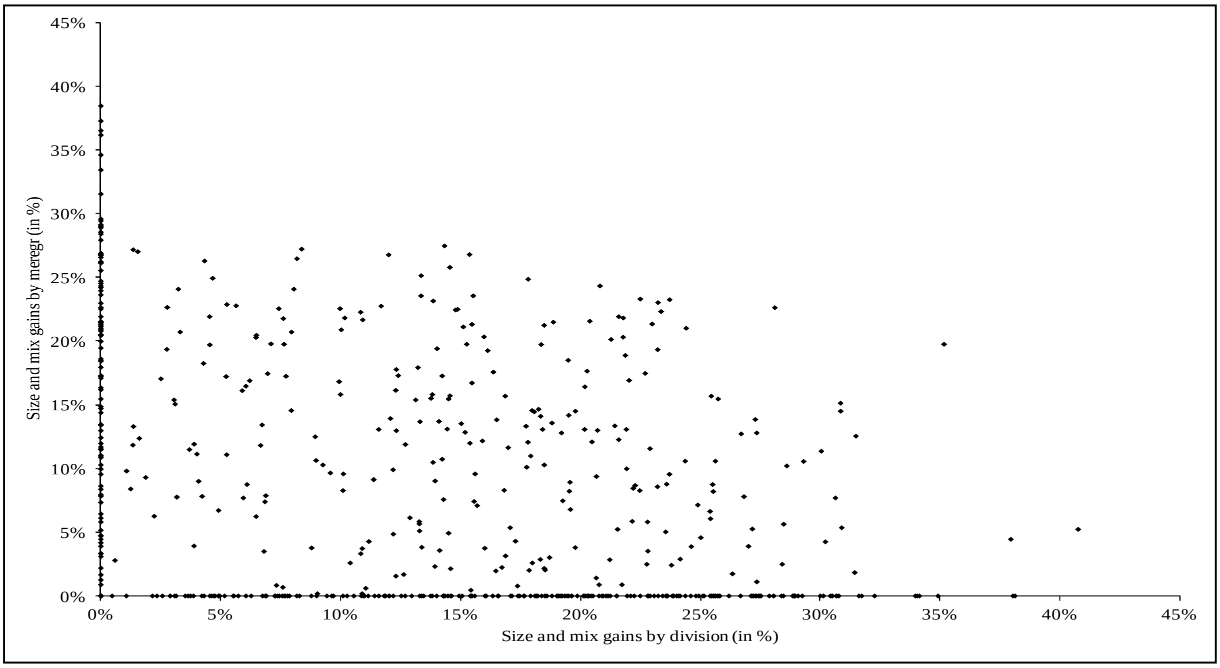


Figure 2. Distribution of farms following size and mix gains



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[9] For reminder, 475 and 370 farms benefiting from division and merger, respectively.

4. Conclusions

This paper has provided new insights on economic gains obtained from diversification and specialization of farm. From two mixed integer programming models, we have determined *i)* whether it is more interesting to break up a large farm into a number of smaller farms or *ii)* whether it is more interesting to merge smaller farms into a large farm. These programs are mainly based upon Blancard *et al* (2011) and Bogetoft and Wang (2005). From a sample of French farms, we demonstrated that gains can be obtained both from division and merger processes. However, the potential gains are thrice as high if a division process instead of merger is initiated. These results can explain in part the trend toward more specialization.

Crop farms are the type which would benefit the least to the division but on the other hand the more to the merger. However, to obtain maximum merger gains, a great effort in terms of mix change is needed. Concerning the livestock farms, it is in a best interest to divide rather than merger. Furthermore, in accordance with intuition, mixed farms should be split especially in order to benefit from a change in the output mix.

In closing, note that our study has only considered the possible economic gains. However, as Ray and Mukherjee (1998), we neglect the induced costs as e.g. the adjustment and coordination costs. Moreover, we do not capture the other mix benefits leading to more diversification and thus to risk reduction. The environmental impacts of specialization and diversification process are also not considered. Therefore, any final decision should be taken with full knowledge of these elements.

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