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Potential gains from specialization and diversification further to the reorganization of activities

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ABSTRACT

In economic activities, two main forces guide firm and market structures: specialization and diversification. This paper provides new insights on this topic. We propose measuring gains due to simulated division and/or merger processes of firms. Potential gains come from a reorganization of activities through specialization/diversification and/or size effects. From a database of French farms, our findings demonstrate that even if both processes are beneficial for farming systems, the division gains outweigh the gains obtained by a merger. Moreover, mix changes are more important following a division than following a merger, implying more specialization gains than diversification gains.

1. Introduction

In economics, it is well known that the market structure and number of firms in the industry are directly linked to specialization and/or diversification phenomena. While labor division and the specialization of units facilitate technical progress and productivity enhancements, diversification is recognized as a factor of a scope economy linked to environmental synergies between different firms' activities and risk-management strategies. Economies of scope are defined as cost savings resulting from producing jointly many goods by one diversified firm rather than producing them separately by several specialized firms [30,5].[1] In some industries, however, economies of scope do not necessarily imply an absence of the benefits of specialization (*vice versa*). Indeed, specialization and diversification processes can coexist and must collide. So a relevant question is: Between specialization and diversification, which process generates the most gains for firms and is the most economically justifiable?

In this context, the development of tools to disentangle the two processes and assess cases in which one process economically dominates the other is a major methodological challenge. As such, this paper provides new insights into the diversification and specialization phenomena. More precisely, we measure and compare the potential gains in terms of cost reduction that firms may realize with a higher degree of specialization or diversification. We further decompose the gains obtained from the two types of reorganization – division and merger – into technical, size and mix gains. Explicit analysis of gains is an important task in determining the best direction to steer the reorganization (e.g., a division or a merger with or without mix changes). Moreover, by examining the output mix effect, we can determine whether the firm should go toward more specialized or mixed activities and compute the potential gains from the specialization and diversification processes.

To measure the potential gains *a priori* due to a merger, our approach is quite similar to the one adopted by Bogetoft and Wang [7] or Kristensen et al. [26]. Following these authors, we also employ the same concept of mix to capture the effect of this reorganization. However, our study differs from the above papers and others (e.g., [18,23,15,16]) in two important respects. First, in addition to the merger, we also examine the division process by relying on the methodology developed by Blancard et al. [3] for quantifying potential gains. Second, we estimate these two types of gains using non-convex technologies. Indeed, as Farrell [20] stated and Cherchye and Post [14] re-expressed, the convexity assumption that implies additivity and divisibility does not allow the highlighting of gains achieved through specialization and can only reveal economies of scope. More recently, Sahoo and Tone [38] recalled that the convexity assumption of

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[1] Economies of scope can come to the cost complementarity between two productions and/or the sharing or joint utilization of quasi-fixed inputs.

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production technologies might be prejudicial in real-life case studies. Carvalho and Marques [9] also emphasized that the imposition of convexity led to the results which support economies of scope. Hence they proposed a novel approach based on partial frontier nonparametric methods. This second point, which consists of rejecting this assumption, allows us to deviate from Ray [34] and Peyrache [31] in particular.

From the methodological viewpoint, we identify potential gains from both specialization and diversification based on an activity analysis framework [25,4]. Our starting point is activity analysis models without convexity. The Free Disposal Hull (FDH) model was introduced by Deprins et al. [17]. This model relaxes the convexity assumption by ignoring both additivity and divisibility. Later, Tulkens [40] and Bogetoft [6] introduced the Free Replicability Hull (FRH) by rejecting divisibility only. Ray and Hu [36] proposed that integral replications of all observed input-output combinations are feasible. More recently, Green and Cook [22] considered only additivity without replicability in the Free Coordination Hull (FCH) approach. In our paper, we employ the FCH and FDH models to analyze specialization and diversification processes.[2] An attractive feature of the FDH and FCH approaches is to allow only directly observed Decision Making Units (DMUs) to define the production technology. Additionally, by assuming only the additivity assumption, the FCH approach can allow the summation of these observed DMUs. Therefore, it appears appropriate for analyzing the reallocation of large firm activities among smaller units (division process) and, alternatively, the reallocation of small firms' activities among a larger unit (merger process).

The utility of this methodology is demonstrated on a sample of 608 French farms specializing in crops, in livestock and diversified during 2003.

Several papers in the agricultural literature have dealt with diversification. Fernandez-Cornejo et al. [21], for example, identified substantial dynamic economies of scope between cattle and other German agricultural products (crops, hogs and milk). Chavas and Aliber [12] highlighted important economies of scope of farms in Wisconsin that produced crops and/or livestock, and Morrison Paul and Nehring [29] found that product diversification contributed to US farms' economic performance. Later, in a sample of farms in Missouri, Wu and Prato [42] showed that the cost of joint production of crops and livestock is less than the cost of separate production. More recently, Chavas and Di Falco [13] investigated farm diversification linked to economies of scope and risk management. An empirical analysis of Ethiopian farms demonstrated a significant incentive for farmers to diversify.

Contrary to these studies on diversification, Blancard et al. [3] were interested in potential gains from specialization in agricultural activities. Using a sample of farms located in northeast France, the authors revealed that the main way to reduce production costs is indeed to increase the specialization of farms in terms of crops or livestock. This could partly explain the increasing shift to greater specialization observed in the French agricultural sector over the past few decades. A few years earlier, Chavas [10,11] suggested that the benefits of specialization and the enhancement of productivity could explain the trend toward more specialized farms. However, as already stated, this does not necessarily imply the absence of economies of scope. More recently, Atici and Podinovski [1] consider the use of data envelopment analysis (DEA) for the assessment of efficiency of units whose output profiles exhibit specialization.

Given these various issues, the structure of this paper is as follows. The next section describes our alternative approach to the computation of potential gains derived to output mix, size and technical effects. Our findings from empirical analyses are discussed in the next-to-last section. Finally, some concluding comments are presented in the last section.

2. Methodology

The analysis of production structure and gains due to activity reorganization requires a representation of the underlying production technologies. The latter can be modeled thanks to an Activity Analysis Model (AAM) introduced by Koopmans [25] and Baumol [4]. AAM is a mathematical programming-based technique composed of multiple inputs and outputs. The main advantage of AAM is the ability to estimate technology without specifying any functional form between inputs and outputs. We employ the general framework developed by Shephard [39] to model the technology by production possibility set.

Consider the situation with K DMUs and $\mathfrak{K}=\{1,\dots,K\}$ being the corresponding index set. We also assume that DMUs use a vector of N inputs $x=(x^1,\dots,x^N)\in R_+^N$ to produce a vector of M outputs $y=(y^1,\dots,y^M)\in R_+^M$. The respective index sets of inputs and outputs are defined as $\mathfrak{N}=\{1,\dots,N\}$ and $\mathfrak{M}=\{1,\dots,M\}$.

Following Green and Cook [22] and Blancard et al. [3], we now consider different technologies by postulating (or not) the additivity assumption (FCH or FDH technologies). Furthermore, we consider the set of all DMUs and different subsets composed only of similar DMUs in terms of output *mix* relative to the evaluated DMU (hereafter denoted smix). By denoting $s=$ FDH or FCH and $r=$ all or smix, the production possibility set $T(s,r)$ is defined by:

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

In (1),

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

In FDH and FCH technologies, λ is a binary variable leading to the Mixed Integer Program (MIP). Formally, the difference between FDH and FCH concerns the presence or lack of $\sum\lambda_k=1$. Contrary to FDH, FCH allows one to sum DMU activities given the additivity assumption.[3] Hence, FCH is less restrictive than FDH.

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

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

In this paper, the Hamming distance[4] (denoted H) is retained to determine the DMUs with an output mix similar to that for the evaluated DMU. It is measured by summing the absolute deviations between two DMUs in terms of structure of output. Formally, for DMUs k and o, we have:

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

[2] An alternative approach could be the FRH model instead of FCH allowing the replicability observed DMUs as developed by Ray and Hu [36] or Ray [33].

[3] This is particularly attractive when we aim to compare a sum of smaller units to a large one and so to reveal size inefficiency.

[4] The Hamming distance was proposed by Hamming [24] and initially developed in information theory.

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where $f_j^m = \frac{p_j^m y_j^m}{\sum_m p_j^m y_j^m}$, $j = o, k$ is the share of output m in total output value with p as the output price for DMU j. The maximum value of the Hamming distance is 1 when the two DMUs under comparison are each fully specialized into a different output, and the minimum value is 0 when all output shares are equal.[5]

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 main purpose is to determine whether it is more efficient to (i) break up a large firm into a number of smaller units or (ii) merge smaller firms into a larger one. We also discuss the implications in terms of management and reorganization of activities.

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 the minimum cost (C^*) to the observed cost for DMU $o(C_o)$ given the definition of the technology in (1). The minimum cost is computed using the following MIP:

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

where C_k measures the total cost of DMU k.[6] Moreover, because we want to examine whether the multiproduct firm would benefit (or suffer) from reorganizing production activities into two or more smaller firms, we also consider the constraint $\sum_{k \in \Re(r)} \lambda_k \geq 2$ in a model based on the production possibility technology $T(\text{FCH}, r)$. Traditionally, cost efficiency varies between 0 and 1 because the evaluated DMU is included in referents and can be compared to itself [8]. Here, by adding $\sum_{k \in \Re(r)} \lambda_k \geq 2$, we have a case where the minimum cost C^* can be smaller than, equal to or greater than C_o. Thus, CE_o is no longer bounded by 1. If CE_o exceeds unity, the division is costly, i.e., the evaluated DMU o loses in terms of cost by reorganizing its activities into smaller units. If $0 \leq CE_o \leq 1$, 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 firms into which the observed firm should be broken up. Because the optimization may lead to combinations with a great number of small DMUs, let us note that it is possible to limit the split into $R_{\max}$ referents by adding the constraint $2 \leq \sum_{k \in \Re(r)} \lambda_k \leq R_{\max}$. The rationale behind this option can be found in the importance of adjustment costs induced by a breaking-up into numerous firms. As mentioned by Williamson [41], during the negotiation and adjustment periods, ex ante costs (e.g., negotiation costs) and ex post costs (e.g., organization and operating costs or adjustment costs) are expected. In case transaction costs are unobserved the proposed constraint is a way to consider their impact on the reorganization.

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

Gains from a merger are considered at the individual firm level. Therefore, in our framework, for each firm, all potential combinations entering a merger process are simulated. Then, the best alternative is selected and as a consequence, a DMU could appear in several potential reorganizations. It is clearly different from a planner point of view who would have to prioritize mergers by constraining that a DMU is taking only once in a merging process. To estimate the potential gains from the merger including the evaluated firm o, we solve one program for each firm that could be considered as a referent firm, denoted ref, to which the merger must be similar. For any referent ref that produces a larger output than that produced by the evaluated firm, the maximum cost reduction of the merger is computed by the following program:

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

where y_{ref}^m is the referent's output and C_{ref} its observed total cost. l is the index relative to firms that can potentially belong to the merger; if $\lambda_l = 1$, firm l enters into the merger. If $\delta^{-1} < 1$, firm ref produces more than the merger at the least-cost. The cost reduction for the merger is equal to $[(\delta - 1) \times 100]\%$. The MIP (6) is nonlinear, as 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 relative to all referent firms producing more output. Finally, among the set of all referents ref for which program (6) is solved, we retain the merger, which allows the maximum cost reduction. Thus, if we assume an equal sharing of gains among the DMUs entering the merger, we compute the cost efficiency score for DMU $o(CE_o)$ as the ratio of minimum cost ($\delta^{-1} C_o$) to the observed cost for DMU o (C_o).

In the same spirit of division, the optimization may lead to combinations having a great number of small DMUs. However, it is possible to limit the merger to $R_{\max}$ referents or to avoid unsuitable DMUs, respectively, by adding the constraint $1 \leq \sum_{l \in \Re(r)} \lambda_l \leq R_{\max}$. Similarly to the previous case of division, the idea behind the possibility to limit the merger to $R_{\max}$ referents can be a way to consider unobserved transaction costs induced by a reorganization involving a great number of DMUs. Moreover, the reference set can be limited to DMUs having the same characteristics as the evaluated DMU. In their case study, Bogetoft and Wang [7] proposed to restrict the merger to only units that 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 $\lambda_l = 0 \quad \forall \ l$, 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

When the most general production possibility set defined as $T(FCH, \text{all})$ is considered, the total gains for each process (division/merger) are revealed from programs (5) and (6). These gains have three potential sources: technical, size and mix gains.

First, the technical inefficiency of DMU o is obtained by solving program (5) with $s = \text{FDH}$ and $r = \text{smix}$ or program (6)

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

[6] By considering C_k instead of $\sum_{n=1}^{N} w_k^n x_k^n$, where w_k^n are the input prices of DMU k, we implicitly make the assumption that all DMUs face identical input prices. This assumption is relevant in case of price-taker DMUs.

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indifferently with $\lambda_l = 0 \quad \forall\ l$. This score can be denoted $S_{T(\mathrm{FDH,smix})}$. By rejecting the additivity assumption and limiting the production possibility set to DMUs with the same output mix, solely the technical inefficiency is exclusively revealed. In other words, size and mix effects do not play any role in inefficiency.

Second, concerning size efficiency, the notion proposed by Maindiratta [28] and developed by Ray and Mukherjee [37],[7] is retained rather than the classical measure of scale efficiency. Indeed, insofar as we relax the divisibility assumption, we exclude logically any measure of scale inefficiency based on the most productive scale size concept [2]. Hence, to assess the size effect during the division process, the comparison between the evaluated DMU and the smaller ones having the same output mix is required. In the merger case, the aggregated costs of the evaluated DMU and the candidates for merging (with the same output mix) are compared with those of the firms that produce at leastas much asalltogether. In other words, size gains may be identified in a situation where it is possible to find a sum of smaller DMUs with the same output mix and/or where it may profit to merge with one or several DMUs having the same output mix. By considering $s =$ FCH and $r =$ smix, the size inefficiency of DMU o is added to the FDH score. By comparing the efficiency scores under $T(\mathrm{FCH, smix})$ and $T(\mathrm{FDH, smix})$ from models (5) or (6), respectively and denoted $S_{T(\mathrm{FDH,smix})}$ and $S_{T(\mathrm{FCH,smix})}$, we can measure the net effect of size inefficiency. Thus, we have the following:

(1) $(S_{T(\mathrm{FCH,smix})} - S_{T(\mathrm{FDH,smix})}) = 0$ indicates that DMU o operates at the efficient size of production. Here, changing its size does not allow the DMU to obtain gains.
(2) $(S_{T(\mathrm{FCH,smix})} - S_{T(\mathrm{FDH,smix})}) > 0$ indicates that DMU o can decrease its costs by splitting its activities among smaller units when it engages in a division process or alternatively by merging with other firms 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 $T(\mathrm{FCH}, r)$, a third case may be highlighted in case of division:
(3) $(S_{T(\mathrm{FCH,smix})} - S_{T(\mathrm{FDH,smix})}) < 0$ indicates that DMU o increases its costs by splitting its activities among smaller units. Thus, the operation at a small scale resulting from a division process is not beneficial.[8]

Third, if the reference set of the evaluated DMU is composed solely of DMUs that differ in output composition, then the potential gains obtained by a change in output mix can be assessed. Formally, gains resulting from a change in output mix are measured by comparing $S_{T(\mathrm{FCH,all})}$ and $S_{T(\mathrm{FCH,smix})}$. The difference between the technologies $T(\mathrm{FCH, all})$ and $T(\mathrm{FCH, smix})$ is related to the output mix of the DMUs belonging to the production possibility set. By comparing a DMU relative to DMUs with a different mix and then relative to all DMUs, the difference in the resulting efficiency scores gives the potential gains from the output mix change. As $T(\mathrm{FCH, smix}) \subseteq T(\mathrm{FCH, all})$, two cases are possible:

(1) $(S_{T(\mathrm{FCH,all})} - S_{T(\mathrm{FCH,smix})}) = 0$ indicates that no gain can arise from any output mix change.
(2) $(S_{T(\mathrm{FCH,all})} - S_{T(\mathrm{FCH,smix})}) > 0$ indicates that DMU o can benefit from cost reductions due to a change in output mix.

In summary, the measurement of these different gains proceeds from an appropriate choice of technologies and subsets. Neither a merger nor a division is necessary to realize technical gains. By contrast, size and mix components inform about the gains issued from a division or a merger process. Table 1 presents the different cases that may be revealed within a division or merger process by combining size and mix effects. For a division process, seven cases are possible (denoted a to g), while only three cases (a, b and c) arise in the merger process.

Table 1
Summary of the different cases.

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

Note: In our study, we interrupted the activity reorganization at the step that was more favorable to the firm. Thus, because the mix change was the last step of reorganization, the case of a negative mix effect did not arise.

Lastly, the overall gains measure can be explicitly decomposed into three additive components as follows:

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

The identification of these sources of gains constitutes a help for policy- and decision makers concerned with improving efficiency.

Primarily because of a weakness in management quality, reducing technical inefficiency is possible by learning the practices of more efficient units. The correction can be made in the short term. As noted by Bogetoft and Wang [7], incentive mechanisms may be introduced particularly if the problem stems from lack of motivation rather than a lack of skills.

In contrast, eliminating size and mix inefficiencies respectively involve operation at another scale and change in output composition and both are conceivable in the medium- and long term. Under these circumstances, this may require regulatory or policy intervention.

If size inefficiency revealed by programs (5) and (6) exists, gains could be obtained by respectively breaking up the production into smaller DMUs or by merging the individual units. When the decision-making unit is a multi-plant firm, it could be relevant to closing the large plant and to reallocating its activities between smaller subunits. On the contrary, when a production unit is managed by only one individual as is often the case in small units, this strategy is not applicable or at least become more difficult. In the latter case, an incentive scheme in favor of small DMUs rather than large DMUs could be useful.

Finally, mix gains may be possible by splitting a DMU into two or more distinct and smaller units in terms of output mix or merging with other firms being different in both aspects. Appropriate incentive mechanisms could be introduced to encourage mix change.

2.3. Assessing the magnitude of change for obtaining potential gains

To complete our analysis, we evaluate the magnitude of change in terms of output mix, needed to obtain the maximum potential gains from specialization and diversification processes. If a mix gain is feasible by division, we compute the *ex post* Hamming between the evaluated DMU and all smaller DMUs in which activity should be reorganized. Therefore, the higher the *ex post* Hamming of the evaluated DMU, the more different in terms of mix are the firms in which the DMU could reorganize its

[7] For further details about the concept of size efficiency, see also Ray [34] or Ray [35].
[8] The fact that an operation at a small scale may or may not be beneficial depends on the scale properties.

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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 the merger. Thus, the higher the *ex post* Hamming of the evaluated DMU, the more different are the firms with which it should merge in terms of output mix.

3. Data and empirical results

In France, since the early 1950s, the number of farms has been reduced by a factor of 5, going from 2 million to 490,000 in 2010. The rate of decrease is still significant, decreasing 26% in the past decade.[9] Furthermore, for over fifty years and since the implementation of the Common Agricultural Policy, agriculture has gradually evolved towards specialization instead of a larger production mix. In most French agricultural regions characterized by the trio of activities "crop, mixed, livestock" and despite slowing, the change has comprised a decrease in mixed activity primarily in favor of crops specialization, and, to a lesser extent in favor of livestock specialization. Between 2000 and 2003, mixed farms declined by 14% while farms specialized in crops and livestock decreased by only 5% and 6.4%,[10] respectively. Thus, the share ofspecialized farms and the total agricultural area managed by them have increased.

3.1. Data

A database of 608 farms observed in 2003 was provided by a center in accounting and management –the *Centre d'Économie Rurale de La Meuse*– and funded by the French National Institute for Agricultural Research. The farms are located in the northeast of France, more precisely in the "Département de la Meuse". The latter was selected as the area of study for its agricultural production and distinctive type of farms.

In accordance with this area, retained outputs are the crops (e.g., wheat, barley and rape), livestock products (dairy and beef), and miscellaneous productions (e.g., other agricultural products, annex and residual products). They are expressed in terms of the revenue they generate.

On the input side, four inputs correctly represent the agriculture in this zone: (i) intermediate consumption including operational expenses for crops production (e.g., seeds, fertilizers and pesticides), for livestock production (e.g., feed and veterinary costs) and other costs (water, gas and electricity, etc.); (ii) cost of surface area computed by applying rental prices to both leased and owned land; (iii) taxes, wages paid to employees and costs of family and operator labor; and (iv) cost of capital, including mechanization and building costs. In the literature concerning crop and livestock farms, these inputs are those chosen commonly by researchers. For this empirical illustration, the input data are subsequently aggregated into one overall input – the total cost of production. As mentioned in footnote 6, by considering directly the costs instead of input quantities multiplied by their prices, it is necessary that all DMUs face exactly the same input prices to avoid that merger and division gains reflect price differences rather than local characteristics of the technology. As shown by Färe, Grosskopf and Lee [19] when identical prices are assumed, employing costs or input quantities multiplied by their prices do not modify the constraints and the optimal solution. In our sample, this assumption seems quite plausible because (i) all farms operate in the same area and (ii) generally they purchase from the same local suppliers of inputs having prices fairly similar. In addition, although they may differ in size, the French farms do not have a significantly different market power. Indeed, the underlying market structure is atomistic and prices can be considered exogenous.

Descriptive statistics for the variables employed in the analysis are given in Table 2. The mean, the minimum and the maximum values for our output variables reflect the presence of both perfectly diversified farms and quasi fully specialized farms. In addition, the data are highly variable, as indicated by the large standard deviations compared to the means and the large range values of the variables.

3.2. Results and interpretation

In this section, we present some results obtained from mix integer programming models (5) and (6) when the division and merge processes, respectively, are assumed. We also emphasize the difference in terms of cost reduction and the magnitude of change of these two types of activities reorganization.

3.2.1. Division process

As mentioned above, farms have three ways to reduce their cost, i.e., eliminate their technical, size and mix inefficiencies. Table 3 shows the decomposition results. First, it is worthwhile to note that the potential gains from division are considerable. Hence, the potential overall cost reduction is as much as 18.70% of the total observed cost, thanks to the reduction of technical inefficiency and the reorganization of activities into smaller farms. Of course, the division process can occur 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 more significant effect on cost relative to size and technical effects. In our sample, 432 farms (i.e. 71% of the total sample) benefited from division with output mix change.

The seven cases mentioned earlier allow the distribution of our 608 farms (Table 4). The 432 farms that benefited from a positive mix effect are ranked in cases *a*, *b* and *d*, while the 298 farms (49% of the total sample) with a positive size effect are ranked in cases *a* and *c*. Despite a negative size effect for 58 farms (in cases *d* and *e*), 43 of them compensate through a change in output mix.

Table 5 presents the cardinality of the reference sets of 475 farms (i.e., 78% of the total sample) that would benefit from division (i.e. cases *a*, *b*, *c* and *d*). For these units, the reference set consists of two to eight farms. However, 84% of farms have a reference set composed of two or three farms. As mentioned

Table 2
Descriptive statistics for the 608 farms.

	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 production	32 336	49 439	1 209	865 200
Input (in Euros)				
Total cost of production	210 143	125 087	40 878	1 061 754

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

Note:

[a] The percentage of gains is relative to the total observed cost.

[9] Source: *Agreste – Recensement Agricole 2000* and *Recensement Agricole 2010*.
[10] Source: *Agreste – Recensement Agricole 2000* and *Enquête structure 2003*.

Table 4
Distribution of farms according to case.

Cases	Size effect / Mix effect	Number of farms	% of the total sample
a	+ / +	255	42
b	no / +	134	22
c	+ / no	43	7
d	$-/+(\lvert\text{Size effect}\rvert < \lvert\text{Mix effect}\rvert)$	43	7
e	$-/+(\lvert\text{Size effect}\rvert > \lvert\text{Mix effect}\rvert)$	15	3
f	– / no	18	3
g	no / no	100	16
Total		**608**	**100**

Table 5
Cardinality of reference sets of farms.

# Referents	# Farms	%	Cumulative %
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**	–

Table 6
Illustration with farm ***7589***.

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

above, without major difficulties, we could have limited the number of referents by adding a constraint into program (5) to avoid the too-complex reorganizations of activities.

As a better illustration of our approach, we consider farm ***7589***, which can benefit from the split in Table 6. Indeed, two smaller farms exist in our sample that can produce more at a lower aggregated cost. This farm is thus one of the 247 farms which have two referents and its cost can be reduced by approximately 44%.

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 their orientation (crops or livestock), farms benefit from different levels of division gains (mix or size gains). Livestock farms obtain the highest gains (18.33%) against 7.70% for crop farms. For these two types of farming, division gains mainly concern the size effect (59% for livestock and 73% for crops). Compared to livestock farms, division gains for mixed farms are quite similar (16.62%). However, they are of a different nature, as mix gains represent 68% of the division effect for mixed farms while they do not exceed 41% for livestock farms. Finally, for mixed farms, the mix change denotes a deeper specialization process as shown by the *ex post* Hamming distance. The latter can be interpreted as a change of 27% in their profile of activities.

In short, and in line with intuition, division gains come from a specialization process for mixed farms, whereas they mainly issue from a size change for specialized farms (crops or livestock orientations).

Table 7
Division gains by 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
• **Division gains (in %)**	7.70 (100%)	18.33 (100%)	16.62 (100%)
- Size gains (in %)	5.61 (73%)	10.79 (59%)	5.31 (32%)
- Mix gains (in %)	2.09(27%)	7.54 (41%)	11.31 (68%)
***Ex post* Hamming distance**	0.08	0.11	**0.27**

Note:

[a] Percentage relative to the total observed cost for all considered farm types.

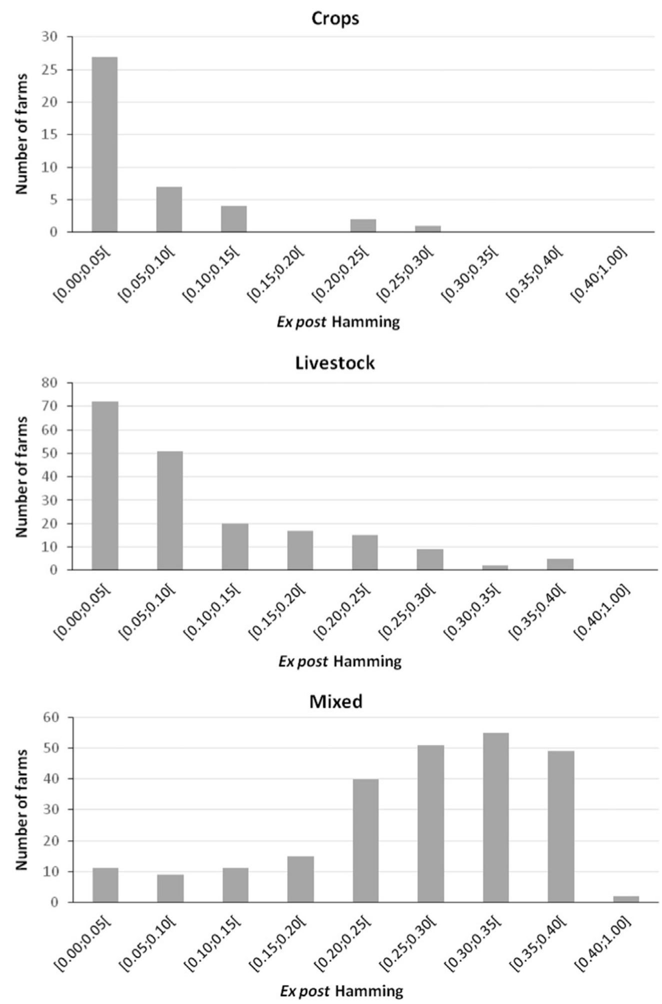

Fig. 1. Distribution of farms benefiting from division gains by the *ex post* Hamming.

To compare the magnitude of output mix change for the farms benefiting from gains after division, Fig. 1 presents the distribution of each type of farm by the *ex post* Hamming (in %), supporting the above conclusions. Among farms that benefit from division gains, the majority of crop and livestock units do not substantially change their *ex post* Hamming distance contrary to mixed units.

3.2.2. Merger process

For easier comparison, we report the findings for the merger process in the same way as for the division process. Hence, Table 8 presents the results of the overall, technical, size and mix gains. By

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merging, the potential overall cost reduction amounts to 7.80% of the observed cost. This reduction comes mainly from size and technical gains (44.6% and 32.6%, respectively). Contrary to the division process, mix gains are not the main force behind the benefits.

Table 8
Overall, technical, size and mix gains.

	Overall	Technical	Size	Mix
Potential reduction (in %[a])	7.80	2.54	3.48	1.78
Share in overall efficiency (in %)	100	32.6	44.6	22.8

Note:

[a] Percentage relative to the total observed cost.

Table 9
Distribution of farms according to case.

Cases	Size effect / Mix effect	Number of farms	% of the farms benefiting from merger gains
a	+ / +	206	56
b	no / +	77	21
c	+ / no	87	24
Total		**370**	**100**

Table 10
Number of farms in the merger.

# DMUs in the merger	Frequency	%	Cumulative %
2	134	36.2	
3	163	44.1	80.3
4	59	15.9	96.2
5	9	2.4	98.6
6	2	0.5	99.2
7	3	0.8	100
Total	**370**	**100**	**–**

Table 11
Illustration with farm ***7589***.

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

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
• **Merger gains (in %)**	6.23(100%)	5.07(100%)	5.17(100%)
- Size gains (in %)	3.57(57%)	3.54(70%)	3.43(66%)
- Mix gains (in %)	2.66(43%)	1.53(30%)	1.74(34%)
***Ex post*Hamming distance**	**0.35**	0.12	0.16

Note:

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

Table 9 presents the distribution of the 370 farms (61% of the total sample) benefiting from merger gains. As mentioned on page 8, these farms can be distributed across only three cases (*a*, *b* and *c*) for the merger process. Fifty-six percent of these 370 farms simultaneously benefited from size and mix gains.

Table 10 presents the number of DMUs in the merger. Thirty-six percent of optimal mergers consist of only two farms, and 44% consist of three farms. Therefore, for 80% of farms, merging with one or two farms allows the maximum cost reduction. The reorganization of activities appears to be relatively simple for a large majority of farms.

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

To expand further, Table 12 presents the percentage of gains obtained by merging, and Fig. 2 displays the distribution of farms by the *ex post* Hamming and according to their orientation (crops, livestock and mixed units).

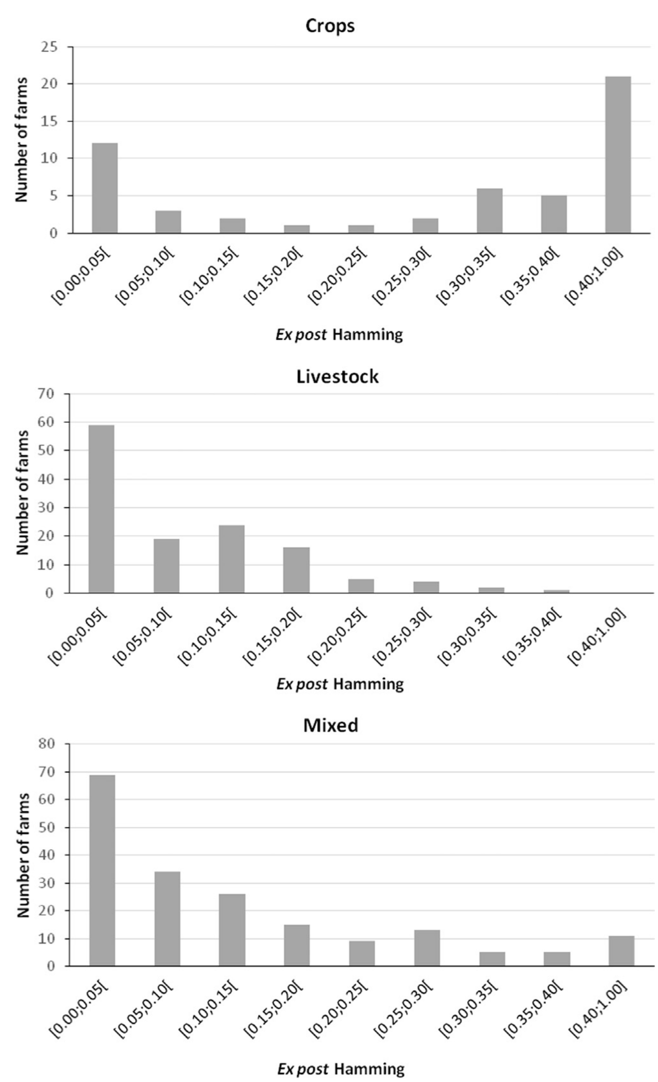

Fig. 2. Distribution of farms benefiting from merger gains by the *ex post* Hamming.

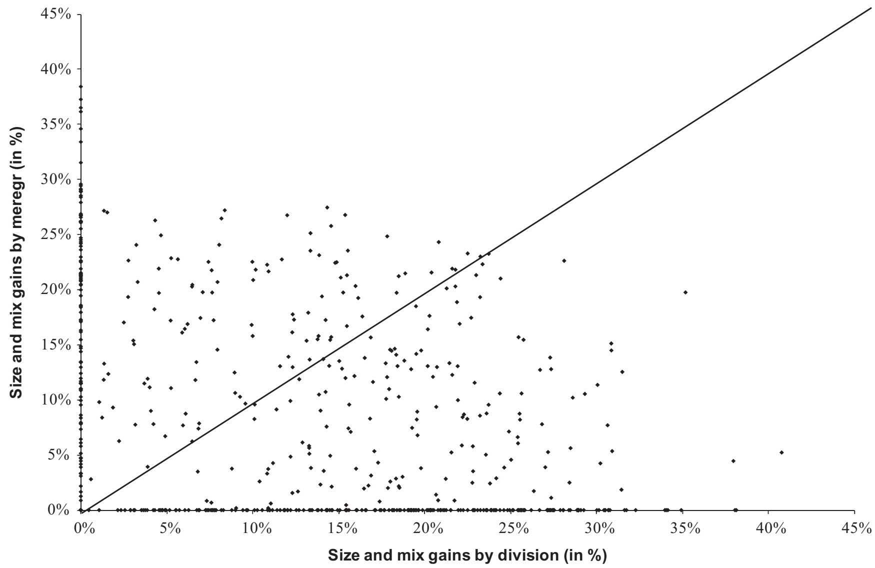

Fig. 3. Distribution of farms following size and mix gains.

Compared to Table 7, merger gains are smaller than division gains for all types of farming. Moreover, gains due to the merging process come essentially from a size effect. Mix gains appear more noteworthy for crop farms, implying a strong diversification process regarding the *ex post* Hamming distance, which denotes a change of 35% in their profile of activities.

At the sector level, after the elimination of technical inefficiency, relative to division, the merger results in less significant cost reduction, i.e., 5.26% versus 16.16%, respectively. Thus, we can conclude that potential division gains outweigh the benefits from the merger process.

In Fig. 3, all farms following size and mix gains obtained by division and merger are represented.[11] For all farms located on the horizontal or vertical axes (i.e., 57%), the choice of reorganization is unambiguous (division or merger). By contrast, for the other 264 farms (i.e., 43% of our sample) and particularly for those locating around the bisecting line, the choice of reorganization is less obvious because they can benefit from both division and merger processes.

4. Conclusion

This paper has provided new insights into the economic gains obtained from the division and merging of farms. From two mixed integer programming models, we have determined whether it is more beneficial to (i) divide a large farm into a number of smaller farms or (ii) merge smaller farms into a large farm. These programs are primarily based upon Blancard et al. [3] and Bogetoft and Wang [7].

From a sample of French farms, we demonstrated that gains can be obtained from both division and merger processes. However, the potential gains are three times as high if a division process is initiated instead of a merger. For instance, concerning the livestock farms, it is in the farms' best interest to divide rather than to merge, and their gains come primarily from the size effect. However, crop farmsare the typethat would benefit the least from division and more from a merger. To obtain maximum merger gains, a great effort in terms of mix change is needed through a diversification process. Furthermore, mixed farms should be split especially to benefit from a change in the output mix.Consistent with intuition, these results explain in part the trend toward more specialization for this type of farm.

In closing, note that our study focused on potential economic gains obtained from a reorganization but this is not sufficient to make the final leap. In the real world mergers and divisions are complex processes. We do not consider some induced costs such as transaction costs (adjustment and coordination costs), and additional costs related to resistance to change (psychological costs, loss of control of decision making, change in practices, …).

Moreover, we did not capture the other mix benefits that would lead to more diversification and thus to risk reduction. The environmental impacts of specialization and diversification processes could be considered by introducing undesirable outputs in the production technology [27,32]. Therefore, any final decision should be taken with full knowledge of these elements.

[11] As a reminder, 475 and 370 farms benefit from division and merger, respectively.

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