Productivity, efficiency and technological change in French agriculture during 2002-2014: A Färe-Primont index decomposition

L. Latruffe¹; K.H. Dakpo²; Y. Desjeux³; P. Jeanneaux⁴

1: INRA, SMART-LEREPO, France, 2: INRA, UMR Economie Publique, France, 3: INRA, UMR SMART-LEREPO, France, 4: VetAgro Sup, Territoires, France

Corresponding author email: laure.latruffe@inra.fr

Abstract:

We assess total factor productivity (TFP) change and its components technological change and efficiency change in French agriculture during 2002-2014 with a novel approach. We use the economically-ideal Färe-Primont index which allows for multi-temporal/lateral comparisons. To compare the technology gap change between six types of farming, we provide the first extension of the Färe-Primont index to the metafrontier framework. Results indicate that all types of farming farms had TFP progress. Beef farms had the highest increase in TFP change and efficiency change. The metafrontier analysis indicates that field crop farms’ technology was the most productive.

Acknowledgment:

JEL Codes: C61, D24

#1832
Productivity, efficiency and technological change in French agriculture during 2002-2014: A Färe-Primont index decomposition

Abstract

We assess total factor productivity (TFP) change and its components technological change and efficiency change in French agriculture during 2002-2014 with a novel approach. We use the economically-ideal Färe-Primont index which allows for multi-temporal/lateral comparisons. To compare the technology gap change between six types of farming, we provide the first extension of the Färe-Primont index to the meta-frontier framework. Results indicate that all types of farming farms had TFP progress. Beef farms had the highest increase in TFP change and efficiency change. The meta-frontier analysis indicates that field crop farms’ technology was the most productive.

Keywords: total factor productivity, Färe-Primont index, meta-frontier, French farms

1 Introduction

Total factor productivity (TFP) change is a crucial component of competitiveness as it reveals long term potential. In the literature, TFP change in agriculture is generally evaluated with the Malmquist index, allowing productivity growth assessment and its decomposition into two components: frontier shift or technological change; and technical efficiency change (Färe et al., 1994a, Färe et al., 1994b). Applications to the agricultural sector of the Malmquist index can be found in, e.g. Piesse et al., 1996, Fulginiti and Perrin, 1997, Mao and Koo, 1997, Lambert and Parker, 1998, Tauer, 1998, Nin et al., 2003, Umetsu et al., 2003, Zhengfei and Lansink, 2006, Yeager and Langemeier, 2011, Baležentis and Baležentis, 2016, Kunimitsu et al., 2016. Despite these numerous applications to agriculture, the Malmquist index does not verify the transitivity property (or circularity test) and can only be used for binary comparisons (O'Donnell, 2011). Though extensions have been developed to comply with this property (e.g. Berg et al. (1992), Pastor and Lovell (2005), Asmild and Tam (2007)), the Malmquist index is not multiplicatively complete and therefore cannot always be written as a ratio of aggregate output on input indexes (O'Donnell, 2012a, O'Donnell, 2012b, O'Donnell, 2012c). In addition, O'Donnell (2011) also argues that the Malmquist index ignores changes in the input/output mix.

By contrast, the Färe-Primont productivity index based on two quantity indices and proposed by Färe and Primont (1995 pp36-38), is multiplicatively complete and transitive (O'Donnell, 2011, O'Donnell, 2012b). As such the Färe-Primont index can be used for multi-lateral and multi-temporal comparisons. Few applications of this index to the agricultural sector exist in the literature despite its attractive features (e.g. Tozer and Villano (2013), Islam et al. (2014), Khan et al. (2015), Rahman and Salim (2013), Baležentis (2015), Baráth and Fertó (2016)). To the best of our knowledge, the extension of the Färe-Primont index to the meta-frontier framework has not been done yet. Here we provide this methodological extension, in light of O'Donnell and Fallah-Fini (2011).

The application of the Färe-Primont index is to French farm-level data in the period 2002-2014. Studies on TFP in French agriculture in recent period report contradictory results. During the period 2001-2007, Latruffe et al. (2012) report almost no TFP change for French dairy farms and a

---

1 The transitivity/circularity test implies that cumulative impacts over time can be assessed using yearly results: the productivity index I between t₁ and t₃ can be evaluated through t₂. More explicitly we have: I(t₂, t₃) = I(t₂, t₂) × I(t₃, t₂) (Fried et al., 2008).
technological change of +2.6%, while the figures for the cereal, oilseeds and proteinseeds farms were a TFP progress of 4.6% and a technological progress of 3.9%. The lack of TFP increase is confirmed by Boussemart et al. (2012). The authors indicate that TFP in French agriculture has grown at an annual rate of 1.44% during 1959-2011 but the annual rate was less than one (namely 0.94%) during 2003-2011, a discrepancy that the authors attribute to a lack of output progress during this last period. Similarly, for the period 1990-2006, Latruffe and Desjeux (2016) report a deterioration of TFP of about 2%, as well as slight technological regress of French farms in the field crop sector, dairy sector, and beef cattle sector. Barath and Ferto (2014) also find that TFP decreased by 2% during 2000-2010 for the whole French agricultural sector. Not focusing on TFP but using a stochastic frontier including time, Latruffe et al. (2016) indicate that French dairy farms experienced technological regress during 1990-2007. The picture is therefore gloomy for French agriculture in recent periods.

The objective of our paper is to apply for the first time to French micro-economic farm data the more rigorous Färe-Primont TFP index and providing the first extension to meta-frontier. Using data for farms that are representative of French agriculture, we aim at assessing whether the above-mentioned TFP decrease is confirmed during 2002-2014, and at shedding light on the sources of TFP change: technological change and efficiency change, the latter including technical, mix, scale and residual efficiency changes. This period of 13 years allows capturing the 2006 implementation of the decoupled Single Farm Payment (SFP) of the European Union’s (EU) Common Agricultural Policy (CAP), following the 2003 CAP Luxemburg reform. Several articles have provided evidence of a positive effect of decoupled payments on farmers’ investment decisions (e.g. Sckokai and Moro (2009), Serra et al. (2009)) and it may therefore be expected that technological progress, and hence productivity increases have followed.

Several types of farming (i.e. main farm specialisations) are considered here: field crop farms; dairy farms; beef cattle farms; pig farms and poultry farms; mixed crop and livestock farms; and sheep farms and goat farms. TFP will firstly be assessed for each type of farming, that is to say with respect to their own frontier. Secondly, TFP will be assessed with respect to a common frontier, namely a meta-frontier (Battese et al., 2004, O’Donnell et al., 2008). Comparing the results obtained with respect to the separate frontiers and those with respect to the meta-frontier will enable computing technology gap ratios that can show the most productive types of farming.

The rest of the paper is organised as follows. Section 2 presents the methodology, namely the Färe-Primont TFP index and the extension of the meta-frontier concept to this index, and describes the data. Section 3 presents the results and Section 4 concludes.

2 Methodology and data

2.1 Färe-Primont TFP index

Let’s consider a set of $n = 1, ..., N$ producers and $t = 1, ..., T$ periods of time. Each producer uses $x \in \mathbb{R}_+^k$ inputs to produce $y \in \mathbb{R}_+^q$ outputs. The benchmark technology for period $t$, whose properties have been discussed in Färe (1988), is defined as follows:

$$\Psi_t = \{(x^t, y^t) \in \mathbb{R}_+^{k+q} \mid x^t \text{ can produce } y^t\}$$  \hspace{1cm} (1)

The Shephard input ($D_t^I$) and output ($D_t^O$) distance functions can be estimated using:

$$D_t^I(x, y) = \sup_{\theta > 0} \left[\left(x^\theta, y^\theta\right) \in \Psi_t\right]$$  \hspace{1cm} (2)
TFP is the ratio of an output quantity index on an input quantity index:

$$ TFP_t = \frac{Y(y^t)}{X(x^t)} $$

where $Y(y^t)$ is the aggregate level of outputs and $X(x^t)$ is the aggregated inputs. The aggregator functions $Y(.)$ and $X(.)$ used for the Färe-Primont index are based on the distance functions in (2). For fixed reference vectors of inputs and outputs $\bar{x}, \bar{y}$ and a fixed period $\bar{t}$, TFP can be evaluated as:

$$ TFP_t = \frac{D^O_t(\bar{x}, y^t)}{D^I_t(x^t, \bar{y})} $$

From (4), the Färe-Primont TFP change index can be computed as follows:

$$ FPP_{t,t+1} = \frac{TFP_{t+1}}{TFP_t} = \frac{D^O_t(\bar{x}, y^{t+1})}{D^I_t(x^{t+1}, \bar{y})} \times \frac{D^I_t(x^t, \bar{y})}{D^O_t(\bar{x}, y^t)} $$

Practically, the reference (benchmark) input/output vectors and the fixed period are chosen to be representative of the sample under analysis.

Following O’Donnell (2008), O’Donnell (2010), the Färe-Primont TFP change index in (5) can be decomposed into technological change and several efficiency changes. Technological change (frontier shift) $(\mathcal{E})$ is evaluated at points of maximum productivity which are common each year to all observations of each period. As for efficiency change, it can be decomposed into changes of several efficiency measures:

- Technical efficiency change: this is measured with changes in output (respectively, input) technical efficiency. Technical efficiency here is the classic measure of pure technical efficiency (that is to say technical efficiency calculated under the assumption of variable returns to scale- VRS), which assesses the radial expansion (respectively, contraction) of all outputs (respectively, inputs) in order to reach the production frontier (Farrell, 1957). In other words, output technical efficiency (respectively, input technical efficiency) measures the maximum achievable TFP using the same amount of aggregated inputs (respectively, outputs) while holding input and output mixes fixed. Technical efficiency change is calculated as the geometric mean of output technical efficiency change and input technical efficiency change.

- Scale efficiency change: this is measured with changes in output (respectively, input) scale efficiency change. Scale efficiency change is computed as the ratio of the technical efficiency scores under constant returns to scale (CRS) and the technical efficiency scores under VRS. OSE therefore captures the difference between TFP at a technically efficient point and maximum TFP that is possible at the point of mix-invariant optimal scale associated to the CRS mix-invariant production frontier. Here also scale efficiency change is the geometric mean of output and input measures.

- Residual mix efficiency change: residual mix efficiency captures the difference between TFP at a point located on the CRS mix-invariant production frontier and maximum attainable productivity $(TFP^*)$.

2.2 Meta-frontier Färe-Primont index

When farms belong to a reasonable number of groups with distinct technologies, an appropriate approach for their comparison is through the estimation of a meta-technology (or meta-frontier) which
envelopes all the group technologies (Battese and Rao, 2002, Battese et al., 2004, O'Donnell et al., 2008). The difference between one group frontier and the meta-frontier is assessed through a technology gap ratio (TGR) also called the meta-technology ratio (MTR). This ratio captures the potential improvements in the group performance if all farms in this group have access to all available technologies (i.e. technologies of other groups). The latter is a fundamental assumption of the meta-frontier construction. Let \( s = 1, \ldots, S \) represents the different available technologies. The meta-technology in time \( t \) can be represented as:

\[
M_t = \Psi_t^1 \cup \Psi_t^2 \cup \ldots \cup \Psi_t^S
\]

(6)

where \( \Psi_t^s \) is the benchmark technology of each group \( s \) defined as in (1).

\[
\Psi_t^s = [(x_t^s, y_t^s) \in \mathbb{R}^{K+Q} | x_t^s \text{ can produce } y_t^s]
\]

(7)

thereby

\[
M_t = [(x_t, y_t) \in \mathbb{R}^{K+Q} | x_t \text{ can produce } y_t]
\]

(8)

\( M_t \) in (8) is defined independently of the group of each DMU. Similarly to the case of separate (group) frontiers, the meta-frontier Färe-Primont change index is computed for the global technology (the one that envelopes all the individual technologies), as follows:

\[
MFPP_{t,t+1} = \frac{MTFP_{t+1}}{MTFP_t}
\]

(9)

As discussed in O'Donnell and Fallah-Fini (2011), the TGR can be assessed by comparing the points of maximum productivity on the group frontier and on the meta-frontier. Since these points are common to all observations in each specific period, the TGR is a single common measure for all observations, assessed without imposing any restrictions on input and output levels and mixes. This single structure of the TGR makes sense since the heterogeneous technologies are defined on a qualitative basis, i.e. in each group all observations use the same technology (e.g. beef vs. crop production technology). Algebraically we have:

\[
TGR_t^s = \frac{TFP_t^{*s}}{MTFP_t^*}
\]

(10)

where \( TGR_t^s \) is the meta-technology ratio for group \( s \) in period \( t \), \( TFP_t^{*s} \) is the point of maximum productivity relative to the group \( s' \) frontier, and \( MTFP_t^* \) is the meta-frontier point of maximum productivity.

2.3 Data

We use farm-level data from the French Farm Accountancy Data Network (FADN) database. This database includes yearly accountancy data (along with some technical and economic information) for around 7,000 professional French farms with an annual rotating rate of about 10% making the sample used an unbalanced panel data sample during the period considered here, 2002-2014. The FADN database is representative of professional farms which have a total standard output above a given threshold (25,000 Euros for France) to be considered as commercial farms. Six types of farming are subject to our analysis: field crop farms; dairy farms; beef cattle farms; sheep/goat farms; pig/poultry farms; mixed farms (with crop and livestock productions). For the analysis, four inputs are used: the farm utilised agricultural area (UAA) (in hectares), the labour force (expressed in full time equivalent units, the annual working units – AWU), intermediate consumption (in constant Euros) and capital (in constant Euros). For comparison purpose (and also for an easy implementation of meta-frontier approach) only one output is used: the value of the farm total output (in constant Euros). The descriptive statistics of the final samples during the whole period are displayed in Table 1.
3 Results

Results obtained with separate frontiers per type of farming are first presented, followed by results obtained with a meta-frontier enveloping all types of farming. The results reported are change indices, where an index below 1 indicates deterioration, an index equal to 1 indicates stagnation, and an index above 1 indicates progress. Given the unbalanced structure of the panel used here, the Färe-Primont change index and its components have been computed using the geometric mean of each year as observations for the different necessary variables. For instance, the output technical efficiency in year t is the geometric mean of all observations for year t.

Table 2 reports in its top part the average Färe-Primont TFP change indices as well as the average change components between 2002 and 2014 using separate frontiers. The indices indicate that for all samples, there has been TFP growth, as all average indices are above 1. The smallest growth is recorded for pig/poultry farms (4.5%) and the largest for beef farms (19.1%). The latter are followed by field crop farms and dairy farms with similar TFP growth (16.3% and 16.1%, respectively), while the growth for mixed farms and sheep/goat farms was 10.6% and 7.4%, respectively. Technological change is positive for only three types of farming, with a considerable value of 27.7% for mixed farms, and lower values for dairy farms (12.1%) and sheep/goat farms (7.2%). By contrast, beef farms, which performed the best in terms of TFP change, experienced technological regress (-2.2%) but strong efficiency progress (+21.8%). For pig/poultry farms, technological regress is about -3.3%. Field crop farms recorded almost no technological change over the period of analysis (2002-2014). Mixed farms had a substantial decrease in technical efficiency of -13.4% which explains why their global TFP growth is medium compared to field crop farms and dairy farms. In dairy farms, not only technology progressed but efficiency as well, which is unusual. It has been documented that technological change often goes in opposite to efficiency development, as not all producers are able to adjust instantly to the new technology (Brümmer et al., 2002, Latruffe et al., 2012). This is the case for field crop farms and sheep goat farms, where either technological change or efficiency change has improved.

The further decomposition of efficiency change shows that for beef farms, the main source of efficiency growth between 2002 and 2014 is technical efficiency improvement (15.4%), although the other components of efficiency also progressed (+2.1% for scale efficiency and +3.3% for residual mix efficiency). This suggests that farmers in this sample have improved their farming practices, enabling the increase of output produced and/or the decrease of input use. The field crop farm sample is the other sample where all three efficiency components improved, in similar terms: +3.8%, +6.8% and +5.4%, for technical efficiency, scale efficiency and residual mix efficiency change, respectively. Dairy farms rather progressed in terms of technical efficiency and scale efficiency, sheep/goat farms in terms of scale efficiency, and pig/poultry farms in terms of scale efficiency but before all in terms of residual mix efficiency (+10.9%). By contrast, mixed farms experienced no progress in efficiency: they maintained their technical efficiency (the index is close to 1), but had a decrease in scale efficiency and in residual mix efficiency.

The second part of Table 2 shows the TFP change and its component for all types of farming when the meta-frontier is used. Results reveal that when all French farms are taken together (except permanent crop farms and vegetable farms which are not considered here), the agricultural sector experienced a TFP growth of 13% between 2002 and 2014, mostly due to efficiency change (+13.4%) while technology has stagnated (technological change index close to 1). The last column of Table 2 shows the technology gap ratios (TGR). The reveal that the meta-technology is mostly made of the field crop farms as they have the highest TGR, suggesting that they have access to a more productive technology than the other farming types. In fact the overall technology gap for field crop farms is almost equal to one, indicating that almost only field crop farms are on the meta-frontier. The least productive technology is the one associated to sheep/goat farms with a TGR of 0.645%, indicating
that those farms reach only 64.5% of the maximum productivity that is feasible under the meta-
technology.

Not shown on the table is the evolution of TFP change and components. Technological change was the highest for the whole French agricultural sector (under the meta-frontier) in 2010. When taking types of farming separately (own frontiers), it is also clear that the peak of technological change is within 2009-2011, while is has rather decreased during 2006-2008. This decrease had occurred after the implementation of the 2003 Luxembourg CAP reform, which saw the introduction of decoupled payments (SFP), although it could have been expected that such payments may increase technological change through investment effects, and thus productivity change. By contrast, the economic crisis in the following years seems to have forced farmers to adjust their technology.

4 Conclusion

The objective of this article was to assess productivity change in French agriculture during 2002-
2014, namely total factor productivity (TFP) change and its components technological change and efficiency change. For this, we used the economically-ideal Färe-Primont index which verifies the multiplicatively completeness property and is also transitive, allowing for multi-temporal/lateral comparisons. To compare the technology gap change between the six types of farming considered, we extended the Färe-Primont to the meta-frontier framework.

Results indicated that during 2002-2014, all types of farms had TFP progress. Pig/poultry farms had the lowest TFP increase (4.5%) while beef farms had the highest (19.1%). The latter also had the strongest increase in efficiency change (21.8%). For these farms technological progress was rather existent in the 90es due to the introduction of advanced technologies such as feed distribution equipment. Our results show that in the 2000es beef farmers managed to adjust their practices to the technologies introduced in the 90es, and became highly efficient. Pig/poultry farms had the lowest change in technical efficiency during the period. This stability may be due to the fact that such farms were not highly dependent on subsidies provided in the frame of the CAP as several studies show that technical efficiency of other types of farming (field crop, grazing livestock) is strongly influenced by CAP subsidies (see the review by Minviel and Latruffe (2016)).

When technologies are compared to each other using a meta-frontier, results indicate that field crop farms had the most productive technology. However, in future research non-agricultural goods should be accounted for when computing and comparing productivity changes across types of farming. Livestock farming and crop farming contribute to various environmental and social goods which are more and more demanded by policy makers and society (Cooper et al., 2009). Findings such as the classification of types of farms may not be the same when these goods are accounted for. (Dakpo et al., 2016) for example showed for French sheep meat farms a discrepancy in efficiency evolution depending on whether the focus was on meat or on greenhouse gases.

From a methodological point of view, the Färe-Primont index which, as aforementioned, is multiplicatively complete and satisfies the transitivity property, requires the definition of a representative observation. For our case study, we chose the average observation of the pooled sample containing all the farm types. It is worth mentioning that the decomposition of the Färe-Primont productivity index might be sensitive to this representative observation. Therefore, in further research, for robustness check a sensitivity analysis of this decomposition should be performed using different representative observations. Subsampling techniques as discussed in Simar and Wilson (2011) can certainly be helpful in dealing with this issue and at the same time deriving statistical properties (confidence intervals).
5 References


### Tables and figures

Table 1: Descriptive statistics of the French FADN samples used over the period 2002-2014

<table>
<thead>
<tr>
<th>Category</th>
<th>UAA (hectares)</th>
<th>Labour (AWU)</th>
<th>Intermediate consumption (thousand Euros)</th>
<th>Capital (thousand Euros)</th>
<th>Total output (thousand Euros)</th>
<th>Number of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Field crop farms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAA (hectares)</td>
<td>6.40</td>
<td>0.20</td>
<td>5.54</td>
<td>1.10</td>
<td>2.66</td>
<td>22,208</td>
</tr>
<tr>
<td>Max</td>
<td>705.63</td>
<td>26.45</td>
<td>682.15</td>
<td>1,304.16</td>
<td>1,674.97</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>139.27</td>
<td>1.81</td>
<td>78.71</td>
<td>137.45</td>
<td>163.72</td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td>83.88</td>
<td>1.31</td>
<td>54.61</td>
<td>125.44</td>
<td>122.88</td>
<td></td>
</tr>
<tr>
<td><strong>Dairy farms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAA (hectares)</td>
<td>10.25</td>
<td>0.95</td>
<td>5.78</td>
<td>8.31</td>
<td>10.59</td>
<td>13,316</td>
</tr>
<tr>
<td>Max</td>
<td>431.13</td>
<td>8.19</td>
<td>456.11</td>
<td>1,217.82</td>
<td>615.60</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>88.61</td>
<td>1.88</td>
<td>71.26</td>
<td>192.54</td>
<td>137.87</td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td>48.88</td>
<td>0.90</td>
<td>47.35</td>
<td>132.38</td>
<td>83.22</td>
<td></td>
</tr>
<tr>
<td><strong>Beef farms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAA (hectares)</td>
<td>16.00</td>
<td>0.78</td>
<td>3.38</td>
<td>10.16</td>
<td>4.54</td>
<td>7,341</td>
</tr>
<tr>
<td>Max</td>
<td>484.26</td>
<td>6.00</td>
<td>274.34</td>
<td>973.09</td>
<td>421.85</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>118.19</td>
<td>1.54</td>
<td>46.11</td>
<td>198.23</td>
<td>79.69</td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td>66.37</td>
<td>0.72</td>
<td>31.19</td>
<td>121.88</td>
<td>52.10</td>
<td></td>
</tr>
<tr>
<td><strong>Sheep/goat farms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAA (hectares)</td>
<td>0.50</td>
<td>0.50</td>
<td>3.63</td>
<td>4.38</td>
<td>3.41</td>
<td>3,948</td>
</tr>
<tr>
<td>Max</td>
<td>555.70</td>
<td>8.39</td>
<td>355.12</td>
<td>840.25</td>
<td>607.38</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>99.91</td>
<td>1.82</td>
<td>50.60</td>
<td>143.68</td>
<td>86.87</td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td>76.53</td>
<td>0.98</td>
<td>40.16</td>
<td>108.06</td>
<td>74.02</td>
<td></td>
</tr>
<tr>
<td><strong>Pig/poultry farms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAA (hectares)</td>
<td>0.10</td>
<td>0.50</td>
<td>5.18</td>
<td>1.12</td>
<td>14.18</td>
<td>2,639</td>
</tr>
<tr>
<td>Max</td>
<td>299.40</td>
<td>12.00</td>
<td>2,356.71</td>
<td>2,667.01</td>
<td>2,217.74</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>54.84</td>
<td>2.10</td>
<td>230.35</td>
<td>191.35</td>
<td>340.86</td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td>43.36</td>
<td>1.32</td>
<td>228.25</td>
<td>205.09</td>
<td>301.16</td>
<td></td>
</tr>
<tr>
<td><strong>Mixed farms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAA (hectares)</td>
<td>22.00</td>
<td>0.60</td>
<td>8.35</td>
<td>2.15</td>
<td>7.49</td>
<td>7,623</td>
</tr>
<tr>
<td>Max</td>
<td>737.76</td>
<td>10.52</td>
<td>650.57</td>
<td>1,374.09</td>
<td>1,196.53</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>154.52</td>
<td>2.22</td>
<td>107.46</td>
<td>247.74</td>
<td>199.76</td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td>92.40</td>
<td>1.15</td>
<td>70.98</td>
<td>166.76</td>
<td>131.72</td>
<td></td>
</tr>
<tr>
<td><strong>All types of farming together</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAA (hectares)</td>
<td>0.1</td>
<td>0.2</td>
<td>3.38</td>
<td>1.10</td>
<td>2.66</td>
<td>57,075</td>
</tr>
<tr>
<td>Max</td>
<td>737.80</td>
<td>26.45</td>
<td>2,356.71</td>
<td>2,667.01</td>
<td>2,217.74</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>120.2</td>
<td>1.86</td>
<td>81.68</td>
<td>175.77</td>
<td>154.57</td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td>79.07</td>
<td>1.14</td>
<td>79.81</td>
<td>141.64</td>
<td>133.20</td>
<td></td>
</tr>
</tbody>
</table>

Source: the authors, based on the French FADN data.
Table 2: Average TFP change and components, and technology gap ratios, for the French FADN farms the period 2002-2014

<table>
<thead>
<tr>
<th>Type of farming</th>
<th>TFP change</th>
<th>Technological change</th>
<th>Efficiency change</th>
<th>Technical efficiency change</th>
<th>Scale efficiency change</th>
<th>Residual mix efficiency change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field crop farms</td>
<td>1.163</td>
<td>0.996</td>
<td>1.168</td>
<td>1.038</td>
<td>1.068</td>
<td>1.054</td>
</tr>
<tr>
<td>Dairy farms</td>
<td>1.161</td>
<td>1.121</td>
<td>1.035</td>
<td>1.025</td>
<td>1.022</td>
<td>0.988</td>
</tr>
<tr>
<td>Beef farms</td>
<td>1.191</td>
<td>0.978</td>
<td>1.218</td>
<td>1.154</td>
<td>1.021</td>
<td>1.033</td>
</tr>
<tr>
<td>Sheep/goat farms</td>
<td>1.074</td>
<td>1.072</td>
<td>1.002</td>
<td>0.962</td>
<td>1.042</td>
<td>0.999</td>
</tr>
<tr>
<td>Pig/poultry farms</td>
<td>1.045</td>
<td>0.967</td>
<td>1.081</td>
<td>0.944</td>
<td>1.032</td>
<td>1.109</td>
</tr>
<tr>
<td>Mixed farms</td>
<td>1.106</td>
<td>1.277</td>
<td>0.866</td>
<td>0.994</td>
<td>0.940</td>
<td>0.927</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of farming</th>
<th>TFP change</th>
<th>Technological change</th>
<th>Efficiency change</th>
<th>Technical efficiency change</th>
<th>Scale efficiency change</th>
<th>Residual mix efficiency change</th>
<th>Technology gap ratio (TGR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All types of farming</td>
<td>1.130</td>
<td>0.996</td>
<td>1.134</td>
<td>1.020</td>
<td>1.066</td>
<td>1.043</td>
<td>0.999</td>
</tr>
<tr>
<td>Field crop farms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.738</td>
</tr>
<tr>
<td>Dairy farms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.681</td>
</tr>
<tr>
<td>Beef farms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.645</td>
</tr>
<tr>
<td>Sheep/goat farms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.828</td>
</tr>
<tr>
<td>Pig/poultry farms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.834</td>
</tr>
<tr>
<td>Mixed farms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: TFP change is decomposed into technological change (TC) and efficiency change (EC). Efficiency change is then decomposed into technical efficiency change, scale efficiency change and residual mix efficiency change. Technology gap ratio (TGR) is calculated with the group (type of farming) own frontier and the meta-frontier.

Source: the authors, based on the French FADN data and using R software.