Technical Change *vs* Efficiency Change: Performance of Food Industries over Time

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Introduction

Question: What are the respective contributions of technical change and efficiency change in the evolution of the TFP of an industry ?

Usual approach:

1. Specifying a distance function: $D_O(x, y) = \min\{\theta | (x, y/\theta) \in$ **Production set**$\}$ with $x \in R^p_+$ (inputs), and $y \in R^q_+$ (outputs)
2. Computing **Malmquist indices** to assess the relative weights of efficiency change and technical change in productivity growth from the base period **b** to the current period **c**.
3. Implementing the two previous steps using **DEA scores**.

Problem: Definition of the production set of the current period ?

This procedure is generally implemented using the following production sets:

1. Contemporaneous production set:

$$T_c^{Con} = \left\{ (x, y) \mid y \leq \sum_i z_{ic} Y_{ic},\ x \geq \sum_i z_{ic} X_{ic},\ \text{all } z_{ic} \geq 0 \right\}$$

2. Using sequential production set à la Diewert (1980):

$$T_c^{Seq} = \left\{ (x, y) \mid y \leq \sum_{\tau=b}^{c} \sum_i z_{i\tau} Y_{i\tau},\ x \geq \sum_{\tau=b}^{c} \sum_i z_{i\tau} X_{i\tau},\ \text{all } z_{i\tau} \geq 0 \right\}$$

3. Implementing window DEA:

$$T_c^{Win} = \left\{ (x, y) \mid y \leq \sum_{\tau=c-w}^{c+w} \sum_i z_{i\tau} Y_{i\tau},\ x \geq \sum_{\tau=c-w}^{c+w} \sum_i z_{i\tau} X_{i\tau},\ \text{all } z_{i\tau} \geq 0 \right\}$$

Limits:

1. Contemporaneous: Generally, b and c consecutive periods
2. Sequential: Implicit assumption of technical progress
3. Window DEA: Ambiguous treatment of technical change ($c - w \leq b \leq c + w$?).

Aim of the paper: To propose an iterative procedure for testing periods of technical progress and periods of technical regress.

Related literature:

1. Tulkens, H. and P. Vanden Eeckaut (1995) → General discussion on technical progress/regress.
2. O'Donnell *et al.* (2009) → Metafrontier analysis

Methodology

Testing procedure: Based on an **iterative procedure**, i.e. for $t = 0, ..., T$ where $T \equiv c - b$,

(a) Compute the efficiency scores of firms present the current year c using

(b) The Forward Increasing Production Set:

$$T_c^{FIPS} = \left\{ (x, y) \mid y \leq \sum_{\tau=b}^{b+t} \sum_i z_{i\tau} Y_{i\tau},\ x \geq \sum_{\tau=b}^{b+t} \sum_i z_{i\tau} X_{i\tau},\ \text{all } z_{i\tau} \geq 0 \right\}$$

(c) Or the Backward Increasing Production Set

$$T_c^{BIPS} = \left\{ (x, y) \mid y \leq \sum_{\tau=c-t}^{c} \sum_i z_{i\tau} Y_{i\tau},\ x \geq \sum_{\tau=c-t}^{c} \sum_i z_{i\tau} X_{i\tau},\ \text{all } z_{i\tau} \geq 0 \right\}$$

(d) Test the equality of each pair of two consecutive efficiency distributions.

(e) If equality rejected → Detection of technical regress or progress.

(f) Regress or progress ? : see the following example.

How to identify "technical regress"? A simulation exercise.

Generation of a dataset of $N = 100$ firms with one input and one output for 3 different years using:

$$y_t = x^{0.5} \times \exp\{-0.25 \times (t-1)\} / (1 + u_t)$$

with $x_t \sim U[0, 1]$ and $u_t \sim \mathcal{N}^+(0.2, 0.25)$ as illustrated in Figure 1.

Figure 1 : Simulating technical regress over time

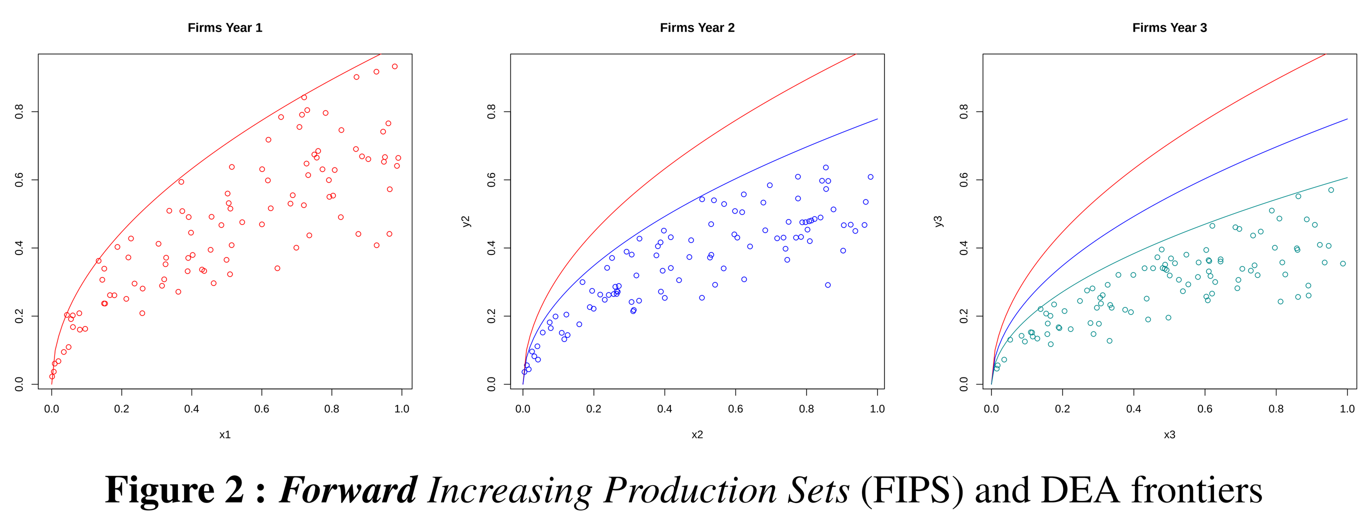


Figure 2 : ***Forward*** *Increasing Production Sets* (FIPS) and DEA frontiers in the case of technical regress.

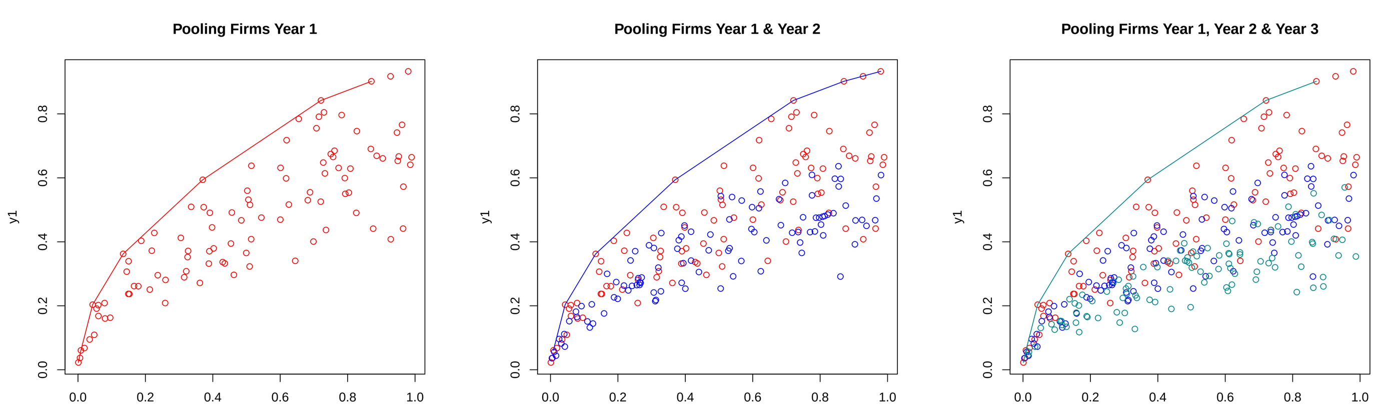
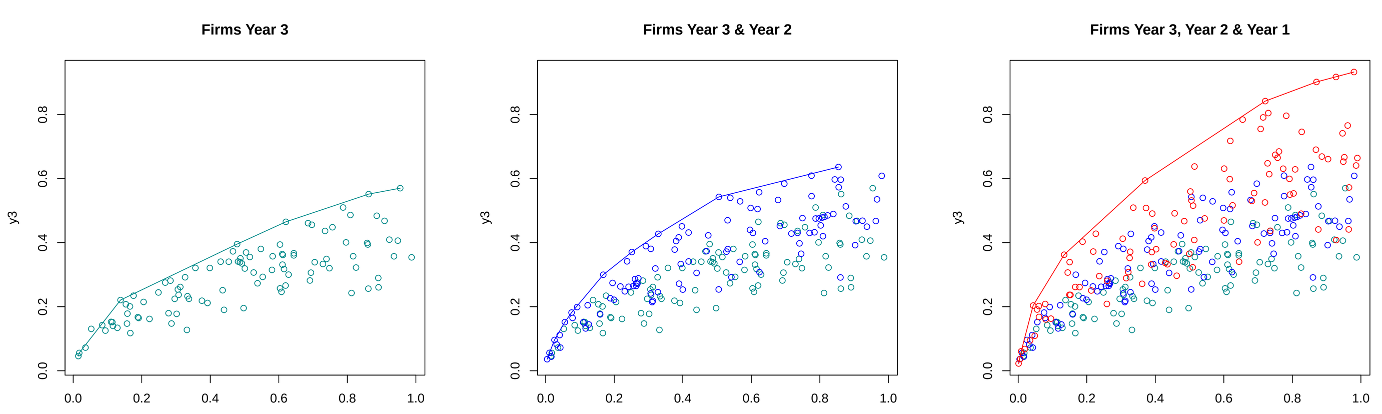


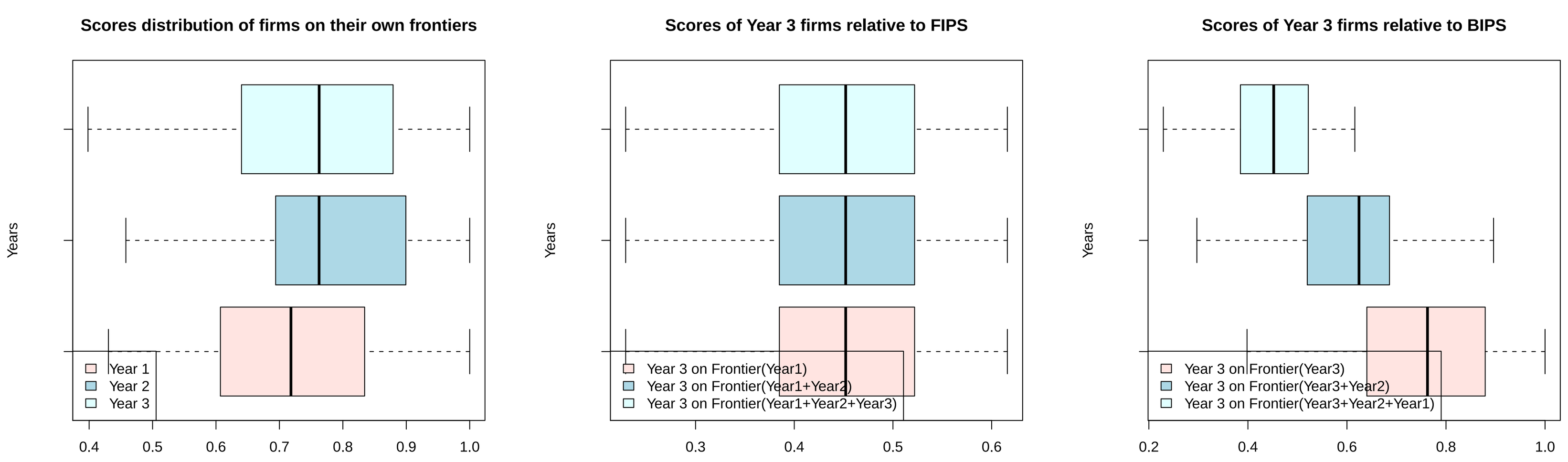
Figure 3 : ***Backward*** *Increasing Production Sets* (BIPS) and DEA frontiers in the case of technical regress.



Figures **2** and **3** illustrates how the methodology works. Each figure provides the sample of observation used in order to estimate the production frontier and its DEA estimates. These estimates do not shift when using FIPS while they shift up with BIPS.

Figure **4** reports the efficiency distributions. With the FIPS (Figure 4b), the efficiency scores do not change with the pooling, while with the BIPS (Figure 4c) the efficiency scores decrease when pooling backward annual observations. This pattern clearly reveals the presence of technical regress over the 3 years. The same simulation exercice, but with technical progress, emphasizes a symmetric pattern of FIPS and BIPS efficiency distributions.

Figure 4 : Distribution of DEA based efficiency scores :
(a) of firms each year on their contaporaneous frontiers; (b) of firms in Year 3 on FIPS frontiers; (c) of firms in Year 3 on BIPS frontiers



Application to French Food Industries (1996-2006)

Data

We use data from an accounting survey (Enquête Annuelle d'Entreprise) which provides the following information at the firm level: Production in value (Y), Stock of Capital (K), Labor (L) both in volume (number of employees) and value, and Materials expenditures (M) in value. We use annual data over the 1996-2006 period. Firms are classified with respect to their main production, using a 4-digit classification level (41 food industries). Values are converted in volume using appropriate price indices obtained from the French National Statistical Institute. We consider the value of production excluding trade activities. Materials expenditures are net of stock variation. Finally, the stock of capital is estimated at constant prices rather than historical prices. In this paper, we select two food industries (chicken meat industry and cheese industry) based on the number of firms (about 200 firms in each industry) and their economic importance (respectively 5 and 8% of total food industry production).

Results

We perform FIPS and BIPS computation using data on cheese and chicken meat industries over the period [1996, 2006]. We then estimate DEA frontiers on these production sets and compute the efficiency scores of 2006 firms data relative to those frontiers (Figure **5** and **6**).

Figure 5 : Distribution of DEA based efficiency scores for the Cheese industry :
a) Firms in 2006 on FIPS frontiers; b) Firms in 2006 on BIPS frontiers

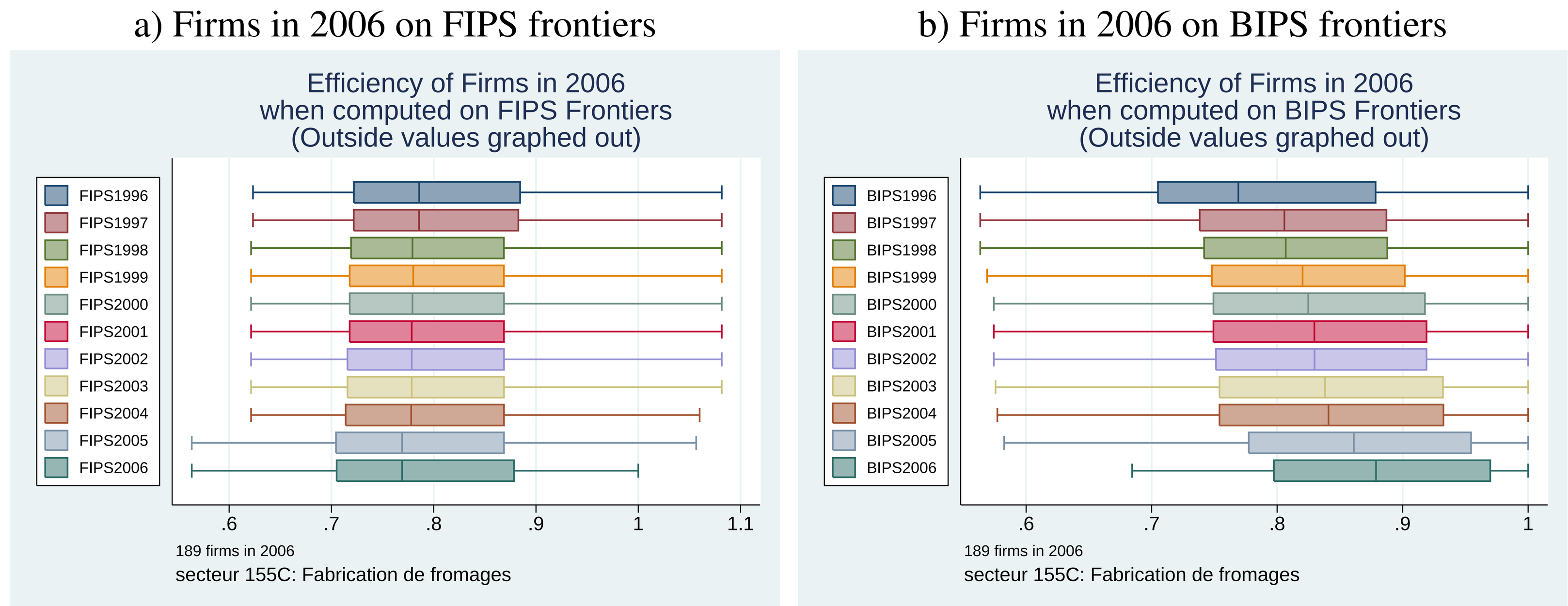
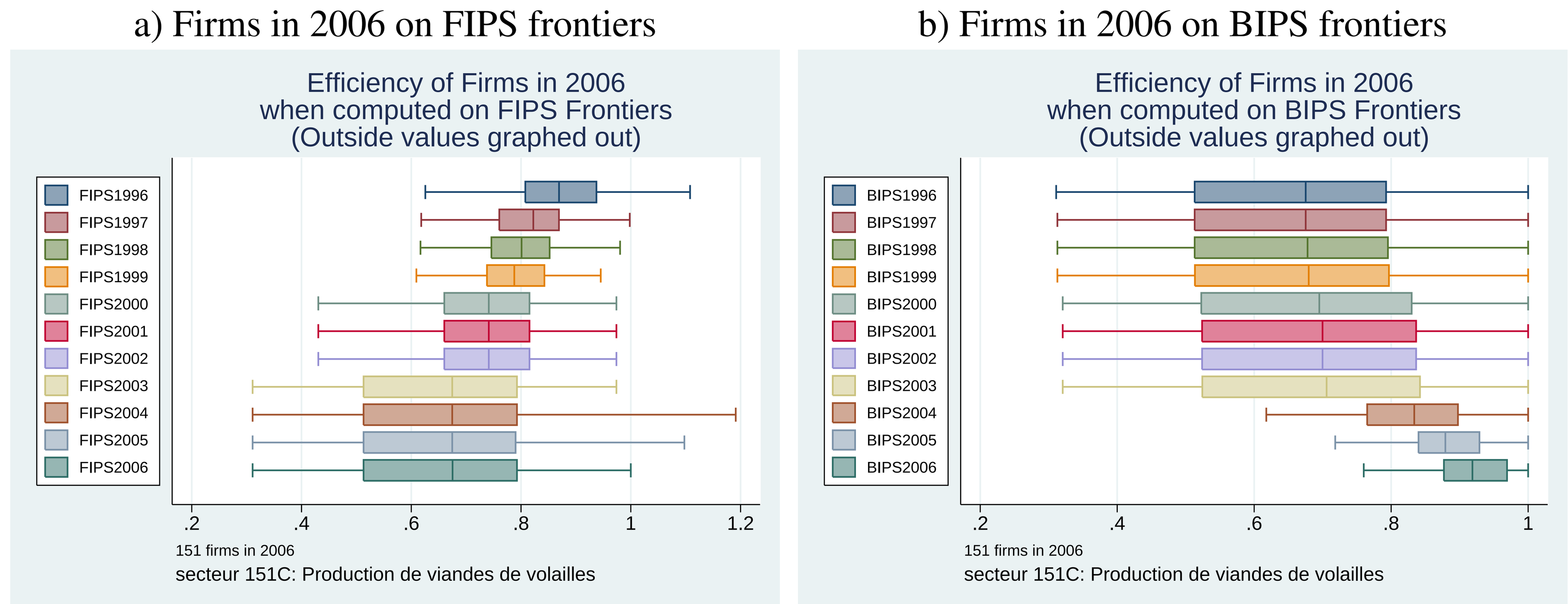


Figure 6 : Distribution of DEA based efficiency scores for the Chicken Meat Industry :
a) Firms in 2006 on FIPS frontiers; b) Firms in 2006 on BIPS frontiers



Results from the visual inspection of the evolution of efficiency score distribution can be confirmed using tests of equality of densities (Li, Maasoumi & Racine, 2009).

Table 1 : Test of equality of consecutive efficiency distribution distribution (Chicken meat)

FIPS		BIPS	
Null Hypothesis	Test (T_n *Value*)	Null Hypothesis	Test (T_n *Value*)
...	...	...	...
$H_0 : \Phi^F_{2001} = \Phi^F_{2000}$	**Not Rejected** (-0.581)	$H_0 : \Phi^B_{2002} = \Phi^B_{2001}$	**Not Rejected** (-2.105)
$H_0 : \Phi^F_{2002} = \Phi^F_{2001}$	**Not Rejected** (-0.403)	$H_0 : \Phi^B_{2002} = \Phi^B_{2001}$	**Not Rejected** (-2.435)
$H_0 : \Phi^F_{2003} = \Phi^F_{2002}$	**Reject** (4.838)	$H_0 : \Phi^B_{2003} = \Phi_{2002}$	**Not Rejected** (-2.235)
$H_0 : \Phi^F_{2004} = \Phi^F_{2003}$	**Not Rejected** -3.022)	$H_0 : \Phi^B_{2004} = \Phi^B_{2003}$	**Reject** (14.161)
$H_0 : \Phi^F_{2005} = \Phi^F_{2004}$	**Not Rejected** (-1.166)	$H_0 : \Phi^B_{2005} = \Phi^B_{2004}$	**Reject** (9.027)
$H_0 : \Phi^F_{2006} = \Phi^F_{2005}$	**Not Rejected** (-3.225)	$H_0 : \Phi^B_{2006} = \Phi^B_{2005}$	**Reject** (5.12)

Conclusion

The distributions show that the cheese industry seemed to have experienced technical regress over the whole period (Figure **5**). Thus, the distribution of efficiency scores under the FIPS procedure does not significantly change over the period while it changes when using the BIPS procedure. On the chicken meat industry, we observe a period of technical progress from 1996 to 2002 and technical regress from 2003 to 2006 (Figure **6**). The consecutive distribution tests performed on the FIPS and BIPS for the Chicken meat industry (Table **1**) confirm a clear-cut technical regress pattern on the period [2003-2006]. Technical regress might be a consequence of higher constraints exerted on the industry such as environmental or sanitary constraints that might have increased the cost of production over time.

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