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Efficiency and Technological Progress in Brazilian Agricultural Cooperatives

Neves, Mateus de Carvalho Reis (1); Gonçalves, Marcos Falcão (1,2); Gomes, Adriano Provezano (1); Braga, Marcelo José (1)

1: Federal University of Viçosa, Brazil; 2: Banco do Nordeste do Brasil BNB

Against a background of concentrated production chains and profound changes in the agri-food system, Brazilian agricultural cooperatives are challenged to remain competitive to withstand large multinational companies. This paper proposed to investigate nuances in the behavior of these cooperative organizations due to the changes in their operating environment. It does so by analyzing alterations in efficiency and total factor productivity of a sample of Brazilian agricultural cooperatives, classified according to size, from 2006 to 2010. For this, non-parametric models of Data Envelopment Analysis (DEA) and the Malmquist Index were used. Through the DEA approach, it was seen that larger cooperatives faced decreasing efficiency, while smaller ones experienced the opposite. Moreover, as demonstrated by the Malmquist Indices, the cooperatives, on average, presented negative technological variations, and smaller cooperatives underwent positive changes in technical efficiency. The results suggest directions which public policies could take to strengthen Brazilian agricultural cooperatives in the face of new challenges.



1. Introduction

Changes forced on the food system as a result of its becoming demand-oriented, undoubtedly require and impose new management logic (PRESNO, 2001). Furthermore, the concentration of production, distribution chains and global trade liberalization have spotlighted certain sectors of agribusiness (GOMEZ, 2006). In this context, cooperatives are particularly relevant in that they play the vital role of coordinating farming activities as well as trying to eliminate superfluous intermediaries (PERROT *et al.*, 2001).

Agricultural cooperatives currently face the serious challenge of continuing to be competitive, while seeking to operate in international or domestic markets, and almost constantly compete with large multinational companies. Simultaneously they must remain faithful to cooperative principles, satisfy the needs of cooperative members, and maintain adequate levels of quality and efficiency through investment in technology and productivity. These factors and others have led to changes both in the organization and functioning of cooperative agricultural systems of production and marketing. Some authors have used the term “entrepreneurial revolution” to describe such transformation (NILSSON *et al.*, 1997; PRESNO, 2001).

In recent years studies have addressed the process of adaptation of agricultural cooperatives. In this regard, the analysis of productivity and its essential components (efficiency and technological changes) is an invaluable tool for describing this movement and has been used by numerous authors, such as Ferrier, Porter (1991); Ariyaratne *et al.* (1997); Damas, Romero (1997); Hughes (1998); Reinhard *et al.* (2000); Vidal *et al.* (2000); Kawamura (2000); Montegut *et al.* (2002); Kondo, Yamamoto (2002); Tupy *et al.* (2004); Ferreira (2005); Gómez (2006); Ferreira, Braga (2007), with a view to measuring the sustainability of cooperative enterprises facing this increasingly competitive scenario.

This paper set out to analyze the efficiency and changes in total productivity of 40 Brazilian agricultural cooperatives, spread over the states of Minas Gerais, Paraná, Rio Grande do Sul, Santa Catarina and São Paulo, by using the data envelopment analysis model (DEA), and the nonparametric product-oriented Malmquist indices in an effort to identify what caused such changes. In this regard, changes in the productivity of cooperatives can be taken as an important indicator of the adjustment of such organizations to market conditions.



In addition to the introduction, this study also consists of a literature review on the theme under review, followed by a section explaining the methodology. The results are then presented and the study finishes with closing remarks.

2. Literature Review

The increasingly competitive environment in which agricultural cooperatives are rooted calls for constant adjustment. In order to maintain their market position and the sustainability of their activities, they must seek innovation and greater productivity (GOMÉZ, 2006). The process of adaptation of agricultural cooperatives to new market conditions is common to many countries. It can be seen in European countries and also in countries such as USA, Canada, Japan, Australia and New Zealand (MÉNARD; KEIN, 2004).

In Brazilian agriculture, in particular, and also in Europe, although the pace of change in the economy exceeds the capacity of cooperatives to respond, they tend to become providers of some of the elements necessary for competitiveness, and adapt agricultural activity in these regions to the modern agri-food market (NILSSON *et al.*, 1997; NEVES; BRAGA, 2013).

According to data from the Organization of Brazilian Cooperatives - OCB (2011), agricultural cooperatives are part of one of the most representative branches of the cooperative movement in Brazil, with a total of 23% of all active cooperatives, and generate most employment. They allow for more organized rural production, which brings professionalization to the countryside and minimizes the role of the middleman. In addition in 2009, according to the OCB, agricultural cooperatives accounted for 38.4% of Agricultural Gross Domestic Product (GDP) and generated US\$ 4 billion in direct exports.

Ferreira (2002) notes that in several Brazilian regions, agricultural cooperatives are the only means that associates have for adding value to their production, and they facilitate the participation of small and medium producers in concentrated markets. The tendency towards less intervention and greater decentralization of market regulation is due, in large part, to these organizations.

Moreover, cooperatives end up facing the burden of crop failures, low commodity prices and other unforeseen occurrences, especially when the financing of supplies and production tools for the members involves the cooperative. So, while they make production



and commercialization viable for their members, cooperatives in a way, assume the activity risks of their members (FERREIRA, 2002).

Productivity and efficiency indicators are useful tools for studying strategic change. The coordination and management of the members' production are motivated primarily by productivity gains (GOMÉZ, 2006). Many studies have focused on these issues for agricultural cooperatives in different countries: Ferrier, Porter (1991), and Ariyaratne *et al.* (1997), in the United States; Sueyoshi *et al.* (1998), Kawamura (2000), and Kondo, Yamamoto (2002), in Japan; Segura, Vidal (2002), Sabaté (2002) and Gómez (2006), in Spain; Tupy *et al.* (2004), Ferreira (2005) and Ferreira *et al.* (2007), in Brazil.

This research on the analysis of efficiency and productivity changes in cooperatives adds to such studies, while featuring the latest trends in Brazilian agricultural cooperatives.

3. Methodology

3.1. Data Envelopment Analysis – DEA

Charnes *et al.* (1978) were the first to design the Data Envelopment Analysis model (DEA), as an extension of the model presented by Farrell (1957). In conceptual terms Ferreira and Gomes (2009) consider it to be a non-parametric approach to analyzing the efficiency of firms with multiple supplies and products.

3.1.1. Constant Returns to Scale

The seminal work of Farrell (1957) was innovative in that it proposed a model to measure efficiency without using a theoretically defined production function: from then on it would be possible to calculate efficiencies on the basis of empirical data, which would serve as a basis for building hypothetical observation units, which are considered efficient. Such innovation made it possible to conceptualize technical efficiency as maximum radial equiproportional reduction of all inputs while maintaining output constant¹. Figure 1 shows the concept of technical efficiency proposed by Farrell (1957).

¹ Farrell (1957) considered input orientation in his study. He proposed a way of minimizing input usage, while keeping the product constant.



When considering a firm which uses two inputs to produce a single product and assuming constant returns to scale, the OP curve in Figure 1 represents the number of inputs per unit of output. The various combinations of these two inputs which a firm should use to efficiently produce one single product are represented in the isoquant SS' .

[Figure 1]

A firm represented by Q could be considered more efficient than a P firm, since both have the same output, but the former uses only a fraction of the inputs used by the latter. Thus, the OQ/OP ratio could be defined as the technical efficiency of firm P . Based on knowledge of input prices, represented by line segment AA' , the allocative efficiency² can be measured by means of the ratio OR/OQ . Economic efficiency can be found through a combination of both, as shown in (1):

$$\text{Economic efficiency}_{IN} = \frac{OQ}{OP} \times \frac{OR}{OQ} = \frac{OR}{OP} \quad (1)$$

Alternatively, the problem above can be considered, *ceteris paribus*, taking product orientation, that is, starting from a fixed portion of inputs, in which such resources are optimized, and the maximum output is obtained, as shown in Figure 2.

When analyzed from this aspect, considering ZZ' the curve of production possibility and DD' isoincome, technical efficiency is described by ratio OA/OB , while allocative efficiency can be found by ratio OB/OC . Analogous to input orientation, economic efficiency can be achieved by equation (2):

$$\text{Economic efficiency}_{OUT} = \frac{OA}{OB} \times \frac{OB}{OC} = \frac{OA}{OC} \quad (2)$$

[Figure 2]

²Here the definition of Coelli *et al.* (1998) is used. It considers efficiency to be the ability of a production unit to obtain the maximum level of output, with a given set of inputs or, from a given level of output, to be able to produce with the lowest combination of inputs; while allocative efficiency indicates the ability of a plant to use inputs in optimal proportions, given their respective prices and obtain a certain level of output at the lowest cost or, for a given level of cost, to get the maximum amount of products.



Charnes *et al.* (1978) generalized the Farrell model (1957) for multiple inputs and products, given constant returns to scale. Decision units were called “DMU” (decision making units) in order to emphasize that the interest of the authors is to assist in the decision making process of nonprofit organizations, and not firms or industries.

The model proposed by Charnes *et al.* (1978) consists of solving a linear programming problem, which maximizes the efficiency of each DMU, subject to the restriction that no other DMU has an efficiency score greater than unity. With the aim of minimizing the virtual input (product orientation), in which the virtual production cannot exceed the virtual inputs in any DMU, we arrive at the following problem of input minimization:

$$\min h_0 = \frac{\sum_{i=1}^m v_i x_{i0}}{\sum_{r=1}^s u_r y_{r0}} \quad (3)$$

s.t.:

$$\frac{\sum_{i=1}^m v_i x_{ij}}{\sum_{r=1}^s u_r y_{rj}} \geq 1 ; \quad j = 1, \dots, n$$

$$u_r, v_i \geq 0; \quad r = 1, \dots, s; \quad i = 1, \dots, m$$

where:

y_{rj} : are the known outputs used by DMU j (non-negative);

x_{ij} : are the known inputs used by DMU j (non-negative);

u_r and v_i : are the weights associated with product and input, respectively, which are determined by the solution of the problem.;

n : number of DMUs;

m : number of inputs;

s : number of outputs.

The subscript 0 in the objective function serves to demonstrate that efficiency is always relative, that is, the efficiency of a DMU is always computed as a function of the others. It can be seen that this is an infinite solutions model.

The problem proposed by Charnes *et al.* (1978) can be linearized (multiplier method) as adapted by Ferreira, Gomes (2009):



$$\min h_0 = \sum_{r=1}^s v_i x_{i0} \quad (4)$$

s.t.:

$$\sum_{r=1}^s u_r y_{rj} - \sum_{i=1}^m v_i x_{ij} \leq 0; j = 1, \dots, n$$

$$u_r y_{rj} = 1$$

$$u_r, v_i \geq 0; \quad r = 1, \dots, s; \quad i = 1, \dots, m$$

The linear programming problem presented in (4) can also be solved in its dual form (envelopment model), as suggested by Ferreira, Gomes (2009). According to Coelli *et al.* (1998), the (dual) model involves fewer restrictions than the primal. In the presence of $(k + m)$ variables in the primal model, the dual will have $(k + m)$ restrictions, less than the $(n + 1)$ restrictions of the primal model:

$$\max_{\phi, \lambda} \phi \quad (5)$$

s.t.:

$$-\phi y_{rj} + \sum_{r=1}^s y_{rj} \lambda_{rj} \geq 0 \quad j = 1, \dots, n$$

$$x_{ij} + \sum_{i=1}^m x_{ij} \lambda_{ij} \geq 0 \quad r = 1, \dots, s; \quad i = 1, \dots, m$$

$$\lambda \geq 0$$

where:

ϕ scale, whose value provides the inverse measure of efficiency of the DMU j ;

λ is a column vector $(n \times 1)$, whose values are calculated to obtain the optimal solution.

That is, the values obtained in λ are the weights used in the linear combination of other efficient DMUs (benchmarks for the DMU evaluated), which influence the projection of the inefficient DMU on the calculated frontier, thus providing its virtual DMU. For $\lambda = 0$, the DMU under study is efficient.

Efficiency value is given by:

$$\theta = \frac{1}{\phi} \quad (6)$$



While the final value related to the projected DMU can be found by:

$$x_{ij} = x_{i(j-1)}\lambda_{i(j-1)} + x_{i(j+1)}\lambda_{i(j+1)} \quad (7)$$

Or by:

$$x_{ij} = \theta x_{ij} \quad (8)$$

where:

$x_{i(j-1)}$ and $x_{i(j+1)}$ represent the input of the DMUs which serve as benchmarks, anterior and posterior, respectively, to that analyzed;

$\lambda_{i(j-1)}$ and $\lambda_{i(j+1)}$ represent the weight obtained for the DMUs which serve as benchmarks, anterior and posterior, respectively, to that analyzed.

Ferreira, Gomes (2009) warn of the possibility of slacks, a situation where the calculated efficiency score is located on that part of the frontier parallel to the corresponding axis (input or output). This situation supports the inference that, despite the fact that the value of λ projects the DMU analyzed to the efficient frontier, the projected point still has some inefficiency. On considering input, it would be the case where the DMU could reduce the amount of a certain input and still produce the same amount of product. Or analogously for product, it would be able to increase it without needing to increase the use of one or more inputs.

To identify and solve problems related to slacks, authors such as Ali, Seiford (1993) and Cooper *et al.* (2000) suggested a two-stage method. After measuring efficiency scores in the first stage, all possible slacks are found in the second stage:

$$\min_{\lambda, O_r, I_i} -(M'_1 O_r + K'_1 I_i) \quad (9)$$

s.t.:

$$\begin{aligned} -y_{rj} + (\sum_{r=1}^s y_{rj})\lambda - O_r &= 0, & j &= 1, \dots, n & r &= 1, \dots, s; \\ \theta x_{ij} + (\sum_{i=1}^m x_{ij})\lambda - I_i &= 0, & i &= 1, \dots, m \\ \lambda &\geq 0; O_r \geq 0; I_i \geq 0 \end{aligned}$$



where:

O_r corresponds to the slack related to output r ;

I_i corresponds to the slack related to input i .

Thus, the value of the projected DMU can be found:

$$x_i = \theta x_i - I_i \quad (10)$$

Alternatively, one could insert the second stage into the first:

$$\min_{\theta, \lambda, O_S, I_S} \theta \quad (11)$$

s.t.:

$$\begin{aligned} -y_{rj} + (\sum_{r=1}^s y_{rj})\lambda - O_r &= 0, & j &= 1, \dots, n & r &= 1, \dots, s \\ \theta x_{ij} + (\sum_{i=1}^m x_{ij})\lambda - I_i &= 0, & i &= 1, \dots, m \\ \lambda &\geq 0; O_r \geq 0; I_i \geq 0 \end{aligned}$$

3.1.2. Variable Returns to Scale

Banker *et al.* (1984) extends the results proposed by Charnes *et al.* (1978) when they determine the region in which the DMU analyzed is found within the context of the others, that is, it is possible to determine whether the DMU operates with increasing, decreasing or constant returns to scale.

To achieve this, Banker *et al.* (1984) add a convexity restriction, as shown in (12), so that a convex surface of intersecting planes is formed, which is more compact than the surface with constant returns, represented in Figure 3:

$$\sum_{i=1}^n \lambda_i = N_i' \lambda_i = 1 \quad (12)$$

where N_i' is a vector ($n \times 1$) of unitary values.

[Figure 3]

Given the output-oriented envelopment method, equation (5) can now be rewritten considering variable returns to scale:

$$\begin{aligned}
 & \max_{\phi, \lambda} \phi & (13) \\
 \text{s.t.:} & \\
 & -\phi y_{rj} + \sum_{r=1}^s y_{rj} \lambda_{rj} \geq 0 & j = 1, \dots, n \\
 & x_{ij} + \sum_{i=1}^m x_{ij} \lambda_{ij} \geq 0 & r = 1, \dots, s; \quad i = 1, \dots, m \\
 & N'_i \lambda_i = 1 \\
 & \lambda \geq 0
 \end{aligned}$$

In the event that the DMU analyzed offers variable returns to scale, it is still necessary to identify the region in which it lies, if it is that of increasing or of decreasing returns. For this, the equality on the third restriction in (13) can be transformed into inequality. Thus, making $N'_i \lambda_i \geq 1$ imposes a non-decreasing (increasing) return restriction, while $N'_i \lambda_i \leq 1$ imposes a non-increasing (decreasing) return restriction. The result of the efficiency of one or other should be compared with that found for the variable return (VR). Thus, on opting to calculate only the technical efficiency for the non-decreasing return (NDR), there are two possibilities:

$$ET_{NDR} = ET_{VR} \rightarrow \text{increasing returns}$$

$$ET_{RNR} \neq ET_{VR} \rightarrow \text{decreasing returns}$$

3.2. Malmquist Index

In addition, it might be relevant to assess the occurrence of the efficiency variation in the set of DMUs analyzed. The Malmquist Index is a tool which fills this gap, by measuring variation in efficiency, either through change in efficiency (pairing effect) or through technology (displacement effect of the frontier).

The pairing effect can be deduced by calculating the ratio between the distances of two production points of the same unit, in distinct periods, to the frontier constructed. From this perspective the distance from the production point in period $t + 1$ to the frontier in period



t is calculated, and then the distance from the production point in period t to the frontier of period t .

Caves *et al.* (1982) suggest that the Malmquist Index, at moment t , can be defined as:

$$M_0^t = \frac{\theta_0^t(X^{t+1}, Y^{t+1})}{\theta_0^t(X^t, Y^t)} \quad (14)$$

which can be interpreted as:

- i) $M_0^t > 1$: improved efficiency between periods t and $t + 1$;
- ii) $M_0^t = 1$: efficiency between periods t and $t + 1$ remained constant;
- iii) $M_0^t < 1$: reduced efficiency between periods t and $t + 1$.

Similarly, the Malmquist Index can be found at time $t + 1$, from the distance of the point of production for the period $t + 1$ to the frontier in period $t + 1$, and the distance from the point of production in period t to the frontier of period $t + 1$:

$$M_0^{t+1} = \frac{\theta_0^{t+1}(X^{t+1}, Y^{t+1})}{\theta_0^{t+1}(X^t, Y^t)} \quad (15)$$

Using the weighted average of (14) and (15), it is possible to measure the displacement effect of the efficiency frontier, according to the decomposition of the Malmquist Index proposed by Färe *et al.* (1994):

$$M_0^{(x_{t+1}, y_{t+1}, x_t, y_t)} = \frac{\theta_0^{t+1}(X^{t+1}, Y^{t+1})}{\theta_0^t(X^t, Y^t)} \left[\frac{\theta_0^t(X^{t+1}, Y^{t+1})}{\theta_0^{t+1}(X^{t+1}, Y^{t+1})} * \frac{\theta_0^t(X^t, Y^t)}{\theta_0^{t+1}(X^t, Y^t)} \right]^{1/2} \quad (16)$$

where the first ratio measures the change in relative efficiency between the periods t and $t + 1$ (change in technique), while the geometric mean of the expressions in brackets measures the displacement of technology between periods analyzed (change in efficiency).

Färe *et al.* (1994) also discuss the use of variable returns to scale in calculating the Malmquist index. In this situation, the change in efficiency becomes change in pure efficiency and, as highlighted by Sant'Anna, Oliveira (2002), the ratio between them shows the change in production scale.



Ray, Desli (1997) develop the studies of Färe *et al.* (1994) by proposing that a change in the production scale be measured using the geometric mean between two quotients: i) ratios of efficiencies in relation to the constant returns to scale and variable returns to scale frontiers, in period t , with the values of the unit analyzed in periods t and $t + 1$; ii) ratio of efficiencies in relation to constant returns to scale and variable returns to scale frontiers, in periods $t + 1$ of the same DMUs. Finally, the authors also argue technical change be calculated with reference to the variable returns frontier.

3.3. Sample data and variables

Brazilian agricultural cooperatives were used as a reference for this study. They undertake to receive, store and/or process, as well as subsequently trade the agricultural produce of their members.

The analysis considers a balanced data panel (to calculate the Malmquist index) of accounting information from a sample of 40 cooperatives, according to total among distribution through Brazilian territory spread over 5 states, between 2006 and 2010: 11 in Minas Gerais, 9 in Paraná, 8 in Rio Grande do Sul, 5 in Santa Catarina and 7 in São Paulo. Such cooperatives represent the varying realities of the sector in Brazil, and were divided into two groups according to their Gross Sales for the fiscal year 2010, in order to consider the specifics contained in these two groups of different financial statuses. The 20 cooperatives with highest revenues belonged to Group 1, and the 20 cooperatives with lowest sales to Group 2.

The productive activity of these cooperatives was characterized by considering one output, Gross Sales, represented by the volume of sales of the cooperatives, which provided a measure of overall outcome of DMU. We considered two inputs, Operational Expenses, which represented the size of the operational structure, and was a proxy for the level of professionalism of the cooperative management, since much of this amount is made up of salaries, and Fixed Assets, which represent the amount of cooperative capital invested, usually high in agricultural cooperatives.

The DEA model was implemented considering product-orientation. All variables were deflated and are expressed in real terms (millions of US\$). Table 1 presents the descriptive statistics of the variables considered in the study.



[Table 1]

3.4. Uniqueness Test of Efficiency Frontiers

Before going on to calculate the proposed models, it is necessary to check whether the two groups of cooperatives are part of the same efficient frontier or if each group has its own frontier. Therefore, to verify if there are any differences between the efficiency measures of groups of larger and smaller cooperatives, the Mann-Whitney and Wilcoxon non-parametric tests were used.

According to Marinho (1996), the procedure for the application of nonparametric statistics in conjunction with DEA, which sets out to test the hypothesis that two specific sets of DMUs generate two sets of statistically different frontiers, involves the following steps:

- 1 - the group of 40 cooperatives is divided into two subgroups on the basis of Gross Sales: one with the 20 larger cooperatives and the other with the 20 smaller. Then, the DEA is carried out separately in both groups;
- 2 - in each group separately, those DMUs regarded as inefficient should be adjusted to their targets (projected for the efficient frontier);
- 3 - the DEA is carried out for the whole set formed from the union of the two adjusted groups;
- 4 - the statistical tests adjusted to the efficiency coefficients generated in step 3 are applied, in order to test the hypothesis of statistical equality between the initial sub-groups.

Thus, the results of the Mann-Whitney (918.6) and the Wilcoxon (1524.0) tests, with a statistical significance of 0.128 weighted by the Z test lead to the non-rejection of the null hypothesis of equality between the efficiency frontiers. A single frontier for both cooperative groups can be estimated, which makes it possible to compare them.

4. Results

Firstly, it is important to emphasize the justification for dividing the changes in productivity into technical and efficiency variations or the shift of the DMU in relation to the frontier. Nishimizu, Page (1982), precursors in emphasizing this distinction, pointed out that when productivity gains come mostly from shifts in the frontier then there would be innovations which would bring about such movements. Using the same logic, increases in



productivity most related to the movement of DMUs in relation to the frontier would come from the diffusion of technologies or various situational factors (PEREIRA, 1999).

Although the methodology used to calculate the Malmquist Productivity Indexes advocates the existence of constant returns to scale, this study initially presents the behavior of the technical efficiency of the cooperatives analyzed through the use of DEA, while considering the existence of variable returns to scale. The results are shown in Figure 4³.

[Figure 4]

Throughout the period under review a modest growth in efficiency was seen between 2006 and 2009 in Group 1, which was followed by a sharp drop between 2009 and 2010. This result can be explained by a reduction in the level of exports of agricultural cooperatives in the final years of the study, as shown by data from MDIC (2010). It must be emphasized that it is mainly the major Brazilian cooperatives that export which may have been hardest hit by the global economic recession in the harshest years of the 2008/09 crisis.

It was also found that all the cooperatives in Group 1 experienced decreasing returns to scale over the period analyzed. In the years studied, the efficiency levels of the largest cooperatives fell by 20.34%.

By contrast, in Group 2, there was an average 12.74% increase in efficiency, rising from 0.504 to 0.568, but with oscillations throughout the period. These cooperatives may have taken advantage of the favorable economic conditions and high commodity prices of the second half of the 2000s, without, however having been so affected by the 2009 economic crisis, as they based most of their activities in the domestic market.

Despite the sharp decline after the peak growth in efficiency of 2008, the smaller cooperatives, unlike the larger, were beginning to recover in 2010, with the result that there was a certain convergence in efficiency levels between Groups 1 and 2.

In general, it was seen that an opportunity arose, especially for smaller cooperatives, to improve the use of inputs in the generation of products. Such cooperatives would have to improve their use of inputs by approximately 43%, on average, to achieve the maximum level of efficiency in production. In the Group 1 cooperatives, this improvement in input usage

³ Tables A.1 and A.2 in the Appendix of this paper present the levels of efficiency disaggregated for each cooperative.



would have to be about 41%, on average. As can be seen, these high values would indicate, in general, the low efficiency of these institutions.

However, it must be emphasized that the combination of large amounts of fixed assets, characteristic of agricultural cooperatives, and low levels of value-added production could also help explain the low efficiency levels.

The Malmquist Indices, related to changes in total factor productivity, changes in efficiency and technology, are expressed in terms of the average performance of cooperative groups, in the 2006/10 period.

It can be affirmed, according to the analysis of the numbers in Table 2⁴, that the total productivity of cooperatives explained more by the change in technology, in the case of Group 1, is justified by the variation in efficiency in Group 2. Furthermore, the technological change rate in both groups present values below unity, which indicate a negative variation.

[Table 2]

Moreover, for both groups, there is some stability in the indices during the period studied, with the larger cooperatives tending slightly towards a drop in productivity, and the smaller cooperatives presenting the opposite. Thus, the productivity of the smaller cooperatives is seen to be above the average of the total sample. However, on analyzing Figure 5, which presents the behavior of total factor productivity index for each group, over the years, it is observed that, in both groups, the trend in the final years of the analysis was towards a fall in productivity, with a greater loss for the larger cooperatives in Group 1 (30%), between 2007 and 2010, and a consequent reduction in the difference between the groups.

[Figure 5]

As for the rates of change in technical efficiency, Table 2 shows that the cooperatives in Group 2 presented positive growth rates of 2.7%, which is above the total sample average. The evolution of the Technical Efficiency Index is shown in Figure 6. Since this index is based on efficiency analysis with constant returns to scale, it can be seen that the path of the

⁴ Disaggregated indices per year and per cooperative are contained in Tables A.3 to A.8 in the Appendix of this paper.



indexes evolves in a manner quite similar to Figure 4, at least for the cooperatives of Group 1, which peaked in 2009 and decreased, in 2010, to levels below those observed in 2006 (Figure 6).

[Figure 6]

With respect to technological innovations (changes), according to the last column in Table 2, it can be seen that both groups present a tendency towards decrease, despite the fact that in the annualized analysis, shown in Figure 7, one can see quite similar behavior for both Groups, with reduced dispersion between them, and also a recovery of both in 2010, after a sharp reversal in 2008, of the growth trends of the technological evolution.

[Figure 7]

Observing this behavior, it should be noted that, in the last decade, programs, such as RECOOP⁵, PRODECOOP⁶ and PROCAP-AGRO⁷ were introduced in the field of agricultural cooperativism with a view to enabling cooperatives to make investments in infrastructure, improve their management, and reorganize their financial structures. Given the potential impact of such government policies, these could be linked to the technological changes observed in Figure 7. Thus, these programs would have facilitated the adaptation of the cooperatives to the new competitive environments in which they operate.

Finally, according to Marinho, Ataliba (2000), although the levels of technological change index are indicative, when taken in isolation they do not permit us to identify which cooperatives are shifting the productivity frontier. In order to find evidence about which cooperatives could be doing this, it is necessary to check between the periods t and $t + 1$, if for each cooperative the three conditions expressed by the equations below are found:

⁵ Revitalization Program of Brazilian Agricultural Cooperatives. Created by Ministerial Decree n. 26 13/02/1998. Regulated by Decree n. 2936 of 11/01/1999.

⁶ Cooperative Development Program for Value Aggregation to Agricultural Production. Established by Resolution of the Central Bank of Brazil (BCB) n. 2987 of 07/03/2002.

⁷ Capitalization Program for Agricultural Cooperatives. Established by resolution of the Central Bank of Brazil (BCB) n. 3739 of 22/06/2009.

$$\left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})} \frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)} \right) \right]^{1/2} > 1 \quad (17)$$

$$D_0^{t+1}(x^{t+1}, y^{t+1}) = 1 \quad (18)$$

$$D_0^t(x^{t+1}, y^{t+1}) > 1 \quad (19)$$

the first condition (17) referring to the technology index variation greater than unity, indicates that the cooperative can shift the frontier productivity by introducing new technologies. The second condition (18) states that if this frontier is to be shifted by one or more cooperative, they should be on the frontier. According to the third condition (19), if the product of a cooperative at $t + 1$ is greater than the maximum potential output that could be obtained at time t , due to the use of production factors in $t + 1$, then there has been technological progress and, accordingly, the cooperative may be shifting the frontier (MARINHO; ATALIBA, 2000).

Thus, according to the results presented in Tables A.1, A.2, A.7 and A.8 in the Appendix, some of the largest cooperatives in Group 1 in 2007, could have shifted the productivity frontier of the sample analyzed, which would indicate that these cooperatives were capable of producing beyond the optimal level, thanks to technological and/or situational improvements in their operational environments.

5. Closing Remarks

This study set out to examine changes in the total productivity factors of 40 Brazilian agricultural cooperatives, in the 2006-2010 period, classified into two groups, one made up of larger cooperatives and the second, of smaller ones. Two fundamental factors were analyzed: technological change and efficiency. Thus, it was expected to see the transformations occurring in these cooperatives as they faced the constantly changing reality of the agri-food system.

The results demonstrate that, when variable returns to scale are considered for measuring efficiency, the cooperatives in the first group showed modest growth up to 2009, and then experienced a sharp decline in the following year, possibly related to the international financial crisis, which affected their core activities. Cooperatives in the second



group oscillated substantially over the period and, in contrast to the previous group, recovered rapidly in 2010 after shrinking in the 2008-2009 period.

In summary, it was noted that during the period under consideration the external market conditions, which directly reflect the trade prices of international agricultural commodities, and the type of government programs aimed at reinforcing cooperatives, were included among the factors that could have influenced the performance of cooperatives. Thus, in the case of larger cooperatives, the fact that they usually exported to international markets could exert a significant influence on their performance.

On considering the variation in total productivity factors, the variation in technology negatively influenced cooperatives in Groups 1 and 2, while changes in efficiency boosted those in Group 2. Nevertheless, the change in the production frontier was achieved mainly due to some larger cooperatives, members of Group 1.

It is vital to distinguish between the reasons which lead to the change in total factor productivity when drawing up policies, since it is essential to establish and encourage Research & Development programs, when there is no technological progress, as was the case of the cooperatives analyzed. On the other hand, when development is delayed by the efficiency factor or displacement of units in relation to the frontier, there could well be problems in the diffusion of technological innovations, or in their suitability for meeting the real needs of agricultural cooperatives.

In order to reduce the technological stagnation of Brazilian cooperatives, especially those smaller, collaboration incentives can be developed with institutions involved in the creation and improvement of useful knowledge to agricultural cooperatives, including allowing the use of these cooperatives as a place for the application and experimentation of innovative actions developed by institutions such as technical institutes and universities. Moreover, considering the principle of cooperation among cooperatives, entities of representation and organization of Brazilian cooperatives should take charge ever more to encourage innovative practices and mainly spread the good experiences promoted by its members and those observed in other countries, considering the reality of each organization.

Hence the importance of programs to reinforce the capacity of national cooperatives to innovate programs which support access to and dissemination of new production, marketing and management technologies.

Tables and Figures

Table 1 – Descriptive statistics of the sample. Annual average (in millions of US\$*)

Year	Group	Input/output	Average	Std. Deviation	Max	Min
2006	1	Gross Sales	736.60	621.07	3130.32	245.14
		Fixed Assets	140.81	127.50	492.22	15.82
		Operational Expenses	72.54	60.80	280.54	0.34
	2	Gross Sales	108.62	81.42	358.27	8.84
		Fixed Assets	22.72	20.93	93.33	2.52
		Operational Expenses	13.43	10.62	38.39	0.69
2007	1	Gross Sales	889.41	796.82	3993.00	314.37
		Fixed Assets	161.94	144.63	494.53	16.64
		Operational Expenses	80.87	76.86	362.56	4.21
	2	Gross Sales	131.27	92.02	395.20	16.04
		Fixed Assets	24.07	20.52	81.18	3.65
		Operational Expenses	14.54	12.11	45.87	0.73
2008	1	Gross Sales	1052.17	1008.93	4946.88	278.12
		Fixed Assets	174.79	155.35	553.53	17.03
		Operational Expenses	85.46	71.86	340.71	10.46
	2	Gross Sales	135.26	89.79	380.38	24.82
		Fixed Assets	23.23	19.37	66.70	2.85
		Operational Expenses	13.91	13.02	52.22	1.63
2009	1	Gross Sales	1030.50	971.23	4892.59	325.77
		Fixed Assets	203.48	168.49	635.00	19.12
		Operational Expenses	100.90	117.07	563.64	4.80
	2	Gross Sales	138.92	78.71	317.57	24.19
		Fixed Assets	24.62	20.20	77.26	2.71
		Operational Expenses	13.78	11.73	48.23	3.30
2010	1	Gross Sales	990.06	917.32	4583.99	333.32
		Fixed Assets	247.82	174.88	732.45	16.83
		Operational Expenses	104.83	121.55	597.28	17.31
	2	Gross Sales	133.37	76.87	305.98	25.05
		Fixed Assets	30.37	21.88	80.19	1.93
		Operational Expenses	13.45	11.10	49.52	2.51

Source: Research data.

Note: * considering the Brazilian Real/US Dollar exchange rate of December of each year.

Table 2 – Decomposition of total productivity measured by the Malmquist Index, average annual change, 2006/10

	Malmquist Index	Efficiency Variation	Technological Change
Group 1	0.954	1.029	0.927
Group 2	1.029	1.083	0.950
Average*	0.991	1.056	0.939

Source: Research results.

*Values are geometric means. Since the Malmquist Index is multiplicative, the product of the mean variation of inefficiency and technological change is equal to the average of that index.

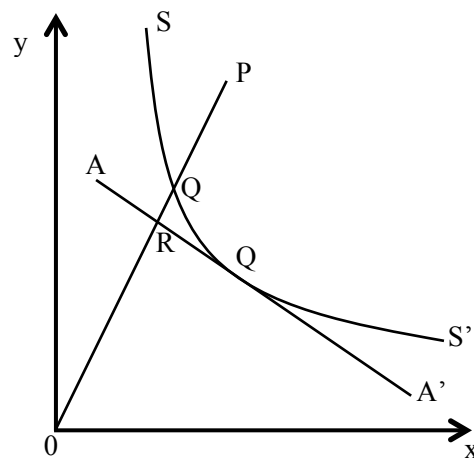


Figure 1 – Isoquant, Technical Efficiency and Price Efficiency
 Source: Farrell (1957).

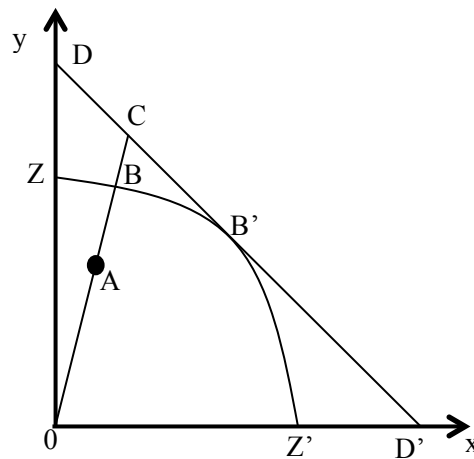


Figure 2 – Efficiency Measure with Output orientation
 Source: Ferreira and Gomes (2007).

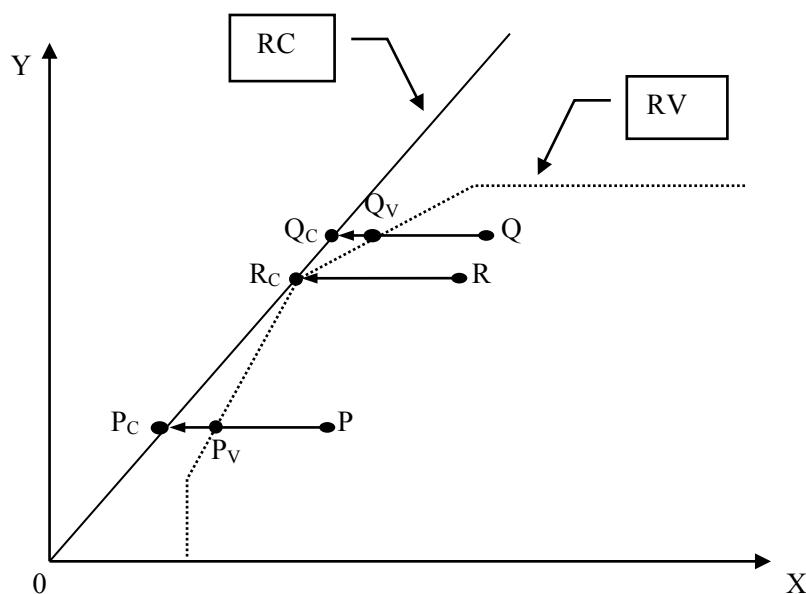


Figure 3 – Technical efficiency and scale efficiency, with constant and variable returns
Source: Ferreira and Gomes (2009).

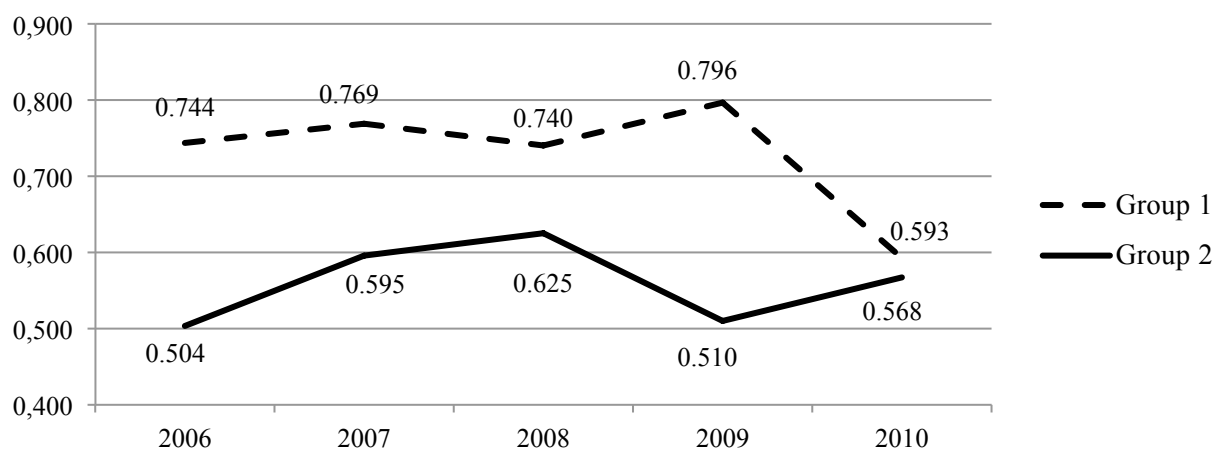


Figure 4 – Technical efficiency of cooperatives, variable returns to scale, per group, 2006/10
Source: Research results.

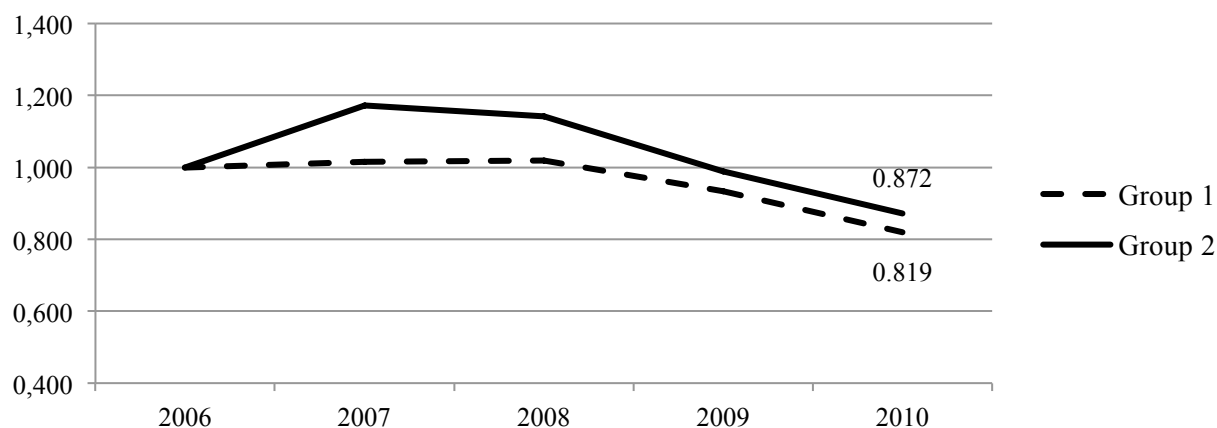


Figure 5 – Total productivity of cooperatives measured by the Malmquist Index, per group, 2006/10

Source: Research results.

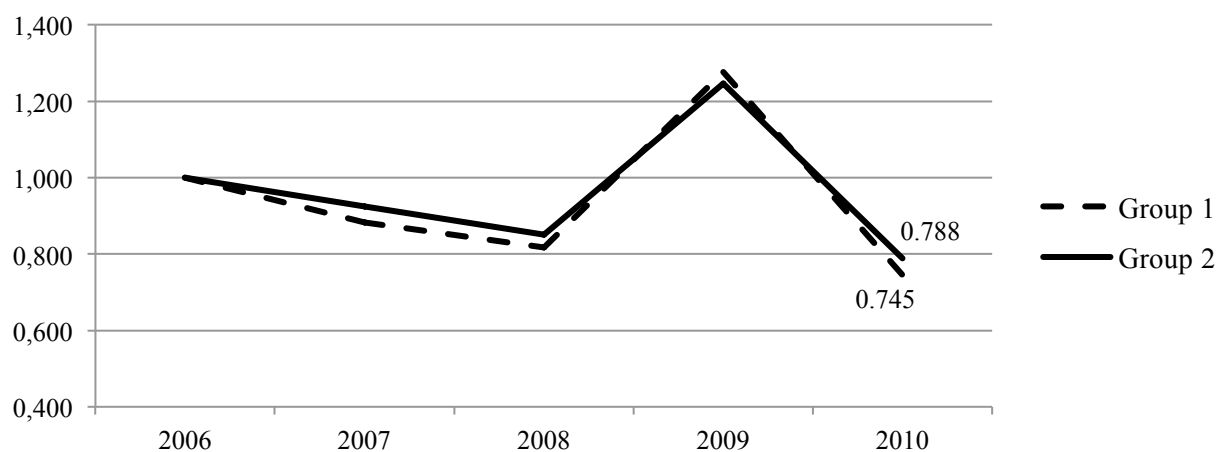


Figure 6 – Technical efficiency change in cooperatives, per group, 2006/10

Source: Research results.

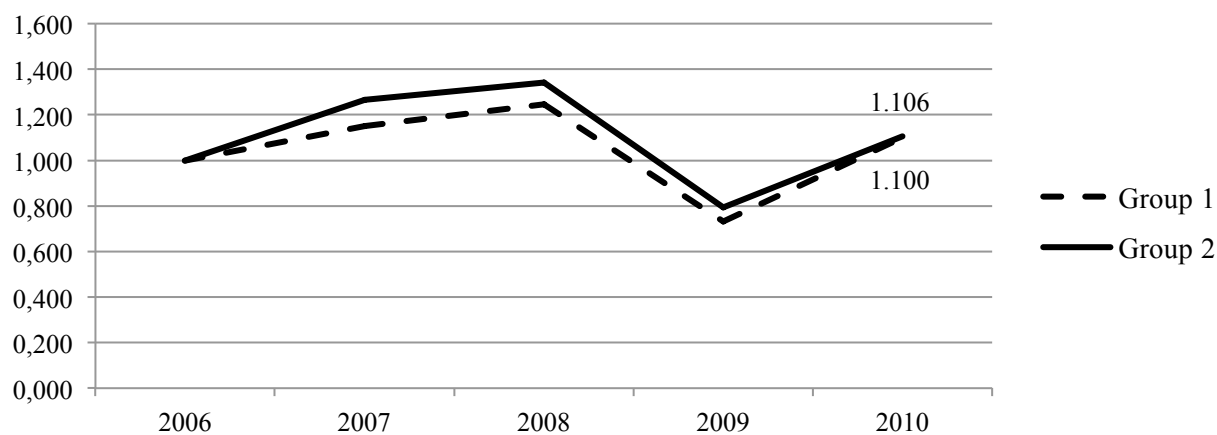


Figure 7 – Technological change in cooperatives, per group, 2006/10

Source: Research results.



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Appendix

Table A.1 – Productive technical efficiency of cooperatives, variable returns to scale, Group 1, 2006/10

	2006	2007	2008	2009	2010
DMU_3	1.000	1.000	1.000	1.000	1.000
DMU_9	1.000	1.000	1.000	1.000	1.000
DMU_12	1.000	1.000	1.000	1.000	0.797
DMU_13	0.769	1.000	0.732	0.921	0.512
DMU_14	0.753	0.766	0.816	0.936	0.661
DMU_15	1.000	1.000	1.000	1.000	1.000
DMU_16	0.678	0.661	0.675	0.739	0.668
DMU_17	0.645	0.644	0.582	0.749	0.510
DMU_18	0.602	0.506	0.429	0.573	0.489
DMU_19	0.843	0.926	0.885	0.912	0.508
DMU_23	0.540	0.659	0.823	0.811	0.614
DMU_24	0.515	0.571	0.615	0.667	0.372
DMU_25	0.600	0.655	0.599	0.756	0.464
DMU_28	0.512	0.490	0.425	0.520	0.499
DMU_30	0.727	0.754	0.582	0.778	0.551
DMU_31	0.577	0.567	0.620	0.775	0.389
DMU_32	0.605	0.665	0.706	0.576	0.508
DMU_36	0.746	0.773	0.666	0.630	0.466
DMU_38	0.772	0.738	0.653	0.585	0.367
DMU_39	1.000	1.000	1.000	1.000	0.481

Source: Research results.

Table A.2 Productive technical efficiency of cooperatives, variable returns to scale, Group 2, 2006/10

	2006	2007	2008	2009	2010
DMU_1	0.468	0.732	1.000	0.611	0.849
DMU_2	0.190	0.258	0.247	0.195	0.290
DMU_4	0.240	0.360	0.476	0.378	0.538
DMU_5	0.397	0.450	0.838	1.000	0.890
DMU_6	0.511	0.431	0.486	0.394	0.591
DMU_7	0.273	0.272	0.312	0.251	0.227
DMU_8	0.980	1.000	0.631	0.629	0.461
DMU_10	0.583	0.857	1.000	0.738	1.000
DMU_11	1.000	1.000	1.000	0.443	0.781
DMU_20	0.376	0.368	0.360	0.405	0.456
DMU_21	0.354	0.526	0.650	0.586	0.360
DMU_22	0.498	1.000	0.621	0.384	0.588
DMU_26	0.301	0.447	0.516	0.403	0.465
DMU_27	0.410	0.372	0.259	0.271	0.289
DMU_29	0.181	0.280	0.287	0.318	0.387
DMU_33	1.000	0.935	1.000	1.000	1.000
DMU_34	0.835	0.903	1.000	0.749	0.446
DMU_35	0.805	1.000	0.866	0.645	1.000
DMU_37	0.342	0.404	0.612	0.485	0.448
DMU_40	0.326	0.314	0.338	0.322	0.287

Source: Research results.

Table A.3 – Total productivity of cooperatives measured by the Malmquist Index, Group 1, 2006/10

	2006	2007	2008	2009	2010
DMU_3	1.000	1.018	0.834	1.256	0.956
DMU_9	1.000	1.095	1.380	0.778	1.505
DMU_12	1.000	0.660	1.254	0.727	0.960
DMU_13	1.000	1.589	0.698	1.012	0.764

DMU_14	1.000	1.034	1.180	0.854	0.985
DMU_15	1.000	1.099	1.248	0.686	0.865
DMU_16	1.000	1.189	1.319	0.787	1.029
DMU_17	1.000	1.050	1.098	0.955	0.898
DMU_18	1.000	0.881	1.060	0.921	0.917
DMU_19	1.000	1.165	1.146	0.944	0.689
DMU_23	1.000	1.216	1.095	1.173	0.889
DMU_24	1.000	1.184	1.120	1.039	0.663
DMU_25	1.000	1.173	1.059	0.985	0.815
DMU_28	1.000	1.147	0.875	0.853	1.241
DMU_30	1.000	1.128	0.976	0.916	0.918
DMU_31	1.000	1.111	0.964	1.104	0.446
DMU_32	1.000	1.258	0.948	0.704	0.887
DMU_36	1.000	1.039	1.047	0.940	0.859
DMU_38	1.000	1.000	0.958	0.773	0.805
DMU_39	1.000	0.251	0.557	1.740	0.235

Source: Research results.

Table A.4 – Total productivity of cooperatives measured by the Malmquist Index, Group 2, 2006/10

	2006	2007	2008	2009	2010
DMU_3	1.000	1.153	1.759	0.705	0.874
DMU_9	1.000	1.160	1.160	0.968	1.143
DMU_12	1.000	1.301	1.160	1.008	1.105
DMU_13	1.000	1.173	1.450	1.894	0.479
DMU_14	1.000	0.914	0.870	1.108	1.213
DMU_15	1.000	1.111	0.965	1.049	0.850
DMU_16	1.000	0.975	0.803	1.075	0.614
DMU_17	1.000	1.290	1.345	0.887	1.153
DMU_18	1.000	1.545	1.955	0.554	1.123
DMU_19	1.000	0.918	0.869	1.081	1.036
DMU_23	1.000	1.405	1.103	0.984	0.744
DMU_24	1.000	1.213	1.189	0.777	1.073
DMU_25	1.000	1.300	1.004	1.034	0.807
DMU_28	1.000	0.947	0.587	1.338	0.959
DMU_30	1.000	1.570	0.889	1.261	1.048
DMU_31	1.000	1.050	1.907	1.191	0.461
DMU_32	1.000	1.124	0.986	0.801	0.514
DMU_36	1.000	1.043	1.467	0.845	1.136
DMU_38	1.000	1.357	1.267	0.967	0.751
DMU_39	1.000	1.176	1.107	0.890	1.098

Source: Research results.

Table A.5 – Rate of technical efficiency variation in cooperatives, Group 1, 2006/10

	2006	2007	2008	2009	2010
DMU_3	1.000	1.000	0.999	1.001	1.000
DMU_9	1.000	1.063	1.616	0.627	1.681
DMU_12	1.000	0.808	2.069	0.449	2.294
DMU_13	1.000	1.741	0.831	0.813	0.935
DMU_14	1.000	1.124	1.411	0.700	1.372
DMU_15	1.000	1.119	1.466	0.553	0.905
DMU_16	1.000	1.374	1.581	0.643	1.292
DMU_17	1.000	1.205	1.320	0.788	1.330
DMU_18	1.000	0.937	1.253	0.740	1.167
DMU_19	1.000	1.182	1.259	0.753	0.776
DMU_23	1.000	1.208	1.264	0.945	0.923
DMU_24	1.000	1.151	1.348	0.841	0.813
DMU_25	1.000	1.199	1.247	0.791	1.030
DMU_28	1.000	1.299	1.040	0.698	1.845
DMU_30	1.000	1.247	1.160	0.744	1.237
DMU_31	1.000	1.325	1.213	0.772	1.023
DMU_32	1.000	1.371	1.124	0.574	1.319
DMU_36	1.000	1.005	1.223	0.759	0.983
DMU_38	1.000	0.980	1.151	0.623	0.968
DMU_39	1.000	1.000	0.897	1.115	0.428



Source: Research results.

Table A.6 – Rate of technical efficiency variation in cooperatives, Group 2, 2006/10

	2006	2007	2008	2009	2010
DMU_3	1.000	1.294	2.109	0.578	1.198
DMU_9	1.000	1.195	1.360	0.778	1.213
DMU_12	1.000	1.437	1.375	0.813	1.423
DMU_13	1.000	1.289	1.742	1.265	0.922
DMU_14	1.000	0.904	1.027	0.893	1.490
DMU_15	1.000	1.167	1.144	0.841	0.898
DMU_16	1.000	0.990	0.846	0.890	0.786
DMU_17	1.000	1.304	1.575	0.715	1.398
DMU_18	1.000	3.010	3.409	0.417	1.479
DMU_19	1.000	0.959	1.039	0.877	1.677
DMU_23	1.000	1.411	1.260	0.791	0.822
DMU_24	1.000	1.173	1.409	0.630	1.139
DMU_25	1.000	1.420	1.198	0.846	1.148
DMU_28	1.000	0.995	0.857	0.939	1.399
DMU_30	1.000	1.807	1.059	1.030	1.494
DMU_31	1.000	1.055	1.986	1.000	0.516
DMU_32	1.000	1.140	0.909	0.711	0.541
DMU_36	1.000	1.058	1.353	0.750	1.278
DMU_38	1.000	1.421	1.490	0.776	1.019
DMU_39	1.000	1.324	1.313	0.713	1.327

Source: Research results.

Table A.7 – Rate of technological change in cooperatives, Group 1, 2010/06

	2006	2007	2008	2009	2010
DMU_3	1.000	1.018	0.835	1.254	0.956
DMU_9	1.000	1.029	0.854	1.242	0.895
DMU_12	1.000	0.817	0.606	1.618	0.418
DMU_13	1.000	0.912	0.840	1.245	0.817
DMU_14	1.000	0.920	0.837	1.220	0.718
DMU_15	1.000	0.982	0.851	1.242	0.957
DMU_16	1.000	0.866	0.834	1.225	0.796
DMU_17	1.000	0.871	0.832	1.212	0.675
DMU_18	1.000	0.940	0.846	1.245	0.786
DMU_19	1.000	0.986	0.910	1.253	0.888
DMU_23	1.000	1.007	0.866	1.242	0.963
DMU_24	1.000	1.029	0.831	1.234	0.815
DMU_25	1.000	0.978	0.850	1.246	0.791
DMU_28	1.000	0.883	0.841	1.222	0.673
DMU_30	1.000	0.905	0.842	1.231	0.742
DMU_31	1.000	0.838	0.794	1.429	0.436
DMU_32	1.000	0.918	0.843	1.228	0.673
DMU_36	1.000	1.033	0.856	1.239	0.874
DMU_38	1.000	1.020	0.832	1.240	0.832
DMU_39	1.000	0.251	0.622	1.560	0.550

Source: Research results.

Table A.8 – Rate of technological change in cooperatives, Group 2, 2006/10

	2006	2007	2008	2009	2010
DMU_3	1.000	0.891	0.834	1.220	0.730
DMU_9	1.000	0.971	0.853	1.245	0.942
DMU_12	1.000	0.906	0.844	1.240	0.776
DMU_13	1.000	0.910	0.832	1.498	0.520
DMU_14	1.000	1.011	0.847	1.240	0.814
DMU_15	1.000	0.952	0.844	1.247	0.946
DMU_16	1.000	0.986	0.949	1.207	0.781
DMU_17	1.000	0.989	0.854	1.240	0.825
DMU_18	1.000	0.513	0.573	1.330	0.759
DMU_19	1.000	0.957	0.837	1.232	0.618



DMU_23	1.000	0.996	0.876	1.244	0.905
DMU_24	1.000	1.034	0.844	1.234	0.942
DMU_25	1.000	0.915	0.839	1.222	0.704
DMU_28	1.000	0.952	0.685	1.425	0.685
DMU_30	1.000	0.869	0.840	1.224	0.702
DMU_31	1.000	0.995	0.960	1.191	0.894
DMU_32	1.000	0.986	1.084	1.126	0.950
DMU_36	1.000	0.986	1.084	1.126	0.889
DMU_38	1.000	0.954	0.850	1.246	0.737
DMU_39	1.000	0.888	0.843	1.249	0.828

Source: Research results.