MEASURING THE EFFICIENCY AND PRODUCTIVITY OF THE CROATIAN BANKS WITH MALMQUISTST INDEX OF CHANGE OF TOTAL FACTOR PRODUCTIVITY

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Abstract

In the literature that deals with the empirical measurement of relative technical efficiency and change in the productiveness of banks over time the Malmquist index of change of total factor productivity has become the most often-used analytical tool. It has been shown that the Malmquist index helps both central and commercial bank analysis to monitor trends within the banking sector, and that it can be used as assistance in controlling the system and in strategic planning.

This investigation is directed at the relative comparison of banks within the banking sector of Croatia in the period from 2000 to 2003, and is the first paper in which the Croatian banking sector has been analysed with the application of the Malmquist index of change in total factor productivity. The scientific contribution deriving from this is heightened by the interdisciplinarity that informs the paper. The primary objective of the investigation is the monitoring of relative trends of banks inside the very dynamic Croatian banking sector. Focus is placed on the need for the development of additional models to cover alternative and above all off-balance-sheet indicators.

Key words: Malmquist TFP index, banking performance

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1 Introduction

At the beginning of the third millennium, the powerful effects of globalisation, computerisation and the development of the new technologies can be felt in all areas of human activity. In the no-holds-barred conditions of the battle for market survival there is often a need for internal analyses of corporate performance as well as analyses of the overall competitive market, and today, with the development of the methodological equipment that exists for business investigation, such analyses are very frequently carried out. In order to retain competitiveness in given markets, firms have to keep on comparing themselves with their competitors, identify the best, and endeavour to learn from them, adjusting the others' plans of development so as to apply them for their own improvement. Well-chosen strategy can assist a firm to catch up with and even overtake the level of business excellence of the firm that is currently rated the best. In recent times, one of the most often-used instruments for the assessment of corporate performance is relative technical efficiency and change of total factor productivity, which breaks down to change in relative technical efficiency and shift of production frontiers between two periods of time. Interpretation of frontier shift, as component of index of change of productivity, is an essential component of every such analysis.

Taking this into consideration, the need arose to find a suitable model for the monitoring of the operations of firms within given groups of activities. The objective of the present paper is to present the Malmquist total factor productivity index (below, MPI) with an illustration of its application to the banking sector of the Republic of Croatia in the period from 2000 to 2003. The index is meant to track the relative position of a bank with respect to the frontier set by the best banks in the sector. In accord with this, the index can be used to provide early warning of the weakness of a given bank within the banking sector, which will help management to take the appropriate preventive measures in due time. Many recent papers have shown the suitability of this method for monitoring trends within a given business sector. The method, developed from the microeconomic theory of learning from the most successful, is today an increasingly important managerial analytical tool in many situations.

The banking sector, it might be said, is the most crucial sector in modern and developed economies. In Croatia this sector is still being developed and still lower than 4% of GDP is derived from the financial services sector and only 1.4% of the working population of Croatia is employed in the bank sector. The Croatian banking sector has an oligopolistic structure. In the first half-year of 2004, the two biggest banks controlled 42.3% and the six biggest banks 79.1% of all the assets of the sector.

From 1990 to 1996 Croatia saw the founding of a great many small new banks. The high market interest at that time enabled the new banks, which were not burdened by inherited debts, to operate with high levels of profit. An interesting question is whether the decision to throw the banking sector open to foreign investors after the banking crisis of 1998 was a good decision for Croatia. The share of foreign owners in the total banking assets of Croatia rose from 6.7% at the end of 1998 to 83.7% at the end of 2000. The decision to bail out some of the banks and let them be taken over by foreigners was clearly taken in the wake of the banking crisis, not only to forestall fu-

ture instabilities of the system, but in order to facilitate to the maximum the transfer of know-how.

The major turbulence in the Croatian banking sector before 2000 led us to investigate the behaviour of banks in the post-trauma period, raising the question: Have the operations of the commercial banks in Croatia achieved stabilisation? At the very beginning of the investigation, for the sake of the creation of a complete panel, banks were selected that during the whole of the four year period under observation had operated with a net profit. Then an analysis was made of the balance sheet positions of banks that later merged with or were taken over by each other, which practically halved the original panel.

The paper is structured in such a way that in the second part Farrell's measures of radial relative efficiency are explained and applied to the measurement of the technical efficiency of the selected sample of banks in the Croatian banking sector. In the third part, the Malmquist index of change of total factor productivity is explained, and the application of it is illustrated with the same sample of banks. The index is broken down to index of change of radial relative efficiency and the index of the production frontier shift. Part four gives some final considerations.

2 Farrell's measures of radial relative efficiency

In 1957 Farrell observed[1] that the efficiency of a company (in the observed example) consists of two components: technical efficiency, which reflects the ability of the firm (the bank) to create the maximum outputs from the available level of inputs, and allocative efficiency, which reflects the ability of the firm (the bank) to make use of inputs in the optimum quantity with respect to price and production technology. These two measures are then combined into a measure of total economic efficiency.

Example 1. To illustrate measures of efficiency oriented towards the reduction of inputs let us consider firms (banks) that via the use of two inputs, x1 and x2, create one output, y, and assume that the production technology satisfies the constant yields axiom. Knowing the isoquant of unit output of technically efficient firms (banks) shown as the SS' line in figure 1 enables the measurement of the technical efficiency of each firm (or bank), in the same, and knowing the fixed prices of inputs assumes the knowledge of the isocost line AA', which enables measurement of allocative and economic efficiency.

Technical efficiency (*TE*) of a firm (or bank) identified with point *P* is defined as:

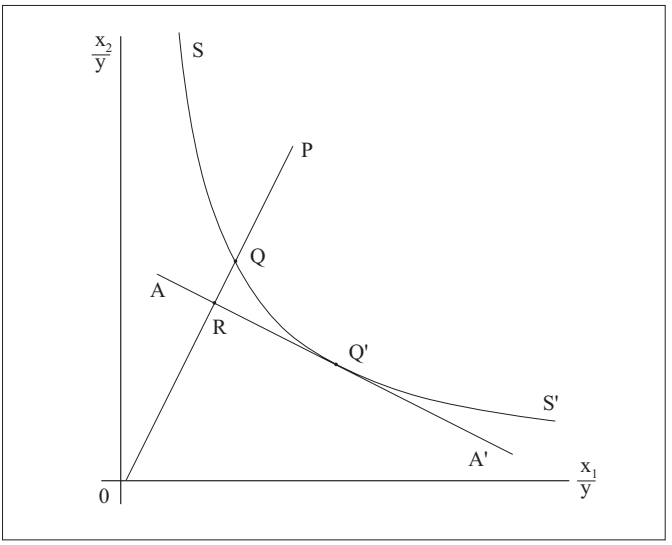
$$TE_I(P) = \frac{OQ}{OP} = 1 - \frac{QP}{OP}. \tag{1}$$

Allocative efficiency (AE_I) of a firm (a bank) identified with point *P* is defined as:

$$AE_I(P) = \frac{OR}{OQ}, \tag{2}$$

[1] The account that follows is based on (Farrell, 1957) and (Coeilli, 2005).

Figure 1 Technical and allocative efficiency of firms for orientation of a model to reduction of inputs



because the distance *RQ* shows a kind of measure of production cost reduction that can be achieved if the production of the firm (the bank) is moved to the allocatively and technically efficient point *Q'* from the technically efficient but allocatively inefficient point *Q*.

The total *economic efficiency* of the bank equated with point *P* is:

$$EE_I(P) = \frac{OR}{OP}, \tag{3}$$

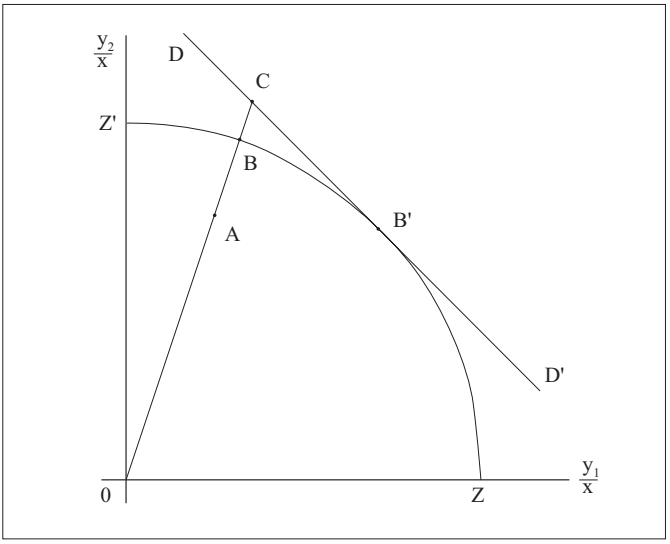
where the distance *RP* can also be interpreted in the form of cost reduction. We would observe that the product of measures of technical and allocative efficiency gives the measure of overall economic efficiency:

$$TE_I(P)AE_I(P) = \frac{OQ}{OP}\frac{OR}{OQ} = \frac{OR}{OP} = EE_I(P). \tag{4}$$

Example 2. Measures of technical efficiency oriented towards the reduction of inputs shown in the previous case respond to the question of how much input quantities can be proportionally reduced concomitantly with the maintenance of the achieved output qualities. Alternatively it is possible to ask how much output quantities can be proportionally increased with the employment of the given level of inputs. The answer to this question is given by measures of efficiency oriented to increase of outputs. For an illustration of measures of efficiency oriented to the increase of outputs we shall consider firms (banks) that produce two outputs, y_1 and y_2, using a single input, x.

If in Figure 2 the ZZ' frontier is a set of productive possibilities, for the technically inefficient point *A,* the distance *AB* is the measure of its technical inefficiency, i.e., the

Figure 2 Technical and allocative efficiency of a firm for the orientation of the model to increase of outputs.



quantity of outputs that could be increased without the use of additional quantities of inputs. Then the measure of technical efficiency oriented towards the increase of outputs can be expressed as:

$$TE_O(A) = \frac{OA}{OB}. \tag{5}$$

If we have the output prices, we can construct the isoincome line *DD'* and calculate the allocative efficiency:

$$AE_O(A) = \frac{OB}{OC}, \tag{6}$$

which can be interpreted in the form of increase of income. Total economic efficiency is defined as the product

$$EE_O = TE_O(A)AE_O(A) = \frac{OA}{OB} \cdot \frac{OB}{OC} = \frac{OA}{OC}. \tag{7}$$

We can perceive certain essential characteristics of Farrell's measures of efficiency. Firstly, technical efficiency is measured along the radial from the point of origin through a point through which the firm or bank that is observed is described. The advantage of radial measures is their invariance with respect to the unit of measurement, i.e., a change in the unit does not affect the value of the measure of efficiency. In general, measures that are not radial are not invariant to the change in the unit of measure, because then a change in the unit of measure results in the finding of another reference point on the frontier. Secondly, allocative efficiency is considered from the point of view of minimising costs and

maximising revenue, but not from the perspective of maximising profit. For no adequate methodology of measuring efficiency based on the maximisation of profit has yet been developed. Thirdly, these measures of efficiency assume that the production function is known. Since in practice this is not the case, the efficient isoquant is estimated from samples of data with stochastic methods or it is assumed it is in parts a linear conic or convex shell of the analyzed firms, as in data envelopment analysis. We should mention that various techniques for the assessment of frontiers and different choices of functional forms can lead to essentially different results.

In the continuation of the paper, for illustration of the concrete analysis of the commercial banks in Croatia, we shall restrict ourselves to the application of nonparametrical deterministic frontiers of data envelopment analysis. More about the formal inscription of the model used can be found in the mathematical annex to this section. A great deal of useful information can be derived with this method.

2.1 Mathematical annex

Empirical measurement of the radial of relative technical efficiency (Farrell, 1957), which for illustration is carried out in the situation in which the producers (the banks) use several inputs for the production of several outputs, is based on output functions of distance (Shephard, 1953). Since the objective of this addition is to present the minimum analytical apparatus necessary for empirical analysis, we shall limit ourselves to an orientation to increase in output. Let us assume that the producers (banks) use a non-negative input vector $x \in R_+^m$ in order to produce a non-negative output vector $y \in R_+^s$, and recall the basic concepts from the econometric theory of the enterprise (Coelli 2005; Kumbhakar 2003).

The graph of production technology in the time period *t*,

$$GR\ (t) = \{(y, x) \mid x \text{ can produce } y \text{ in the time period } t\}, \tag{8}$$

describes a set of possible input-output vectors in time period *t*.

Sets of outputs of production technology in time period *t*,

$$P^t\ (x) = \{y \mid (y, x) \in GR\ (t)\} \tag{9}$$

describe sets of outputs that are possible for each input vector *x* in time period *t.*

The *isoquants of outputs* in time period *t,*

$$IsoqP^t\ (x) = \{y \mid y \in P^t\ (x), \lambda y \notin P^t\ (x), \lambda > 1\}, \tag{10}$$

describe levels of outputs that can be produced with input vector *x,* but for which further radial expansion is not possible with the application of input vector *x* in time period *t.*

According to Shephard (1953) *the output function of distance* in time period *t* is the function:

$$D_0^t\ (y, x) = \min\ \{\mu \mid y / \mu \in P^t\ (x)\}. \tag{11}$$

An output oriented measure of technical efficiency of a producer (*y, x*) in time period *t* can be described with the use of the distance function is written as the function:

$$TE_0^t\ (y, x) = [\max\ \{\varnothing \mid D_0^t\ (\varnothing\, y, x) \leq 1\}]^{-1}. \tag{12}$$

2.2 llustration of Farrell's radial relative technical efficiency taking the example of the Croatian banking sector

Table 1 Farrell's measure of radial relative technical efficiency to the frontier of the Croatian banking system in the year observed [a]

No.	Bank	Relative radial technical efficiency			
		2000	2001	2002	2003
1	Centar banka	0.38783	0.43277	0.62966	0.52534
2	Credo banka	0.19033	0.33816	0.56861	0.30025
3	Gospodarska kreditna banka	1.00000	0.84196	0.28819	0.44706
4	Hrvatska poštanska banka	0.07001	0.12908	1.00000	1.00000
5	HVB splitska banka	0.32937	0.72273	0.85903	0.77331
6	Hypo Alpe-Adria	0.96694	1.00000	1.00000	1.00000
7	Imex banka	0.74262	1.00000	1.00000	1.00000
8	Istarska kreditna banka	0.59644	0.75046	0.77655	0.86438
9	Jadranska banka	0.03719	0.15132	0.06561	0.18361
10	Karlovačka banka	0.44358	0.17485	0.42050	0.36507
11	Kreditna banka Zagreb	0.07231	0.07843	0.14592	0.38588
12	Kvarner banka	0.24637	0.51573	0.59673	0.63200
13	Nava banka	0.53615	0.27552	0.50247	0.44027
14	Partner banka	0.32058	0.78340	0.71859	0.91901
15	Podravska banka	0.05879	0.24179	0.47177	0.48501
16	Požeška banka	1.00000	1.00000	0.71703	0.05562
17	PBZ	0.60351	0.89589	1.00000	1.00000
18	PB – Laguna banka	0.33572	0.62486	0.79484	0.73978
19	Raiffeisenbank	0.99311	1.00000	0.64615	0.90909
20	Riadria banka	0.18739	0.86475	0.93602	1.00000
21	Samoborska banka	0.02909	0.05525	0.10625	0.00723
22	Slatinska banka	0.29704	0.45957	0.70055	0.51040
23	Štedbanka	1.00000	1.00000	1.00000	1.00000
24	Varaždinska banka	0.34816	0.73235	0.83901	1.00000
25	Volksbank	0.96945	0.81737	0.50993	0.49897
26	Zagrebačka banka	1.00000	0.53916	0.73392	0.99804

[a] *The calculation was carried out with the use of the programme created by Tomislav Petrov M.Sc. for his own purposes in the Mathematica application. The results were later checked out with the use of the commercially available DEA Excel Solver.*

In an illustrative case the output-oriented measure of technical efficiency is produced by the use of three inputs – labour, capital and assets, and two outputs, - pre- and post-taxation profits, with the assumption that the *Farrell polyhedral cone* (Charnes, 1978) is

a graph of production technology that satisfies the constant yields axiom. Although several investigations of the Croatian banking sector speak of the "presence of economies of scale" (Jemrić and Vujčić, 2002), a methodology for testing "yields with respect to the level of inputs invested" (Simar and Wilson, 2002) as a publicly available programme (Wilson, 2005) was incorporated for the first time only after the writing of this paper. For these reasons, no testing of "the existence of the economics of scale" in the Croatian banking sector has been carried out in this work.

The choice of inputs and outputs is from Zhu (2000) but because of the paucity of publicly accessible data the total archived revenue had to be replaced by pre-tax profit. We should mention that it is useful to calculate the measure of relative technical efficiency for every sub-model of the model used, and instead of the use of equity (balance sheet), which is not always correlated with the capital really committed to the production of outputs, it is a good idea to use some other measure that plays a direct part in the creation of new value. Irrespective of it being impossible to use satisfactory data, for the reason cited in the beginning of the section, the selection made is nevertheless in accord with the contemporary understanding of the methodology, which allows the use of any outputs and inputs that can be put into some meaningful economic relation. Because of the invariance of MPI with respect to changes in the units of measurement, it was unnecessary to evaluate the labour input, rather instead of labour costs expressed in kuna (with an estimate of payments in the form of shares, training, use of company cars, phones, entertaining and so on) the data concerning the number of persons employed in a given bank were used. Financial inputs and outputs were translated into real values with the use of the cost of living index. Efficiency measures are almost unchanged if the translation of nominal into real values is carried out with retail price indices or the inflation index. A detailed discussion of the right index to use is to be found in Berger, Forsund and Jensen (1992). Economic analysts even today do not have the same views about which index to use, although the most commonly employed is the retail price index.

In the previous table the amounts of relative radial technical efficiency for given banks in the 2000 to 2003 period are given. These results mark the relative position of a given bank from the sample as compared with the efficient frontier of the banking sector in a given year. Banks in which the value of relative radial technical efficiency came to 1.00 constituted the effective frontier of the banking system in the given year. Values lower than 1.00 show how efficient the given bank was in percentage points of the reference benchmark point on the frontier. Eleven out of the 26 banks constituted the effective frontier during the time period observed. It is interesting to point out that in all four years, Štedbanka was on the efficiency frontier. For three years in a row, from 2001-2003, runners-up, in the sense of efficiency, were Hypo Alpe-Adria and Imex. In 2003, the last year of the period under observation, the frontier consisted also of the Hrvatska Poštanska banka, Privredna banka Zagreb and Varaždinska banka. A very interesting example is to be found in the Hrvatska Poštanska banka, which from being a very inefficient bank in 2000 (7%) and in 2001 (12.9%) in 2002 became efficient, as it remained in 2003. Požeška banka is also an interesting example but unfortunately illustrates an entirely opposite trend. Of one among four effective banks in 2000, and one of the five efficiency banks in 2001, in the last two years of the period, Požeska banka has been marked first

of all by a moderate decline in efficiency, in 2002, when it was 71.7% efficient, and then a year later the efficiency decline was so dramatic that the one-time "success leader" had an efficiency of only 5.56%. Similar positive movements in the sense of efficiency were found in Riadria and Varaždinska banka. The efficiency of the two banks rose relatively abruptly in 2001 as against 2000, then came close to the efficient banks, and they found themselves among the efficient in 2003. Two banks with a relatively large market share and rather strange efficiency trends are Raiffeisenbank and Zagrebačka banka. In 2001 and almost in 1000 Raiffeisenbank was poised on the very frontier, its relative radial technical efficiency being cut by practically a half in 2002. In 2003 it once again recorded renewed growth in efficiency, which came in that year to about 91%. Zagrebačka banka, which in 2000 was a component part of the productive frontier, cut its efficiency in half in 2001. The next two years its efficiency rose again gradually, and in 2003 it came to 99.8%, which definitely made it, in efficiency frontier terms, one of the most successful banks in the Croatian banking system.

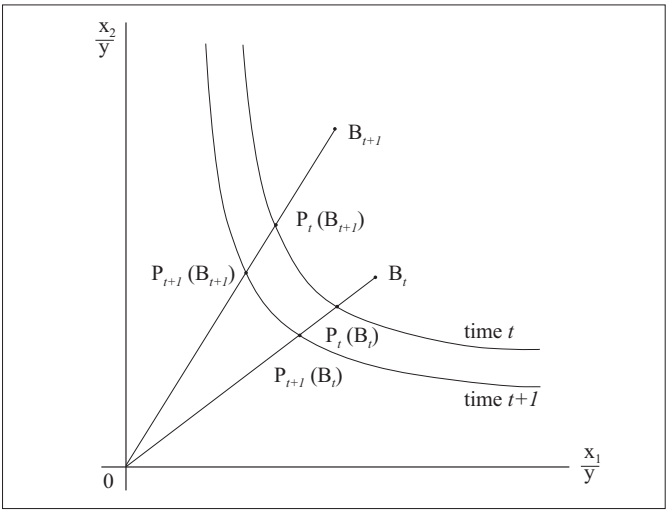
We should point out that the empirical benchmark production frontier derived from Farrell's polyhedral cone is an uninterrupted and partially linear function, set by the technically efficient banks in the sample. Of course, there is no guarantee that a deterministic frontier so defined as a correlation with the real frontier. And so a deal of circumspection is necessary in the interpretation of the results.

3 Färe's variant of Malmquist's productivity index

In a one-output and one-input situation, productivity is defined as the ratio of quantities of outputs and inputs. When firms (banks) are defined by several inputs and several outputs, the productivity of the analysed firms or banks is defined as the ratio of the index of the level of output and the index of the level of inputs, and a change in this ratio during time reflects a change in the productivity of the firm or bank. In today's time the fact is accepted that during the course of time the productivity of a firm can change with a shift in the frontier (because of a technological process that has occurred) and via a change of relative technical efficiency of a firm (we determine it in relation to the frontier of the moment observed). The *shift of the frontier* reflects technological progress that has happened inside the analysed sample of firms or banks, and the change in relative technical efficiency of a firm within the analysed sample of firms during the course of time reflects the shift of the firm with respect to the efficient frontier of the sample at the beginning and at the end of the observed interval. The change in total factor productivity is often measured with the Malmquist index,[2] and linear programming is used for the calculation

[2] Mamlquist's Total Factor Productivity Change Index was not invented by Malmquist. In his paper (Malmquist, 1953) he brought input functions of distance into an analysis of consumption, developing a method for the empirical measurement of standard of living. The change in living standards is defined as the ratio of two input functions of distance. Before the Malmquist paper, the input function of distance was brought into a paper by Debreu (Debreu, 1951), and the output function of distance was introduced by Shephard in his book (Shephard, 1953). The natural development of their papers was the definition of the index of change of total factor productivity as the ratio of two input or output functions of distance. Some 31 years had to pass before it arrived. The Malmquist index of change in total factor productivity was proposed in a paper for the first time in (Caves, 1982a). Today these indices are entitled partially oriented indices of change in total factor productivity. In the case of production technology that satisfies the constant yields axiom, the indices are the same.

Figure 3 Illustration of the Malmquist index of change of productivity



of it.[3] For in many situations, particularly in an analysis of the growth of public sector institutions, there are no data about the prices (weights) of inputs and outputs. Often the problem of determining the weights of inputs and outputs is pointless. For example, what price is to be assigned to a human life lost in a traffic accident? Since it does not require price information, does not require the imposition of a functional form of copying that associates inputs with outputs, nor does it require explicit assumptions about the behaviour of the analysed units and the process of optimalisation, the Malmquist index of total factor productivity change has today achieved great popularity. For a graphic illustration of the Malquist index of change of productivity we shall use a description of the banks with two inputs and one output.

If from *d(A,B)* we mark the Euclidian distance of points *A* and *B,* the Malmquist index of change of the productivity of a firm presented by point B_t at the moment *t* and by the point B_{t+1} at the moment *t +1* is the geometrical mean:

$$MI = \sqrt{\frac{\dfrac{d(0,P_t(B_{t+1}))}{d(0,B_{t+1})}}{\dfrac{d(0,P_t(B_t))}{d(0,B_t)}} \cdot \frac{\dfrac{d(0,P_{t+1}(B_{t+1}))}{d(0,B_{t+1})}}{\dfrac{d(0,P_{t+1}(B_t))}{d(0,B_t)}}} \quad . \tag{13}$$

[3] For a calculation of the Malmquist index of change in total factor productivity it is necessary to calculate four indices of relative distance (solve four linear programmes), as proposed in the paper (Färe, 1989). For mathematically more demanding readers who seek an enlarged methodological and prescriptive focus, see (Lovell, 2003).

This can be analysed into index of change of relative technical efficiency and index of shift of the frontier[4] in this way:

$$MI = EFF \cdot TECH = \frac{\frac{d(0,P_{t+1}(B_{t+1}))}{d(0,B_{t+1})}}{\frac{d(0,P_t(B_t))}{d(0,B_t)}} \sqrt{\frac{d(0,P_t(B_{t+1}))}{d(0,P_{t+1}(B_{t+1}))} \cdot \frac{d(0,P_t(B_t))}{d(0,P_{t+1}(B_t))}} \,. \qquad (14)$$

The first component determines the change in relative technical efficiency of the observed firm between times t and $t + 1$, reflecting the shift of the firm as compared with the effective frontier of the sample of firms. If it is greater than 1, the firm analysed has shifted towards the frontier of the sample, and if it is less than 1, the firm has moved away from the frontier. The second component determines the shift of the actual border between times t and t +1, and reflects the technological progress that has taken place within the sample. The shift of the frontier is measured by the geometrical mean of the ratio of distance from the originating points of the projection onto the border in periods t and $t + 1$ for points B_t and $B_{t+1.}$ A value for this component greater than 1 reflects the technological progress that has taken place intra-sample, just as a value for this component of less than 1 would reflect technological regress.

3.3 Explanation of the interpretation

After we have intuitively explained MPI and its decomposition for productive technology derived from the constant yields axiom, we are now ready to write it in the form of an operationally useful mathematical form that will additionally explain the index. Using the graph of the benchmark of productive technology derived from the constant yields axiom c in time period s, we can write the output function of distance D_O as $D_O^{CS}(y,x)$. The output oriented Malmquist index of change of total factor productivity between time t and $t + 1$ for the benchmark productive technology in the time period is defined as follows:

$$M_o^{cs}(y^t, x^t, y^{t+1}, x^{t+1}) = \frac{D_o^{cs}(y^{t+1}, x^{t+1})}{D_o^{cs}(y^t, x^t)} \,. \qquad (15)$$

By the ratio of value, then, that the distance function takes on if the productive unit is observed in periods $t + 1$ and t. Since we wish to measure the change in total factor productivity between period t and $t + 1$, the technology from one of these periods can be taken as the benchmark production technology. Of course, since distance functions give the measure that is relative to the technology, for the technology from period $s = t$ and the period $s = t + 1$ various results can be obtained. That is why in the article of Caves, Christensen and Diewert (1982b) the Malmquist index of change of total factor productivity between the period t and the period $t + 1$ is defined as their geometrical mean, i.e.:

[4] The index of frontier shift is in the paper (Färe, 1994a) called the index of technological progress. It wa then thought that a shift of the benchmarking frontier, in line with the economic theory of a market of perfect 6.competition reflected technological progress. We would point out that during calculation of the index of technological progress constant yields are assumed with respect to the scale of action. So the known decomposition of the index of change of relative technical efficiency, in the case of productive technology, is derived from the variable yields axiom, to change in pure technical efficiency and change in scale of operations efficiency (Färe, 1994b) is practically unusable as addition to decomposition (14).

$$M_{OC}^{t,t+1}\left(y^t, x^t, y^{t+1}, x^{t+1}\right) = \sqrt{M_o^{c,t}\left(y^t, x^t, y^{t+1}, x^{t+1}\right) \cdot M_o^{c,t+1}\left(y^t, x^t, y^{t+1}, x^{t+1}\right)}\,. \quad (16)$$

Index C, to make the writing more readable, has been put into the denominator although it still describes the productive technology derived from the constant yields axiom. A value of greater than 1 indicates growth in total factor productivity, a factor of 1 suggests stagnation, and a value of less than 1 suggests the reduction of total factor productivity between periods t and $t + 1$.

$$M_{OC}^{t,t+1}(y^t, x^t, y^{t+1}, x^{t+1})$$

Equation (14) can be written via the output distance function (11) in the form of:

$$M_{OC}^{t,t+1}(y^t, x^t, y^{t+1}, x^{t+1}) = TE\Delta_C^{t,t+1}(y^t, x^t, y^{t+1}, x^{t+1}) \cdot T\Delta_C^{t,t+1}(y^t, x^t, y^{t+1}, x^{t+1})\,, \quad (17)$$

where

$$TE\Delta_C^{t,t+1}(y^t, x^t, y^{t+1}, x^{t+1}) = \frac{D_O^{c,t+1}(y^{t+1}, x^{t+1})}{D_O^{c,t}(y^t, x^t)} \quad (18)$$

determines the change of relative technical efficiency, and

$$T\Delta_C^{t,t+1}(y^t, x^t, y^{t+1}, x^{t+1}) = \sqrt{\frac{D_O^{c,t}(y^{t+1}, x^{t+1})}{D_O^{c,t+1}(y^{t+1}, x^{t+1})} \cdot \frac{D_O^{c,t}(y^t, x^t)}{D_O^{c,t+1}(y^t, x^t)}} \quad (19)$$

the geometrical mean of the magnitude of the shift of the frontier along the radial through (y^{t+1}, x^{t+1}) and (x^1, y^1). This change in the work of Fare et al. (1994) is called *technological change.*

3.2 An illustration of the Malmquist index of change of productivity from the sample of banks inside the Croatian banking sector

In this section we follow the work of Fare et al. (1994) who first carried out empirical measurement pursuant to the theory presented.

Just how popular the Malmquist index is can be seen from the fact that it is today used in more than 1000 theoretical and survey articles published in 68 countries (Felthi and Olgu, 2004a), and as for works that are used for the analysis of the banking sector, we shall mention the following papers.[5]

Before embarking on an interpretation of the results obtained, we should recall that MPI observes a bank as a black box without getting into any analysis of its specific features from the point of review of inputs and outputs and the limitations that the model should take into account. The idea of the MPI is to notice any change in the operations of the bank pursuant to statistical data, and to suggest to the practical person which black box to explore from the point of view of managerial strategy or cost accounting.

[5] (Casu, 2004), (Fixler, 1999), (Gilbert, 1998), (Grifell-Tatje, 1996), (Grifell-Tatje, 1997), (Jun, 2004), (Mohan, 2004), (Mukherjee, 2001), (Rebelo, 2000), (Rime, 2003), (Rogers, 1998), (Sathye, 2002), (Stiroh, 2000), (Wheelock, 1999) and (Worthington, 1999).

Table 2 The Malmquist index of change of productivity, index of change of relative technical efficiency and index of frontier shift of the Croatian banking sector.[a]

No.	Bank	Malmquist's index			Change of efficiency			Frontier shift		
		00-01	01-02	02-03	00-01	01-02	02-03	00-01	01-02	02-03
1	Centar banka	0.901	1.301	0.766	1.116	1.455	0.834	0.807	0.894	0.919
2	Credo banka	1.369	1.558	0.504	1.777	1.681	0.528	0.771	0.927	0.955
3	Gospodarska kred. banka	0.557	0.286	1.334	0.842	0.342	1.551	0.662	0.834	0.860
4	Hrvatska poštan. banka	1.548	7.191	0.940	1.844	7.747	1.000	0.839	0.928	0.940
5	HVB splitska banka	2.231	1.048	0.716	2.194	1.189	0.900	1.017	0.882	0.796
6	Hypo Alpe-Adria	1.304	0.860	0.738	1.034	1.000	1.000	1.261	0.860	0.738
7	Imex banka	1.217	0.866	0.938	1.347	1.000	1.000	0.903	0.866	0.938
8	Istarska kreditna banka	1.077	0.961	1.023	1.258	1.035	1.113	0.856	0.928	0.919
9	Jadranska banka	3.427	0.405	2.699	4.069	0.434	2.799	0.842	0.934	0.964
10	Karlovačka banka	0.414	2.092	0.696	0.394	2.405	0.868	1.050	0.870	0.802
11	Kreditna banka Zagreb	0.871	1.696	2.651	1.085	1.861	2.644	0.803	0.911	1.002
12	Kvarner banka	1.764	0.979	0.920	2.093	1.157	1.059	0.842	0.846	0.869
13	Nava banka	0.401	1.755	0.843	0.514	1.824	0.876	0.780	0.962	0.962
14	Partner banka	1.851	0.830	1.261	2.444	0.917	1.279	0.758	0.905	0.986
15	Podravska banka	2.653	1.726	1.022	4.113	1.951	1.028	0.645	0.885	0.994
16	Požeška banka	0.616	0.619	0.077	1.000	0.717	0.078	0.616	0.864	0.989
17	PBZ	1.181	1.033	0.851	1.484	1.116	1.000	0.796	0.925	0.851
18	PB – Laguna banka	1.274	1.130	0.935	1.861	1.272	0.931	0.684	0.889	1.004
19	Raiffeisenbank	1.177	0.542	1.072	1.007	0.646	1.407	1.169	0.839	0.762
20	Riadria banka	3.670	0.982	1.035	4.615	1.082	1.068	0.795	0.907	0.969
21	Samoborska banka	1.460	1.753	0.070	1.900	1.923	0.068	0.769	0.911	1.027
22	Slatinska banka	1.164	1.400	0.738	1.547	1.524	0.729	0.752	0.918	1.013
23	Štedbanka	0.770	0.989	1.077	1.000	1.000	1.000	0.770	0.989	1.077
24	Varaždinska banka	1.699	1.047	1.124	2.103	1.146	1.192	0.808	0.914	0.943
25	Volksbank	0.887	0.537	0.767	0.843	0.624	0.979	1.052	0.860	0.784
26	Zagrebačka banka	0.487	1.262	1.180	0.539	1.361	1.360	0.902	0.927	0.868

[a] *The data used in the calculation were taken from analyses of the banking sector published in Privredni Vjesnik.*

From Table 2 we can see that the cause of the change in the Malmquist Index of Change of Total Factor Productivity in the sector of the commercial banks in Croatia is above all a shift in the frontier. The shift of the productive frontier for most of the banks was relatively stable and negative, $T\Delta<1$, while positive changes, technological progress, $T\Delta>1$, was recorded in an insignificant number of banks in the sample, i.e., only on some parts of the frontier. This result is expected because of the already mentioned economic interpretation of the index. The cause of the technological retrogression derives from the

stabilisation of the banking sector. With a rise in competition and gradual reduction of interest rates, the profitability of the banks has been reduced, and since the variants of profits are outputs in the model used, the appearance of the frontier numerically described in the table is understandable. In addition, the index of efficiency change in some of the banks has changed dramatically. This result too is expected because of the use of a *methodology sensitive in its construction to variability of outputs*[6], and in most of the banks observed in the period of time under analysis, they changed considerably.

As in most of the cases the shift of the border was negative and constant, we may concluded that MPI variations are mostly caused by a change in relative technical efficiency. MPI>1 presents a positive change of total factor productivity, while MPI<1 marks a negative change of total factor productivity. The first component of MPI, change in relative technical efficiency, has changed considerably. TEΔ>1 marks a positive change in relative technical efficiency, i.e., some given bank's approximation to the efficient productive frontier, while a value of TEΔ<1 indicates a movement away from the said frontier, which does not necessarily have to indicate any fall in the productivity of a given bank, but can simply be caused by a positive shift of the frontier. A bank the value of which is TEΔ=1 has retained the same relative position with respect to the frontier.

It is customary in a second step in an analysis to explain by a regression model each component of changed productivity by exactly determined deterministic method. Unfortunately, statistical analysis for a banking sector as turbulent as the Croatian has proved useless, bearing out the work of Fethic, Shaaban and Weyman-Jones (2004b).

4 Conclusion

The large number of mergers and takeovers in the banking sector in Croatia, a few collapses by smaller banks and a large number of banks that in the 2000 – 2004 period operated with a negative profit led us in the analysis carried out to orient ourselves only to that part of the banking sector comprising banks that in the period under observation recorded a profit at the end of each business year. Considering the selection of adequate inputs and outputs, and wishing them to be as representative as possible, at the outset we thought that profit should not be one of the selected outputs. For profit as a position in the calculation of profits and losses does not reflect just the performance of the bank, but also depends on its objectives, strategies and business policies to do with the allocation of new value. However, we concluded that it would be a mistake to attempt to define an output to be representative for all banks in the sector, and realised that *an analyst can develop his intuition concerning the business strategies and financial trends inside a sector analysed only if he or she uses several different selections of inputs and outputs.*

At the end, we would point out that the primary aim of the paper has been to present a new scientific methodology, with an illustration of how it can be applied to the banking sector in the Republic of Croatia. We shall carry out a detailed analysis of the banking sector of Croatia in future papers. Accordingly, we can conclude that the paper has suc-

[6] The pre-tax profit of Zagrebačka banka, between 2000 and 2001, reduced to 50.3%. The result of this change was among other things the amount of its relative radial technical efficiency, which was 53.9% in 2001.

cessfully met the objectives set up. Apart from the easily discernible advantage so fusing the described methodology, its main drawback derives from the fact that *in practical applications all inputs and all outputs do not have equal importance.* Hence the need for it to be adjusted so that *an analyst is able to incorporate his or her professional knowledge and judgements into a measure of efficiency.* To conclude: before the construction of a more serious model for the evaluation of performance based on an analyst's preference's MPI should be used exclusively to supplement classic analyses of financial indicators. In conjunction with an acceptance of the said constraint, this methodology has a good outlook for use in the process of analysing every group of activities.

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