Andrzej Sieradz\textsuperscript{*}  
Bernard F. Kubiak\textsuperscript{**}

Efficiency Analysis of IT investment in Polish Banks (1998-2008): An Application of Malmquist Productivity Index

Introduction

The productivity of IT in banking sector is vital for the performance of the banks. Efficient IT systems in banks can contribute to shareholder values return and helps in creation of financial ROE. First studies on the assessment of banking sector efficiency as whole using Data Envelopment Analysis and Malmquist Index were carried out in U.S., Italy, and Nord European countries. The main reason to use an nonparametric approach on the top of parametric analysis was that financial open markets in those countries, with most advanced technical and technological solutions for the banks were most advance. Not many studies focus on the efficiency of the usage Information Technology in banks, see Table 2.

Main reason is that today’s banks become very complex organization both in products and services offerings, but also in the multi-channel business model allowing customers for easy access to banking services. In Poland banks spend in observed period 25-35\% of the total level of investment for IT systems and infrastructure. In 2008 the whole banking in Poland spend 3.3 billion PLN for support IT systems and new investment combined [Monitor IT, DiS No. 20, 2008, p. 1-2]. The present study is aimed at assessing the performance of Polish banks in terms of efficient use of IT technology and systems. An attempt has been made to quantify productivity change over the time and ascertain changes in the whole sector. In the paper has been used Total Factor Productivity (TFP) growth index to measure of performance. TFP growth has been a commonly-used indicator for the role of technology on productivity [Kisielewska \textit{et al.}, 2007, p. 11-12].

\textsuperscript{*}M.Sc., Doctoral Student, Department of Business Informatics, Faculty of Management, University of Gdańsk, BGŻ Bank, asieradz@wp.pl
\textsuperscript{**}Prof., Ph.D., hab., Department of Business Informatics, Faculty of Management, University of Gdańsk, Poland, ekobk@univ.gda.pl
1. Data and selection of variables

The detailed data set used was obtained from the report of the [Monitor IT, DiS No. 20, 2008] – monitoring the IT spending in the polish banking sector, annual reports of commercial banks listed on Warsaw Stock Exchange during the period 1998-2008. Additionally the quality of data and its consistency has been compared to Annual Report “50 Biggest Banks in Poland” published by monthly magazine “Bank” [Annual Reports for Banks, 2008-2009]. Only commercial, universal banks, which operates on polish market has been included in the study to satisfy the homogeneity of the group of DMU1. In the terms of mergers and acquisition of the banks, data from the previous year, before change has been taken and summarize the actual inputs and outputs. Former studies used tree major approaches to define the input-output relationship for universal banks [Berger, Humphrey, 1992, p. 4-5].

Banks could be viewed as business units acting as intermediation, production, and asset/profit model. There is no consensus among researches of which model should be used for the banks for efficiency evaluation [Berger, Humphrey, 1992, p. 3-4]. In the intermediation framework we assume bank fundamental aim is transform deposits into assets, mainly loans. Second model, pure production model, assumes that bank as any commercial business unit produce products and provide services using resources as input. In such model for banks it is difficult to allocate resources by product and services.

The asset/profit model concentrates on the generating value added for the shareholders in for of assets (loans) and operational results (annually). Such model seems to be used in most of the researches. For comparison and simplification point of view that model has been used for presentation of efficiency in this paper2.

Finally we decided to adopt asset/profit approach, which assumes that the bank’s main economic aim is to maximize the loans (assets) and maximize the financial results (operational profit).

With this approach, three inputs has been used:
- IT personnel – Full Time Employee,
- IT operational cost excluding personal cost3,

---

1 Decision Making Units – (DMU) in this research – universal banks which do not have any shareholding relationship.
2 All models have been calculated, with the same input set.
3 Total operating cost of IT including outsourcing.
IT investment.

As the output has been used two (assets-loans and operational profit before tax). Loans are defined by the net value of loans to customers and other financial institutions. Operational profit is defined as deference between summary of income (interest income and none-interest income) and costs (interest expense and operational costs).

**Figure 1. Definition of the Inputs/Outputs for the model**

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT personnel</td>
<td>Loans</td>
</tr>
<tr>
<td>IT operational cost</td>
<td>Operational result</td>
</tr>
<tr>
<td>IT investments</td>
<td></td>
</tr>
</tbody>
</table>

Source: Assumed model for calculation.

2. Malmquist Productivity Index Model

The Malmquist index evaluates the efficiency change of a DMU between two time periods [Cooper, Seiford, 2006] in most of the cases full consequential years. It is defined as the product of two components "Catch-up" and "Frontier-shift". The “Catch-up” term is related to the degree of efforts that the DMU attained for improve its efficiency from period to period, while the “Frontier-shift” term reflects to the change in the efficient frontiers surrounding the DMU between the two time periods 1 and 2. It is representing the technology change for the whole grup of the DMU. We denote DMU at the time period 1 and 2, by \((x_{o}^{1}, y_{o}^{1})\) and \((x_{o}^{2}, y_{o}^{2})\), respectively. Then, the catch-up effect is measured by the following formula.

\[
\text{Catch-up} = \frac{\text{Efficiency of } (x_{o}^{2}, y_{o}^{2}) \text{ with respect to period 2 frontier}}{\text{Efficiency of } (x_{o}^{1}, y_{o}^{1}) \text{ with respect to period 1 frontier}}
\]

We evaluate each element (efficiency) of the above formula by the non-parametric DEA models as described later. A simple single input and output case is illustrated in Figure 2.

---

4 For calculation the Solver Pro, ver.7.0 ([www.saitech.com](http://www.saitech.com)) has been used.
The catch-up effect (in input-orientation) can be computed as:

\[
\text{Catch-up} = \frac{BD}{BQ} - \frac{AC}{AP}
\]  

(Catch-up)>1 indicates progress in relative efficiency from period 1 to 2, 
(Catch-up=1) indicates status quo 
(Catch-up)<1 indicates regress in efficiency.

In addition to the catch-up term, we must take account of the frontier-shift effect in order to evaluate totally the efficiency change of the DMU, since the catch-up is determined by the efficiencies as measured by the distances from the respective frontiers.

The reference point C of \((x^1_0, y^1_0)\) moved to E on the frontier of period 2. Furthermore the frontier-shift effect at \((x^1_0, y^1_0)\) is evaluated by

\[
\varphi_1 = \frac{AC}{AE}
\]
Efficiency Analysis of IT investment in Polish Banks (1998-2008)…

\[ \varphi_1 = \frac{AC}{AE} = \frac{\text{Efficiency} - \text{of } (x_o^1, y_o^1) \text{ with respect to period 1 frontier}}{\text{Efficiency} - \text{of } (x_o^1, y_o^1) \text{ with respect to period 2 frontier}} \]  \hfill (4)

The denominator is measured as the distance from the period 2 production possibility set to \((x_o^1, y_o^1)\).

Likewise, the frontier-shift effect at \((x_o^2, y_o^2)\) is expressed by the frontier-shift effect is described as

\[ \varphi_1 = \frac{BF}{BQ} = \frac{\text{Efficiency} - \text{of } (x_o^2, y_o^2) \text{ with respect to period 1 frontier}}{\text{Efficiency} - \text{of } (x_o^2, y_o^2) \text{ with respect to period 2 frontier}} \]  \hfill (5)

"Frontier-shift" can be defined by their geometric mean as:

\[ \text{Frontier - shift} = \varphi = \sqrt{\varphi_1 \varphi_2} \]  \hfill (6)

"Malmquist index" is obtained as the product of (Catch-up) and (Frontier-shift). The total Malmquist index is defined as

Malmquist index (TFP) = (Catch-up) x (Frontier-shift) \hfill (7)

It is an index representing Total Factor Productivity (TFP) of the DMU. It reflects progress or regress in efficiency of the DMU along with progress or regress of the change in technology frontier:

- Malmquist Index > 1 indicates progress TFP of the DMU from period 1 to 2,
- Malmquist Index = 1 indicates the status quo,
- Malmquist Index < 1 indicates the decoy of total factor of productivity.

The MI can be computed in number of ways using different Malmquist models. In this paper results are presented based on non-radial Malmquist model input oriented with constant return of scale assumption.
3. Empirical Results

The individual banks Malmquist indexes are given in Table 1. The presented 17 banks are the biggest banks in Poland, representing 85-90% of total asset base within the measured period. The calculation has been done using the model – Non-Radial Malmquist -I-C. In Table 1, grey color indicates the values below or equal to 1.

Table 1. Malmquist Index for Polish banks

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PKO Bank Polski S.A.</td>
<td>1,11</td>
<td>1,12</td>
<td>0,59</td>
<td>1,23</td>
<td>2,80</td>
<td>0,79</td>
<td>0,61</td>
<td>1,34</td>
<td>0,97</td>
<td>0,95</td>
<td>1,15</td>
</tr>
<tr>
<td>Bank Polska Kasa Opieki S.A.</td>
<td>2,25</td>
<td>1,16</td>
<td>0,95</td>
<td>1,07</td>
<td>1,31</td>
<td>1,73</td>
<td>1,21</td>
<td>1,07</td>
<td>0,64</td>
<td>1,01</td>
<td>1,24</td>
</tr>
<tr>
<td>Bank BPH</td>
<td>1,25</td>
<td>0,26</td>
<td>1,19</td>
<td>1,10</td>
<td>1,54</td>
<td>1,10</td>
<td>1,44</td>
<td>2,92</td>
<td>2,11</td>
<td>1,53</td>
<td>1,44</td>
</tr>
<tr>
<td>ING Bank Śląsk S.A.</td>
<td>1,38</td>
<td>1,23</td>
<td>0,83</td>
<td>1,32</td>
<td>1,79</td>
<td>0,91</td>
<td>2,01</td>
<td>0,46</td>
<td>0,85</td>
<td>1,53</td>
<td>1,23</td>
</tr>
<tr>
<td>Bank Handlowy S.A.</td>
<td>1,14</td>
<td>1,26</td>
<td>1,01</td>
<td>1,37</td>
<td>1,20</td>
<td>0,81</td>
<td>2,33</td>
<td>0,61</td>
<td>0,68</td>
<td>1,76</td>
<td>1,22</td>
</tr>
<tr>
<td>Bank BGŻ</td>
<td>1,04</td>
<td>0,83</td>
<td>1,10</td>
<td>1,55</td>
<td>0,95</td>
<td>0,77</td>
<td>1,23</td>
<td>1,36</td>
<td>1,15</td>
<td>1,25</td>
<td>1,12</td>
</tr>
<tr>
<td>Raiffeisen Bank Polska SA</td>
<td>0,95</td>
<td>1,24</td>
<td>0,94</td>
<td>1,24</td>
<td>1,28</td>
<td>1,16</td>
<td>1,53</td>
<td>1,19</td>
<td>0,93</td>
<td>0,99</td>
<td>1,15</td>
</tr>
<tr>
<td>BRE Bank S.A.</td>
<td>1,51</td>
<td>0,27</td>
<td>1,22</td>
<td>2,04</td>
<td>1,44</td>
<td>0,72</td>
<td>1,10</td>
<td>1,33</td>
<td>1,27</td>
<td>1,45</td>
<td>1,24</td>
</tr>
<tr>
<td>Bank Zachodni BZWBK</td>
<td>1,00</td>
<td>1,09</td>
<td>0,52</td>
<td>2,36</td>
<td>1,26</td>
<td>0,93</td>
<td>1,34</td>
<td>1,30</td>
<td>0,96</td>
<td>1,05</td>
<td>1,18</td>
</tr>
<tr>
<td>Kredyt Bank</td>
<td>1,38</td>
<td>0,57</td>
<td>0,63</td>
<td>1,10</td>
<td>1,03</td>
<td>1,32</td>
<td>1,71</td>
<td>0,89</td>
<td>1,25</td>
<td>2,07</td>
<td>1,19</td>
</tr>
<tr>
<td>Bank Millenium</td>
<td>1,15</td>
<td>0,76</td>
<td>0,96</td>
<td>1,26</td>
<td>0,92</td>
<td>2,22</td>
<td>1,38</td>
<td>0,74</td>
<td>1,27</td>
<td>1,60</td>
<td>1,23</td>
</tr>
<tr>
<td>Bank Ochrony Środowiska</td>
<td>0,99</td>
<td>1,01</td>
<td>1,39</td>
<td>0,67</td>
<td>1,19</td>
<td>1,56</td>
<td>1,49</td>
<td>0,73</td>
<td>0,65</td>
<td>1,11</td>
<td>1,08</td>
</tr>
<tr>
<td>NORDEA Bank Polska</td>
<td>0,85</td>
<td>0,66</td>
<td>0,55</td>
<td>0,63</td>
<td>4,41</td>
<td>1,10</td>
<td>1,71</td>
<td>1,07</td>
<td>0,75</td>
<td>1,21</td>
<td>1,29</td>
</tr>
<tr>
<td>LUKAS Bank SA</td>
<td>0,14</td>
<td>2,48</td>
<td>0,82</td>
<td>1,40</td>
<td>1,17</td>
<td>0,79</td>
<td>0,22</td>
<td>6,77</td>
<td>1,04</td>
<td>1,51</td>
<td>1,64</td>
</tr>
<tr>
<td>Fortis Bank Polska</td>
<td>3,02</td>
<td>0,56</td>
<td>0,92</td>
<td>1,70</td>
<td>1,33</td>
<td>0,58</td>
<td>1,00</td>
<td>0,98</td>
<td>0,88</td>
<td>3,67</td>
<td>1,46</td>
</tr>
<tr>
<td>Invest - Bank SA</td>
<td>1,12</td>
<td>0,74</td>
<td>0,66</td>
<td>2,54</td>
<td>1,00</td>
<td>1,46</td>
<td>2,30</td>
<td>1,26</td>
<td>0,24</td>
<td>0,90</td>
<td>1,22</td>
</tr>
<tr>
<td>GETIN BANK SA</td>
<td>2,19</td>
<td>1,19</td>
<td>0,70</td>
<td>2,58</td>
<td>0,10</td>
<td>1,53</td>
<td>0,86</td>
<td>1,53</td>
<td>0,92</td>
<td>3,64</td>
<td>1,52</td>
</tr>
<tr>
<td>Average</td>
<td>1,32</td>
<td>0,97</td>
<td>0,88</td>
<td>1,48</td>
<td>1,45</td>
<td>1,15</td>
<td>1,38</td>
<td>1,50</td>
<td>0,97</td>
<td>1,60</td>
<td>1,27</td>
</tr>
<tr>
<td>Max</td>
<td>3,02</td>
<td>2,48</td>
<td>1,39</td>
<td>2,58</td>
<td>4,41</td>
<td>2,22</td>
<td>2,33</td>
<td>6,77</td>
<td>2,11</td>
<td>3,67</td>
<td>1,64</td>
</tr>
<tr>
<td>Min</td>
<td>0,14</td>
<td>0,26</td>
<td>0,52</td>
<td>0,63</td>
<td>0,10</td>
<td>0,58</td>
<td>0,22</td>
<td>0,46</td>
<td>0,24</td>
<td>0,90</td>
<td>1,08</td>
</tr>
<tr>
<td>SD</td>
<td>0,65</td>
<td>0,51</td>
<td>0,25</td>
<td>0,59</td>
<td>0,93</td>
<td>0,44</td>
<td>0,55</td>
<td>1,46</td>
<td>0,39</td>
<td>0,84</td>
<td>0,15</td>
</tr>
</tbody>
</table>

Source: Own elaboration.

5 Malmquist–I-C means the index calculated with input oriented approach and with the constant scale of return. Software DEA-Solver ver.7.0.
The average efficiency change achieved the positive growth in most banks. The total average value for total period (1999-2008) is 1.27 which indicates positive growth of efficiency for total sector. For individual banks there is none which achieved a positive growth in all years. Banks: Pekao S.A, BRE, BPH have the minimum years (1-2) with negative growth in TFP.

All bank (see last column) achieved a positive growth in average values of TFP in total period.

Even that efficiency change below 1.00 is observed in all analyzed banks, the total picture indicates that technology has a positive effect on the total efficiency change. In the three years average efficiency change in sector was lower than 1.

**Conclusion**

The aim of this paper was to estimate the efficiency of IT spending in banking on the efficiency change in the Polish commercial universal banks. For the estimation we applied Malmquist index (representing Total Factor Productivity (TFP) on the data of 17 biggest banks in Poland.

Such approach is useful for individual banks for comparison to the smaller peer group which those banks treat as direct and close competitors. That in practice is one of many indicators for setting future strategy for IT and investment plans for organization. Second comparison to the whole sector offers banks better understanding of the needed levels of investment into IT technology in order to be able to offer advanced products and services and better shape their competitiveness on the market. Observing MI index for particular bank we also we can trace the link between IT investment and performance of product/service portfolio supported by the information technology. Such comparison might also help with the process of preparing more competitive and advanced product.

Based on the results it appears that the industry efficiency level improved steadily over the period of 1999-2008. Results of the Malmquist indexes annually average are positive in the range of growth of 1.27, nevertheless one might observe difference in the value of the index depending on bank and time. That might be the link with the observation that all measured banks over the time adopting similar technical solutions, but still in different years. Measures the IT spending using the MI shows the stable or increasing level of investment in information
technology not only in particular bank but also equally across entire sector. Malmquist Index for the period indicates that most of the time the process of offering advance solutions (example: Internet banking, Mobile Banking) and prepare range of new products for most of the banks pays off. Nevertheless as results and observation of the market indicated there is different dynamic with adoption of the IT solution supporting the new products and services by banks themselves and clients of another side. Usually we observe a delay between introduction of the IT solution and impact on the organization performance and clients. Furthermore future studies of MI might help to establish the correlation between introduction of new products and services and the performance of the organization.

Additionally MI together with the Data Envelopment Analysis of IT spending efficiency, compared and correlated to overall performance measured by same model, might be used as framework for banks benchmarking.

Table 2. Analysis of earlier studies on IT impact IT in banking sector

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Sample</th>
<th>Technique(s) Used</th>
<th>Main Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Alpar, Porembski, 1989]</td>
<td>30 German banks</td>
<td>DEA</td>
<td>Potential for cost savings from greater IT use was significant in 1989 and in 1994, the effects of IT on cost efficiency were small</td>
</tr>
<tr>
<td>[Alpar, Kim, 1990]</td>
<td>175 U.S. banks</td>
<td>Translog Function</td>
<td>IT contributed to reduction in demand deposits and increase in time deposits. IT also helped to increase in other loans and decrease in installment loans. IT was also responsible for saving labor.</td>
</tr>
<tr>
<td>[Parsons, Gotieb, Denny, 1993]</td>
<td>5 Canadian banks</td>
<td>Translog Function</td>
<td>There was a 17 to 23 percent increase in productivity with the use of computers. The returns were very modest compared to the levels of IT investments.</td>
</tr>
</tbody>
</table>
### Author(s) | Sample | Technique(s) Used | Main Findings
--- | --- | --- | ---
[Wang et al., 1997] | 22 U.S. banks | DEA | Inefficiency in IT-related value added activities always lead to overall inefficiency. Around 64 percent of units that had efficient IT-related activity also had perfect overall efficiency.

[Prasad, Harker, 1997] | Cobb-Douglas Production Function | Additional investment in IT capital had no real benefits and may be more of strategic necessity to stay within the competition. However the results indicated that there were substantially high returns when investment in IT labor was increased.

[Soteriou, Zenios, 1999] | Bank branches of Cyprus | DEA | Micro-environment in the branches had an effect on their efficiency and urban branches had better efficiency than rural branches.

[Department of Banking Supervision, RBI, 2002] | All scheduled commercial banks of India | Ratios | Higher performance levels had been achieved without corresponding increase in the number of employees. Also operating expenses of the banking system had declined during the study period, indicating the positive impact of computerization.

[Takemura, 2003] | Japanese banks | Cobb-Douglas Production Function | IT capital has either positive or no effect on productivity.
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Sample</th>
<th>Technique(s) Used</th>
<th>Main Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Rao et al., 2003]</td>
<td>Indian banks</td>
<td>Cobb-Douglas Production Function</td>
<td>E-business capital and e-business as well as non e-business labor made positive contributions to output. Non e-business capital has either insignificant or negative impact on productivity.</td>
</tr>
<tr>
<td>[Chen, Zhu, 2004]</td>
<td>22 banks of U.S.</td>
<td>DEA</td>
<td>Applying the developed model on the data of 22 banks for the period 1987 to 1989, they concluded that IT budget was not efficiently utilized in the study period.</td>
</tr>
<tr>
<td>[Li, 2007]</td>
<td>All Taiwan banks</td>
<td>DEA and SFA</td>
<td>Low operational efficiencies existed in the banking industry during the study period, 1996 to 2000. These inefficiencies were in nature ascribable to a combination of both wasteful over use of information technology resources and inappropriate scale of information technology investments.</td>
</tr>
<tr>
<td>[Beccalli, 2007]</td>
<td>737 European banks</td>
<td>Ratios and SFA</td>
<td>Investment in IT services from external providers (consulting services, implementation services, training and education, support services) had a positive influence on accounting profits and profit efficiency, while the acquisition of hardware and software reduced banks' performance.</td>
</tr>
</tbody>
</table>
Efficiency Analysis of IT investment in Polish Banks (1998-2008)

Author(s) | Sample | Technique(s) Used | Main Findings
--- | --- | --- | ---
[Chandra-sekhar, Sonar, 2008] | 29 Indian banks | DEA and Malmquist Index | Private sector banks had a slight edge over their industry counterparts during the study period of 2001 to 2006. Further, on the technology front as well as in exercising managerial control, substantial scope existed for improvement, across the sector.

Source: [Dhingra, 2011, p. 2-3].

References
11. Sajay D. (2011), Measuring IT Effectiveness in Banks of India for
Efficiency Analysis of IT investment in Polish Banks (1998-2008): An Application of Malmquist Productivity Index (Summary)

This paper empirically researches the productivity changes of Polish banking industry during period of 1998-2008, by applying a non-parametric Malmquist Productivity Index (MPI) method. This methodology is well establishing approach in exploring performance measures, productivity growth, technological change and technical efficiency. In specifying the variables input-output, an asset/profit approach has been is chosen, which simplify the potential correlation between financial results of the bank with the investment level in IT. Results indicate that during the study period, over eleven years Polish banking industry experienced steady technological progress. All 17 biggest banks chosen for the study, which represent 85% of the asset base, have maintained overall productivity gain. Within this group analysis shows no significant difference linked to the scale/size of the banks. Local inefficiency observed does not seem to have any systematic pattern.

Keywords
Malmquist index, data envelopment analysis, technical efficiency, scale efficiency, total factor productivity, technological change