GSJ: Volume 12, Issue 3, March 2024, Online: ISSN 2320-9186
www.globalscientificjournal.com

Ecological Bank towards Greening Finance

Ines Fdhila[1], Moez Labidi[2] ,

Abstract

The relationship between sustainable banks and their effects on the environment is the main topic of this study. Banks can be more greening, efficient, and environmentally responsible. They could improve greening finance. We consider the 27 biggest banks worldwide from 2007 to 2022. A framework based the Malmquist productivity index. We also investigated index to evaluate eco-efficiency and productivity. The findings indicate that banks must use their resources sustainably by reducing their environmental damage. Sustainable banks must address the effective and efficient use of resources to advance sustainability. Our research's contribution fosters a tradition of ethical behavior in the field of bank sustainability. Our findings can help to pinpoint areas where changes can be made to produce a more sustainable and effective use of resources, over time improves ecological performance and green finance.

Keywords: Sustainable Bank, Greening finance, Environmental performance, Ecological efficiency, Malmquist productivity index.

1. Introduction

By promoting innovative financial products and coordinating activities with climate goals, sustainable banking can be a key component of efforts to decarbonize their operations (Zhang and colleagues, 2022). The promotion of environmental efficiency is the main difficulty facing sustainable banking. These will have an impact on the economy (Chen et al. 2018).

In actuality, the financial sector has a considerably smaller direct influence on the environment than other industries. This is cited by some authors as justification for exempting banks from environmental responsibility disclosure. However, there are solid justifications for including banks in the environment damage. Banks can be facilitators of climate-damaging industrial activity. However, there are valid arguments for the inclusion of banks in environmental damage. Banks can be seen as facilitators of industrial activity that causes climate damage. Furthermore, their investment lending policies can be considered environmentally sensitive. For example, there are direct impacts of firms in polluting industries (Thompson and Cowton, 2004). Banks are also in a unique position to evaluate and value risk. Additionally, banks can create more sustainable products, such ethical or environmental investing funds. On the other side, banks produce wast and use a lot of resources, including paper and energy. As a result, their regulations are crucial for managing recycling and conserving natural resources. These actions imply achieving their environmental responsibility and bank sustainability (Care, 2018). The current research emphasizes numerous strategies, like making a green choice (Ibe-Enwo et al., 2019). Banks often consider eco-preferences when determining consumer satisfaction (Ginovsky, 2009). Additionally, a major objective for businesses is to allocate resources as efficiently as possible. Banks must allocate their resources toward effective and productive uses to increase the desired performance. As a result, it is a powerful mechanism for long-term economic expansion (Gitau and Gor, 2011). Furthermore, the specifications for bank input and output sometimes

[1] DEFI-Tunisia, University of Manouba, ESCT, Tunisia. **Contact :** ines.fdhila@fsegma.u-monastir.tn
[2] University of Monastir, FSEG Mahdia, Tunisia **Contact :** moezlabidi@gmail.com

only include financial indications. For instance, loans are the primary form of payment for capital, deposits, and short-term finance. The environmental input and output of banks are ignored by this definition. The latter, however, makes use of resources from the social and environmental sphere in addition to financial capital. As a result, a lot of environmental discussions center on the connection between eco-efficiency and sustainable banking. These connections enable institutions to simultaneously manage financial and ecological issues. Furthermore, banks' unique characteristics serve as a significant point of differentiation in the complex financial system. However, achieving green sustainability has become difficult because to sustainable banking (Nosratabadi and colleagues 2020). It is critical to have a structure that allows banks to encourage the most sustainable practices. Resource management, cost reduction, stakeholder satisfaction, and reporting on efficiency that contributes to green finance are some examples. Furthermore, banks' obligation for sustainable development has significant implications for efficiency improvement (Belasri et al., 2020). Banks have an essential role in reducing negative environmental impacts due to their understanding of lending risks. Banks can offer varied interest rates (encouraging green projects while penalizing environmental laggards). This price disparity will encourage market price internalization of environmental costs. As a result, banks will be a natural collaborator of governments in preserving the environment. Efficiency, productivity, economic, environmental, and social factors are all implemented by sustainable banks. Additionally, financial considerations are the basis for the conventional standard for evaluating efficiency. According to this perspective, characteristics of ecological, social, and sustainable performance complement financial efficiency (Bergman et al., 2017, Ortiz and Bansal, 2016).

This study attempts to bridge the research gap in the following ways. First, it analyzes the relationship between bank and environmental effects. Second, the study identifies the relationship between eco-efficiency and banks' environmental performance. Third, this research dedicates the major challenge of sustainable banks to contributing to sustainability. Therefore, the main purpose of this is to investigate the impact of sustainable banks on environmental performance by examining eco-efficiency and productivity. This study also examines the mediating role of banking in improving firms' contribution to green sustainability, which combines positive ecological and economic performance and at the same time low costs. To achieve these goals, our study assesses sustainable banks' progress by including in addition to economic resources, environmental resources.
The remainder of the article is structured as follows: section 2 presents the environmental impact of banking. Section 3 surveys the relevant literature on the importance of the relationship between performance, efficiency, and productivity. Section 4 is dedicated to the definition of ecological efficiency. Section 5 covers sampling, the data and the methodological framework. The results for assessment are presented in section 6. Section 7 provides the conclusion.

1. The Environmental Impact of Banking

Currently, banks can play a major role in environmental performance. This involves dealing with internal and external issues. Internally, banks belong to a relatively clean sector. However, the size of the banking system is sufficiently large to have a significant environmental impact (Jeucken and Bouma 1999). A 1995 study of Dutch banks found that waste was perceived as the biggest environmental problem facing banks. Furthermore, three-quarters of the banks surveyed stated that they work on energy efficiency. In the Netherlands, banks consumed approximately 550 million kWh of electricity and 72 million cubic meters of natural gas in 1996 (Jeucken, 1998). While some banks also use renewable energy, other initiatives include water efficiency and transportation policies. They develop more environmentally friendly credit cards. However, measuring environmental performance and interbank comparisons remains challenging. In response, VfU[3] (1998) developed a methodology for standardizing the measurement of environmental pollution in banks.

Externally, banking products have an impact on the environment. The problem is that unlike other sectors in the economy, bank products do not pollute. The users of these products are the ones who affect the environment. This makes it very difficult to assess the environmental impact of external bank activities. In addition, external drivers arise from pressures from governments, customers, competitors, and society. However, banks are held liable for the environmental pollution of their clients or not; the risks of the clients are also the risks of the banks. If a client's continuity is threatened by the new environmental legislation, the bank's continuity will be affected as well. Thus, banks believe that the protection of the external environment would require interference with the activities of their

[3]VfU (Verein fur Umweltmanagement in Banken, Sparkassen und Verseicherungen 1998 Time to Act: Environmental Management in Financial Institutions (Berlin : VfU; http://www.vfu.de).

customers. This is one of the reasons why banks hesitate to promote environmental protection on the external side of their products (even if they may be at risk).

2. Definition of Eco-efficiency

Eco-efficiency is a concept that refers to the ability of an economic activity or process to generate products or services with reduced environmental impact and resource consumption (Belucio and al., 2021). It involves the efficient use of resources, minimizing waste and pollution, and creating more value with few inputs. In other words, eco-efficiency aims to maximize the benefits of economic activity while minimizing the negative impact on the environment (Schuhmacher and Gamboni., 1999). This concept was first introduced by the World Business Council of Sustainable Development in 1992 and has since become a central principle of sustainable development. Eco-efficiency principles can be applied in the banking industry in several ways to reduce the environmental impact of banking operations and promote sustainable development. When considering the relationship between sustainability and eco-efficiency, we can distinguish between weak and strong eco-efficiency improvements (Schaltegger and Burritt, 2000). Major eco-efficiency improvements include improved economic and environmental performance. Therefore, the purpose of our study is to fill this gap.We believe that sustainable banks must manage the impact of their operations on society by using resources efficiently, promoting environmental awareness, and creating values that reduce the negative impact on the environment.

3. Methodological Framework

3.2 Presentation of the Malmquist Productivity Index

The MPI is based on the distance function that provides the efficiency change for a DMU (bank) between two periods. MPI has these advantages. First, we do not need to maximize profits or minimize expenses. Second, it does not assume the prices of inputs and outputs and their information (Kirikal et Tallinna, 2005). The input orientation of MPI and the change in productivity between t and t + 1 is defined as follows:

$$M\,(xt+1, yt+1, xt, yt) = \left[\frac{D_I^t(x^{t+1},y^{t+1})}{D_I^t(x^t+y^t)} \times \frac{D_I^{t+1}(x^{t+1},y^{t+1})}{D_I^{t+1}(x^t+y^t)}\right] = [\,] \; (1) \frac{D_I^{t+1}(x^{t+1},y^{t+1})}{D_I^t(x^t+y^t)} \times \frac{D_I^t(x^{t+1},y^{t+1})}{D_I^{t+1}(x^t+y^t)} \times \frac{D_I^t(x^t,y^t)}{D_I^{t+1}(x^t+y^t)} \quad (1)$$

where M is the Malmquist productivity index supposed for each bank I and for each period t, (t = 1…, T), and the production technology is described as the vector of Inputs x = (x_1,…, x_k), which can be transformed into an output vector y = (y_1,…, y_M). In this formula, the technology of period t is the reference technology.

The two terms in square brackets in equation (1) are:

$$\text{Change in overall technical efficiency} = \frac{D_I^{t+1}(x^{t+1},y^{t+1})}{D_I^t(x^t+y^t)}$$

$$\text{Change in technological progress} = \frac{D_I^t(x^{t+1},y^{t+1})}{D_I^{t+1}(x^t+y^t)} \times \frac{D_I^t(x^t,y^t)}{D_I^{t+1}(x^t+y^t)}$$

Thus, the multiplication of the evolution of technical efficiency and technological evolution leads to the evolution of total factor productivity. Table 1 shows the state of the Malmquist Productivity Index. When M> 1, there is a positive productivity growth rate from period t to period t + 1. In contrast, M <1 implies a decrease in productivity from period t to period t + 1, while M = 1 does not mean any change in productivity.

Table 1: MPI Productivity Level

Malmquist Productivity Index	Productivity level
M> 1	Productivity improvement
M = 1	No change in productivity
M <1	Loss of productivity

3.3 **Modeling of Undesirable Outputs**

Ecological efficiency by carbon emissions in the banking industry is interrelated in several ways. For example, if there is inefficiency in the production processes when it is produced with high CO2 emissions and waste discharges. Banks and other financial institutions are major contributors to carbon emissions, directly and indirectly, through their investments in industries that emit significant amounts of greenhouse gases.

These are undesirable and should be reduced to improve performance (Hassan Dar and al 2021). Using the classification invariance property, we show that the standard DEA model can be used to improve performance by increasing desirable outputs and decreasing undesirable outputs. The method can also be applied to situations where certain inputs need to be increased to improve performance. The linearity and convexity of the DEA are preserved in our proposal. Therefore, we will present a DEA-based linear programming model for the analysis of performance with undesirable results.

Suppose there are n independent DMUs designated by bank (j = 1,…, n). For each DMU, m inputs $x_j = (x_{1j},…, x_{mj})$ are used to produce s outputs $y_j = (y_{1j},…, y_{sj})$. Then, the outputs are classified into desirable and undesirable outputs, in which the outputs corresponding to indices (1,…, p) are desirable outputs and the outputs with indices (p + 1,…, s) are undesirable outputs. In practice, we would like to produce as many desirable products as possibleand as few undesirable products as possible for given input levels.

We first multiply each undesirable output by (-1); then, we find a good vector (y) so that all undesirable outputs are negative.

Let Y be the matrix made up of negative and positive elements and containing the desirable and undesirable outputs observed for the DMUs, and the data matrix Y can be written as follows:

Suppose the DEA data domain is expressed by:

$$Y = \begin{bmatrix} y_j^a \\ -y_j^g \end{bmatrix}$$

where Ya and Yg represent the desirable (good) and undesirable (bad) outputs, respectively. Obviously, after the definitions above, a new model of DEA for undesirable can be shown as follows:

Max (θ -δ)

Under constraint: $\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{i0}$ i = 1,…, m

$\sum_{j=1}^{n} \lambda_j y_{rj}^a \geq \theta y_{r0}^b$ r = 1,…, p

r = p + 1,…, s = $1\sum_{j=1}^{n} \lambda_j y_{rj}^g \leq \delta y_{r0}^g \sum_{j=1}^{n} \lambda_j$

The optimal value of this model implies that the DMU is efficient if and only if the maximum score is close to zero. In other words, the score that is equal to the max implies the worst value observed for this undesirable output.

3.4 **The data**

The sample includes 27 of the world's largest banks, which are ranked by the Banker Database[4]. Our sample includes four groups of banks[5]: Chinese, American, European, and Canadian banks (Table 3). Our analysis framework is based on annual data for a period of 16 years between 2007 and 2022. The sample banks were studied in detail, and the related data were collected from various reliable sources, such as annual reports, sustainability and CSR reports, financial information and extrafinancial disclosures published on the respective websites and data published by the Central Bank and from the BankScope database.

[4]https://www.thebankerdatabase.com/On this website you can find the classification of the 50 largest banks in the world.
[5]After verification, some banks in the ranking were not kept because of lack of data.

Table 2: Sample structure

Bank	Country	World ranking
ICBC	China	1
China Construction Bank	China	2
JP Morgan Chase & Co	US	3
Bank of China	China	4
Agricultural Bank of China	China	5
Bank of America	US	6
Citigroup	US	7
Wells Fargo & Co	US	8
HSBC Holdings	UK	9
Credit Agricole	France	10
BNP Paribas	France	11
Groupe BPCE	France	12
Bank of Communications	China	13
Goldman Sachs	US	14
Barclays	France	15
Royal Bank of Scotland	France	16
Deutsche Bank	Germany	17
Lloyds Banking Group	UK	18
SocieteGenerale	France	19
Credit Suisse Group	Switzerland	20
UniCredit	Italy	21
ING	Netherlands	22
UBS	Switzerland	23
Royal Bank of Canada	Canada	24
Rabobank Group	Netherlands	25
Scotiabank	Canada	26
Nordea bank	Sweden	27
Total number of banks in the sample		**27**

Table 3: Input and output variables used for MPI analysis

Variables	Description	Source
Input		
• **economic**		
Deposits	Total customer deposits in thousand dollars	Bankscope
Tangible fixed assets	Asset expressed in thousand dollars	Bankscope
• **environmental**		
Electricity consumption	Expressed in KWH	RCSR
Water consumption	Expressed in M3	RCSR
Total paper consumption	Expressed in tonnes	RCSR
Output		
Loans	Total customer loans in thousand dollars	Bankscope
Investment	Expressed in thousand dollars	Bankscope
Undesirable output		
Carbon emission	Expressed in tonnes	RCSR

4. Malmquist Productivity Index Results

To measure the MPI, the DEA-Malmquist model is used. Model results are generated using the DEAP application. We obtain an index MPI and its components between a base period t and a period t + 1. According to Coelli et al. 1998, we obtain indices of technical progress when we have panel data.

Indeed, five indices are calculated per bank and per year; they are calculated in relation to the previous year, and the indices relating to the first year are not carried over. They are summarized below:

Table 4: Five indexes from the MPI

effch	technical efficiency change index (CRS technology)
techch	Technological change index
pech	Pure technical efficiency change index (VRS technology)
sech	Scale efficiency change index

tfpch	The total factor productivity change index

6.1Environmental Malmiquist productivity index

The average MPI-environmental data are shown in Table 5 below. This index is a measure of productivity change over time that considers environmental factors such as resource depletion. It is a variation that includes an environmental performance measure in addition to the traditional input and output measures. Overall, banks show on average productivity gains (tfpch) of 5.6%, and a value greater than 1 indicates an improvement in productivity over time largely due to improved technical and technological efficiency. In addition, 19 banks show positive productivity growth (tfpch> 1). It is the result of technological progress (techch> 1). This means that the banks have effectively exploited the scale efficiency gains and the change in pure technical and technical efficiency. Indeed, Group BPCE achieved the best improvement in its environmental productivity, with a growth rate of 36.6%. In addition, Credit Suisse Group and Rabobank Group showed high productivity gains of 28.8% and 25.2%, respectively. In addition, the China Construction Bank has the best change in technological efficiency, with an average annual technological evolution of 14.5%. This could be explained by the fact that the bank started to operate by rationalizing the use of environmental inputs. In addition, Barclays shows a lower level of technological change and therefore experienced lower levels of change in productivity of less than 1. A value less than 1 indicates a decline in productivity. However, in this case, the index considers both economic and environmental performance, providing a more comprehensive measure of productivity.

Table 5: Environmental-Malmquist Index Summary of Firm Means

Bank	effch	techch	pech	sech	tfpch
ICBC	1.000	1.140	1.000	1.000	1.14
China Construction Bank	1.145	1.010	1.118	1.024	1.156
JP Morgan Chase & Co	0.986	1.034	1.130	0.873	1.02
Bank of China	1.000	1.069	1.000	1.000	1.069
Agricultural Bank of China	1.131	1.014	1.086	1.042	1.147
Bank of America	1.003	1.123	1.085	0.924	1.127
Citigroup	0.968	1.057	0.982	0.986	1.023
Wells Fargo & Co	1.064	1.044	1.054	1.010	1.112
HSBC Holdings	0.983	1.087	1.000	0.983	1.068
Credit Agricole	0.975	0.978	0.986	0.988	0.953
BNP Paribas	0.970	1.017	0.986	0.983	0.986
Groupe BPCE	1.260	1.083	1.156	1.090	1.366
Bank of Communications	0.931	0.938	0.967	0.963	0.874
Goldman Sachs	0.937	0.987	0.945	0.992	0.925
Barclays	0.873	0.988	0.916	0.954	0.863
Royal Bank of Scotland	0.932	0.965	0.968	0.962	0.899
Deutsche Bank	0.867	1.076	0.914	0.949	0.933
Lloyds Banking Group	0.940	1.107	0.961	0.977	1.040

Societe Generale	0.972	1.047	0.993	0.979	1.017
Credit Suisse Group	1.087	1.186	1.052	1.033	1.288
UniCredit	1.050	1.118	1.049	1.000	1.174
ING	0.961	1.109	1.000	0.961	1.066
UBS	0.963	0.995	1.017	0.947	0.958
Royal Bank of Canada	0.954	1.115	0.953	1.001	1.064
Rabobank Group	1.114	1.124	1.099	1.013	1.252
Scotiabank	0.913	1.118	0.918	0.994	1.021
Nordea bank	0.910	0.981	0.927	1.000	**0.975**
Mean	0.992	1.010	0.983	0.986	1.056

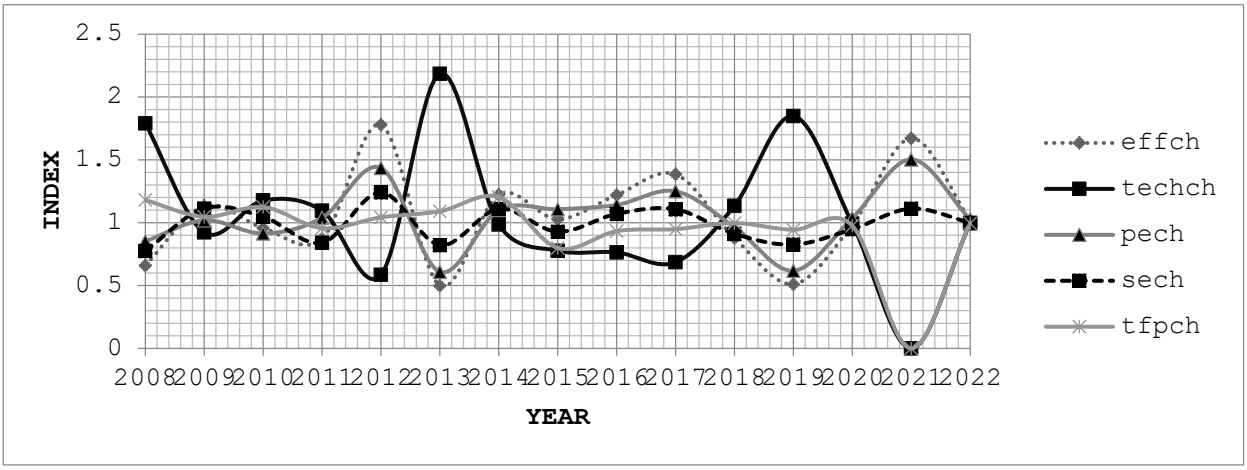
Descriptive statistics

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
effch	27	.9958889	.0893921*	.867	1.26
techch	27	1.055926	.0635603**	.938	1.186
pech	27	1.009704	.0683564**	.914	1.156
sech	27	.9862222	.0403955*	.873	1.09
tfpch	27	1.056148	.124132**	.863	1.366

By using our data, we calculated the environmental-MPI means for each year. The figure below summarizes the results of the evolution of the Malmquist index, as well as its components of productivity. The index values show that bank productivity improved slightly in 2008, declined in 2010, and then improved steadily from 2018 to 2022; however, these index values do not consider banks' environmental performance. To account for environmental performance, we can decompose index values into technical efficiency and technological efficiency. The environmental performance adjusts to the technological change component of MPI. A value greater than 1 indicates an improvement in environmental performance, while a value less than 1 indicates a decline in environmental performance. During this period, the TFP index (tfpch) was less than 1, which means that banks suffered a loss of environmental productivity.

Based on this decomposed index value, we can see that banks' non environmental productivity improved slightly between 2010 and 2017, declined in 2018, and then improved staidly from 2019 to 2022. However, the bank's environmental performance improved consistently over the three-year period, contributing positively to overall productivity improvement. This interpretation of the environmental-MPI highlights the importance of considering both economic and environmental productivity performance when assessing productivity change over time.

Figure 1: Evolution of the Malmquist-environmental productivity index and its components



4.2 Economic Malmquist Productivity Index

In this case, two inputs and two outputs are aggregated, and we analyze these indices by bank. The average results of the economic MPI are presented in Table 7.

Economic-MPI can be used to compare the productivity of banks over time or across different banks. Economic-MPI are presented in table 6. Banks with higher values of the index are more productive than those with lower values. According to Table 6, the range of total factor productivity is between 0.89 and 1.079 with an average value of 0.989. Group BPCE is ranked first with a **tfpch** 1.079 of its productivity, which represents a productivity improvement of 7.9% and ICBC in last place. ICBC's productivity growth rate declined to -8%. It may appear that Group BPCE is more productive than ICBC. Additionally, Glodman sachs saw an improvement in economic TFP of 7.7%. In addition, several banks experienced an expansion in productivity, namely,Credit Agricole, Wells Fargo & Co, Nordea bank, and Rabobank Group, which represent 7.6%, 6.5%, 5.9%, and 5.3%, respectively. We note that the banks have not experienced the same performance both in terms of technical efficiency and in terms of technological progress (columns 2 and 3). A total of 14 banks increased their productivity, and the remainingbanks recorded a loss of productivity. In general, the average value of TFP is above 1,000, which means that the functioning of banks is progressing toward sustainability.

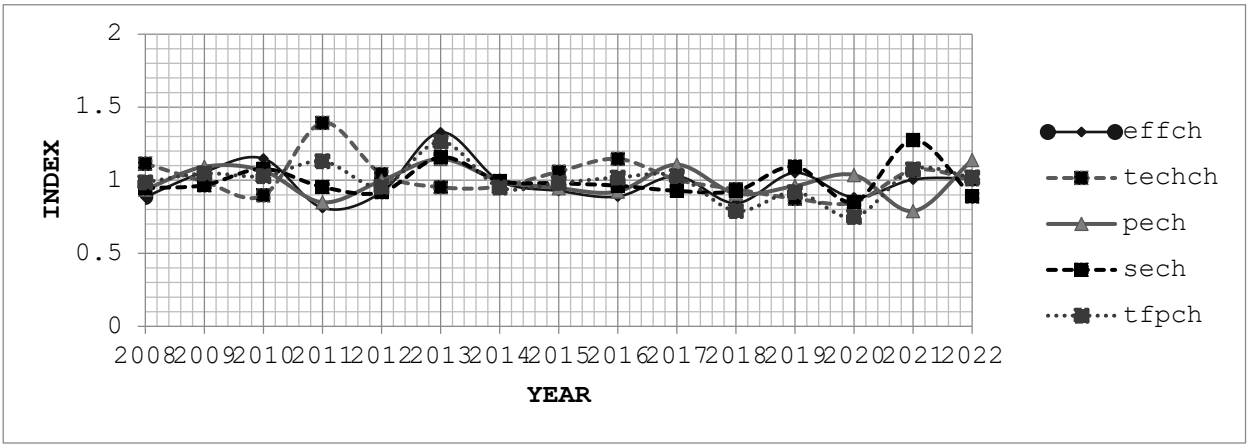
Table 6: Economic-Malmquist index summary of firm means

Bank	effch	techch	pech	sech	tfpch
ICBC	0.910	0.978	0.964	0.945	0.890
China Construction Bank	0.905	0.989	0.961	0.942	0.896
JP Morgan Chase & Co	0.990	1.004	1.021	0.970	0.994
Bank of China	1.016	1.003	1.018	0.998	1.019
Agricultural Bank of China	0.947	0.990	1.018	0.931	0.937
Bank of America	1.000	1.006	1.000	1.000	1.006
Citigroup	1.005	1.005	1.005	1.000	1.010
Wells Fargo & Co	1.012	1.053	1.009	1.003	1.065
HSBC Holdings	0.989	0.974	1.000	0.989	0.962
Credit Agricole	1.032	1.043	1.030	1.002	1.076

BNP Paribas	1.066	0.953	1.065	1.001	1.016
Groupe BPCE	1.055	1.023	1.000	1.055	1.079
Bank of Communications	0.899	1.029	0.927	0.970	0.925
Goldman Sachs	1.000	1.077	1.000	1.000	1.077
Barclays	0.987	1.018	0.991	0.996	1.005
Royal Bank of Scotland	0.987	1.049	0.986	1.001	1.035
Deutsche Bank	0.912	0.999	0.976	0.934	0.911
Lloyds Banking Group	1.010	0.996	1.007	1.003	1.006
Societe Generale	0.912	0.999	0.908	1.004	0.911
Credit Suisse Group	0.902	1.007	0.936	0.963	0.908
UniCredit	0.994	1.013	1.000	0.994	1.007
ING	0.999	0.988	1.000	0.999	0.987
UBS	0.898	1.046	0.908	0.989	0.939
Royal Bank of Canada	0.953	1.022	0.955	0.998	0.975
Rabobank Group	1.017	1.035	1.016	1.001	1.053
Scotiabank	0.974	1.021	0.970	1.003	0.994
Nordea bank	1.062	0.997	1.019	1.042	1.059
Mean	**0.992**	**1.010**	**0.983**	**0.986**	**1.056**
Variable	Obs	Mean	Std. Dev.	Min	Max
effch	27	.979	.0519867*	.898	1.066
techch	27	1.011741	.0272391**	.953	1.077
pech	27	.9885185	.0374036**	.908	1.065
sech	27	.9901111	.0285392*	.931	1.055
tfpch	27	.9904444	.0591383*	.89	1.079

In addition, the figure below shows the annual change in the total productivity of economic factors and their components from 2007 to 2022. The components of total factor productivity also increased and decreased over the study period. Through the figure, the strongest annual growth in TFP is observed in 2010. Between 2007 and 2008, productivity declined. Similarly, the index for the banks in 2016 and 2017 has declined. In year 220, productivity improved relative to the previous year. The economic-MPI subsequently, the economic TFP index improved but with a downward and upward trend. Moreover, the decline in the economic productivity of banks has been mainly caused by a decline in efficiency rather than a decline in technological innovation. Overall, banks can promote their productivity by improving the level of change in technological efficiency (techch). Thus, the improvement in productivity is attributable to technical efficiency. Finally, all sustainable banks demonstrated a high level of productivity compared to unsustainable banks.

Figure 2: Evolution of the economic-Malmquist productivity index and its components



5. Alternative analysis to eco-efficiency

Recall that the demonstration of the rationality of our model is evident by a comparison of the efficiency scales with the ecological Malmquist productivity index EMP. considers environmental efficiency (how efficiently resources are used to minimize environmental impacts). Indeed, eco-efficiency, we can obtain the ecological performance value by including undesirable outputs (such as CO2 emissions). First, to validate our results, table 7 reports an ANOVA test that is a statistical method used to compare means significant. To interpret this result, we can first look at the p value of the F test, which is 0.0028. This value is less than the significance level of 0.05, indicating a significant difference between the means of ecological efficiency by 27 banks.

Table 7 shows that the average eco-efficiency of inefficient banks is 73.5%, which is far higher than the optimal efficiency value, which is zero. The ecological efficiency ranges from 37.1% to 100%. Thus, among inefficient banks, HSBC Holdings. For ICBC, the consumption of energy resources should be the lowest. In addition, ICBC, Deutsche Bank, and ING show high ecological inefficiency scores of 96%, 95% and 93%, respectively. On the other hand, the China Construction Bank and Societe Generale posted the best scores of 37.1% and 40%, respectively. For other banks, ecological efficiency scales vary between 50% and 85%. Therefore, it is important that banks reduce the use of the resources that generate pollution emissions to promote eco-efficiency through the development of green finance. This involves directing capital toward environmentally sustainable investment, such as renewable energy. By doing so, banks can contribute to reducing costs and promoting ecological efficiency.

Overall, improving ecological efficiency in the banking system can have significant benefits for both the environment and the financial sector. Therefore, central banks should develop policies aimed at promoting ecological efficiency and sustainable development. Different provinces should have different strategies for optimizing eco-efficiency. In addition to appropriate technologies, financial support and management policies should be provided according to the attributes of each bank. By promoting sustainable practices and investments, banks can help to drive the transition to a more sustainable economy while also managing risk and creating value for their stakeholders.

In conclusion, we state that improving eco-efficiency does not guarantee sustainability; the latter could be seen as transforming unsustainable development into sustainable development. Therefore, to achieve sustainable development, backward banks should improve the use of resources and simultaneously reduce emissions. In general, if the eco-efficiency indicator is not used by banks, then it will not contribute to improving the environment. Therefore, simply for eco-efficiency to be a good indicator of environmental performance, it should be supported by an analysis that investigates its relationship with large systems, particularly the banking system.

Table 7 : Ecological efficiency by bank

Banque/VRS	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Means
ICBC	1.000	1.000	1.000	1.000	1.000	1.000	0.750	0.888	0.897	1.000	1.000	1.000	1.000	0.834	1.000	1.000	0.960
China Construction Bank	0.267	0.287	0.345	0.218	0.295	0.442	0.384	1.000	0.273	0.356	0.347	0.382	0.362	0.307	0.325	0.358	0.371
JP Morgan Chase & Co	0.992	0.782	0.929	1.000	0.892	1.000	0.930	0.911	0.811	0.905	0.814	1.000	1.000	1.000	1.000	1.000	0.935
Bank of China	0.660	0.671	0.635	0.639	0.693	0.953	0.759	0.612	0.721	0.754	0.715	1.000	1.000	1.000	1.000	0.685	0.781
Agricultural Bank of China	0.360	0.360	0.321	0.306	0.217	0.428	0.555	0.437	0.473	0.438	0.499	0.446	0.342	0.365	0.494	0.381	0.401
Bank of America	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.758	0.556	0.668	1.000	1.000	1.000	0.936
Citigroup	0.968	0.762	0.843	0.816	0.783	0.790	0.808	0.790	0.826	1.000	0.911	0.666	0.754	0.707	0.740	1.000	0.822
Wells Fargo & Co	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.995	0.999
HSBC Holdings	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Credit Agricole	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.717	0.886	0.734	0.656	0.514	0.906
BNP Paribas	0.844	0.369	0.566	0.480	0.517	0.694	0.771	0.782	0.833	0.772	0.856	0.800	1.000	1.000	1.000	1.000	0.767
Groupe BPCE	0.258	0.313	0.325	0.299	0.272	0.440	0.258	0.367	0.305	0.993	1.000	0.248	0.267	0.176	1.000	0.955	0.467
Bank of Communications	1.000	1.000	1.000	1.000	0.414	0.541	0.518	0.664	0.492	0.694	0.575	1.000	1.000	1.000	1.000	0.470	0.773
Goldman Sachs	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.449	0.421	0.666	0.527	0.576	0.440	0.817
Barclays	1.000	1.000	0.797	1.000	0.951	1.000	1.000	1.000	1.000	0.567	0.467	0.502	0.597	0.848	0.720	0.390	0.802
Royal Bank of Scotland	1.000	1.000	0.902	0.946	0.898	0.889	1.000	0.903	1.000	1.000	0.377	0.399	0.505	0.355	0.334	0.399	0.744
Deutsche Bank	1.000	1.000	1.000	1.000	1.000	0.690	1.000	1.000	0.970	0.899	0.793	1.000	1.000	1.000	1.000	1.000	0.959
Lloyds Banking Group	0.420	0.458	0.485	0.606	0.559	0.725	0.647	0.814	0.399	0.834	0.666	0.856	0.661	0.529	0.543	0.465	0.604

Societe Generale	0.282	0.336	0.384	0.285	0.292	0.372	0.329	0.614	0.354	0.529	0.455	0.506	0.392	0.581	0.384	0.305	0.400
Credit Suisse Group	0.350	0.422	0.422	0.382	0.410	0.651	0.500	0.645	0.542	0.690	0.549	0.955	0.748	1.000	1.000	1.000	0.641
UniCredit	0.567	0.678	0.932	0.458	0.406	0.834	0.512	0.704	1.000	0.835	0.770	0.686	1.000	0.533	0.999	1.000	0.744
ING	1.000	0.798	0.798	0.530	0.870	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.937
UBS	0.331	0.292	1.000	0.359	0.259	0.442	0.294	0.396	0.658	0.816	0.521	0.565	0.597	0.606	0.601	0.384	0.507
Royal Bank of Canada	1.000	1.000	0.512	0.536	0.549	1.000	0.575	0.543	0.698	0.660	0.579	0.641	0.564	0.611	0.549	0.480	0.656
Rabobank Group	0.200	0.323	0.356	0.335	1.000	0.495	0.467	0.440	0.329	0.614	0.592	0.251	0.397	0.285	0.400	0.360	0.427
scotiabank	0.658	0.688	0.683	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.545	0.652	0.454	0.855
nordea bank	1.000	1.000	0.965	0.598	0.502	0.592	0.531	0.633	0.535	0.520	0.763	0.427	0.359	0.272	1.000	0.259	0.622
Means	0.746	0.723	0.748	0.696	0.695	0.776	0.725	0.783	0.745	0.810	0.720	0.704	0.732	0.696	0.776	0.677	

ANOVA-Analysis	**SS**	**DF**	**Ms**	**F**	**Signification Prob> F**
Between groups	4208.78049	213	19.7595328	0.87	0.028
Within groups	4971.21951	218	22.8037592		
Total	9180	431	21.2993039		

6. Benchmarking analysis

As part of our process, benchmarking environmental performance and ecological efficiency are used to evaluate the sustainability of banks. The table below provides a benchmark analysis by comparing the environmental performance of banks with the performance of other banks.

The classification of the 27 banks based on sustainability shows that the first position is occupied by Group BPCE. This means that Group BPCE generates sustainability through its high environmental performance using all resources optimally (energy consumption, water, and paper usage). Additionally, Credit Suisse Group and Rabobank Group are ranked in second and third positions, respectively. In addition, the Rabobank group occupies the fourth position. According to the ecological efficiency, the position of Credit Suisse Group has changed significantly by moving to the ninth position. This is mainly due to a lower contribution of the efficiency and productivity of economic resources, which ranks twenty-five. Nevertheless, it should be noted that Credit Suisse Group makes a positive environmental contribution in terms of efficiency and productivity. The same effect is seen for the Rabobank Group. Thus, Table 8 shows that the China Construction Bank is sustainable because it efficiently uses its environmental resources (productivity dimension). Additionally, we add that these positive values are due to the positive contributions of ecological efficiency (in terms of CO2 emissions) and economic indicators. However, the China Construction Bank appears to manage environmental resources more efficiently than the benchmark.

Unlike Rabobank Group, Unicredit, etc. Bank of Communications Royal Bank of Scotland represent low resource contributions to environmental performance in terms of eco-efficiency and productivity. These banks use their resources much less efficiently than the benchmark.Barclays comes in last position. This is mainly due to losses in total factor productivity (environmental and ecological efficiency). These results suggest that both benchmarking environmental performance and ecological efficiency analysis can provide valuable insights into the environmental performance and sustainability of banks.

Overall, over the study period, the result shows a trend toward variability in the sustainability of the bank. However, we conclude that all resources are used efficiently by the Groupe BPCE.
These results confirm that Group BPCE is the benchmark. It creates positive environmental performance throughout the study period. The latter uses all the resources considered in an efficient, productive, and sustainable value-creating manner compared to other banks.
In sum, these results indicate that agricultural credit is sustainable where its resources have been well allocated to achieve the highest possible contribution to sustainable development. This is only done if a bank covers optimization in addition to traditional economic resources and environmental resources. Despite these challenges, environmental performance benchmarks can be useful for banks to identify areas where they can improve their environmental performance, compare themselves to peers, and communicate their sustainability efforts to stakeholders.

Table 8 : Benchmarking analysis

Bank	Productivity dimensions				Ecoligical efficiency	
	Environnemental	Rank	Economic	Rank	Ecoligical	Rank
Groupe BPCE	1.366	1	1.079	1	0.467	5
Credit Suisse Group	1.288	2	0.908	25	0.641	9
Rabobank Group	1.252	3	1.053	6	0.427	4
UniCredit	1.174	4	1.007	11	0.744	12

China Construction Bank	1.156	5	0.896	26	0.371	1
Agricultural Bank of China	1.147	6	0.937	22	0.401	3
ICBC	1.14	7	0.890	27	0.960	25
Bank of America	1.127	8	1.006	12	0.936	22
Wells Fargo & Co	1.112	9	1.065	4	0.999	26
Bank of China	1.069	10	1.019	8	0.781	15
HSBC Holdings	1.068	11	0.962	19	1.000	27
ING	1.066	12	0.987	17	0.937	23
Royal Bank of Canada	1.064	13	0.975	18	0.656	10
Lloyds Banking Group	1.040	14	1.006	13	0.604	7
Citigroup	1.023	15	1.010	10	0.822	18
scotiabank	1.021	16	0.994	16	0.855	19
JP Morgan Chase & Co	1.02	17	0.994	15	0.935	21
Societe Generale	1.017	18	0.911	24	0.400	2
BNP Paribas	0.986	19	1.016	9	0.767	13
nordea bank	0.975	20	1.059	5	0.622	8
UBS	0.958	21	0.939	20	0.507	6
Credit Agricole	0.953	22	1.076	3	0.906	20
Deutsche Bank	0.933	23	0.911	23	0.959	24
Goldman Sachs	0.925	24	1.077	2	0.817	17
Royal Bank of Scotland	0.899	25	1.035	7	0.744	11
Bank of Communications	0.874	26	0.925	22	0.773	14
Barclays	0.863	27	1.005	14	0.802	16

7. Conclusion

In conclusion, sustainable bank can contribute to greening finance in the local and global finance by integrates the optimization of economic and environmental resources. In this context, raising awareness of the ecological use of resources will therefore contribute to increase energy efficiency and improve waste and water management. This study can be seen as the first approach to provide banks with guidelines on how to measure progress in the rational use of resources and how to integrate these results into sustainable finance program. Further implication of the results reveals that a bank creates sustainable performance if it efficiently uses economic, environmental, and social resources compared to the benchmark. While ecological efficiency is not only important to analyze ecological productivity and other environmental factors but can help us make informed decisions about how to manage and protect ecosystems, engage people, technology, and communities. By adopting clear policies, managing climate risks, and engaging with stakeholders, banks can play a crucial role in promoting a green sustainability goals and resilient future.

References

Aman shah A., Wu D., and Korotkov V. (2019). Are Sustainable Banks Efficient and Productive? A Data Envelopment Analysis and the Malmquist Productivity Index Analysis. Sustainability 2019, 11, 8, 2398.

Belucio M. Rodrigues C. Henggeler Antunes C. Freire F. and Dias L, C. (2021). Eco-efficiency in early design decisions: A multimethodology approach. Journal of Cleaner Production. Volume 283, 10.

Bergmann A. Günther E. et Kara S. (2017). Resource Efficiency and an Integral Framework for Performance Measurement. Sustainable Development, 25: 150–165.

Caré. R. (2018). Sustainable Banking Issues and Challenges. ISBN 978-3-319-73388-3 ISBN 978-3-319-733890 (eBook).

Chen and al. (2018). Green banking for environmental sustainability present status and future agenda: experience from Bangladesh. Asian Economic and Financial Review. Vol. 8, No. 5, 571-585.

Ginovsky, J., (2009). Green banking - inside and out. Community Banker, 1(1): 30-32.

Gitau M.G. et Gor S.O. (2011). Measuring factor productivity of the banking sector in Kenya. OIDA International Journal of Sustainable Development.

Hassan Dar A. Kumar Mathur S. and Mishra S. (2021). The Efficiency of Indian Banks: A DEA, Malmquist and SFA Analysis with Bad Output. Jouranal of Quantitative Econonmics volume 19, Page 653-701.

Ibe-Enwo, G. Igbudu, N. Garanti, Z. Popoola, T. (2019). Assessing the relevance of green banking practice on bank loyalty: the mediating effect of green image and bank trust. Sustainability 11(17):4651.

Jeucken M. et Bouma J. (1999). The Changing Environment of Banks. Greener Management International, 27 : 21-3.

Jeucken, M.H.A. (1998). Duurzaam Bankieren: Een visie op bankieren en duurzame ontwikkeling. Banque durable : vision sur la banque et le développement durable.Utrecht: Rabobank. Http// : www.sustainability-in-finance.com.

Kirikal L., Tallinna T. (2005). Productivity, the Malmquist index, and the empirical study of banks in Estonia. Tallinn Technical University Press; 2005.

Nosratabadi, S. Mosavi, A. Duan, P. Ghamisi, P. Filip, F. Band, S. Gandomi, A. H. (2020). Data science in economics: comprehensive review of advanced machine learning and deep learning methods. Mathematics, 8(10), 1799.

Ortiz de Mandojana, N., & Bansal, P. (2016). The long-term benefits of organizational resilience through sustainable business practices. Strategic Management Journal, 37(8), 1615–1631.

Schuhmacher, I., Gamboni, G. (1999). Eco-efficiency in Banking - From Assessing the Risks to Expanding the Opportunities. In: Hitchens, D.M.W.N., Clausen, J., Fichter, K. (eds) International Environmental Management Benchmarks. Springer, Berlin, Heidelberg.

Zhang, W. Chang, C. Xuan, Y. (2022). The impacts of climate change on bank performance: What's the mediating role of natural disasters? Economic Change and Restructuring (2022) 55 :1913–1952.