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Measuring post-crisis productivity for Jamaican banks

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Abstract

The study examines the changes to total factor productivity of Jamaican banks between 1998 and 2007. Using Data Envelopment Analysis with bootstrap to construct a Malmquist index, bank productivity is measured and decomposed into technical progress and efficiency. The results suggest an inconsistent growth pattern for banks between 1998 and 2007 driven mainly by efficiency gains in the immediate post-crisis period to 2002, and by technological progress towards the end of the sample period. The second largest banks along with merchant and locally-owned banks showed significant productivity growth in some models, with modest growth for commercial and foreign-owned banks.

Keywords: Bank productivity, Malmquist Productivity index, DEA, bootstrapping, Jamaica
JEL Codes: G21, G28

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1. Introduction

The global financial crisis, 'credit crunch' and bailout precipitated by the sub-prime mortgage crisis in the United States of America in 2007/8 have been ascribed causality for a number of correlated events. For example, Dr. Robert Bausch of Executive Inc. has noted that 'We will experience dramatic drops in productivity, across all sectors of American business, due to the financial crisis and subsequent bailout, and this will unfortunately continue to have a negative impact for a very long time to come.'[1] Change in productivity levels is usually high on the agenda of issues considered in relation to this arguably unprecedented financial crisis. Certainly, the impact of general instability intensified by a financial crisis and 'credit crunch' will impact the level at which workers are able to produce. However, the exercise of caution is important since correlation does not equate to causation and there is no certainty as to the direction of causation of the apparent relationship, which itself need not be linear. In fact, it is arguable that productivity within different sectors will be affected in different ways by any major change in the landscape of an economy that increases the level of the uncertainty.

In this time of agitation and potentially egregious diagnosis, further caution is necessary due to what Doeringer (1988) describes as a tendency to ignore the occurrence of different productivity patterns within an economy and also to view declines in total factor productivity as symptomatic of deficiencies in human capital (the effort of workers as distinct from managers). In a somewhat dated study analysing the labour market in Jamaica, he argued against the 'conventional wisdom' about Jamaica's productivity problem which he reported as:

> … the Jamaican labour force … has serious productivity problems. Lack of training, poor attitudes, labour turnover, absenteeism, militancy, and generally low levels of effort and commitment to industrial work, are the most commonly mentioned sources of low productivity. These problems are alternatively traced to Jamaica's history of paternalism, to a cycle of low pay, high turnover and absenteeism … and to inefficient work practices, strikes and pressures to retain redundant employees caused by militant unions (1988:469).

[1] http://www.prlog.org/10125173-dramatic-productivity-drops-surround-financial-crisis-credit-crunch-and-bailout.html

Doeringer (1988) noted that the recorded overall decline in labour productivity at the time masked the divergent patterns of productivity in different sectors of the economy. His findings pointed to 'substantially' improved labour productivity in Jamaica resulting from changes in management practices with respect to the organisation and utilization of labour and the quality of human resource management generally, in some sectors.

The purpose of this paper is to examine the changes to total factor productivity of the Jamaican banking sector between 1998 and 2007. The data set consists of an unbalanced panel of twelve banks: six merchant banks and six commercial banks. The non-parametric Data Envelope Analysis (DEA) is used to construct Malmquist productivity indices. DEA is a non-parametric linear programming method that applies observed input and output data to create a 'best practice' frontier. The main drawback of the DEA approach is the assumption of no measurement error in the inputs and outputs as this restricts statistical evaluation. Based on the work of Färe *et al*. (1994) we therefore, and in addition, construct Malmquist productivity indices using a bootstrap framework. The advantage of the Malmquist index is the further possible decomposition of productivity change into its components of technological change, which captures any expansion in the production frontier, and technical efficiency change, which captures movements in relation to the efficient frontier. This decomposition into technological changes and efficiency changes allows for the possibility of investigating the potential effect of specified events on each of the components as well as the contribution of each component to any change in total factor productivity.

The objectives of this paper are three-fold. First, it utilises four alternative model specifications of inputs and outputs as a means of arriving at a realistic robust measure of the productivity of Jamaican banks. Second, it employs a bootstrap method to provide statistical inferential capability to the estimates of productivity of the panel of Jamaican banks, thereby addressing the inherent problem of inference in the use of DEA as a measure of relative performance. Third, it acknowledges that non-performing loans (NPLs) are more than just an inevitable by-product of banking and models NPLs as an undesirable output.

Generally speaking, the findings are indicative of an inconsistent growth pattern for banks between 1998 and 2007 driven mainly by efficiency gains in the immediate post-crisis period to 2002, and by technological progress towards the end of the sample period. The second largest banks along with merchant and locally-owned banks showed significant productivity growth in some models, while more modest growth was evidenced for commercial and foreign-owned banks.

The next section outlines the background to Jamaica's banking sector. Section 3 reviews the literature on bank productivity and the Malmquist methodology. Section 4 discusses the model strategy and data. Section 5 presents the empirical results and Section 6 some concluding remarks.

2. Jamaica and Banking in Jamaica

Jamaica, the largest island in the English-speaking Caribbean and the third largest in the Caribbean as a whole, may be said to be the archetype of a typical developing country. With income *per capita* of about US$3,710 (2007) and primary school enrolment of approximately 90.3% (2005) Jamaica has a relatively well-educated population.[2] In many ways Jamaica's economic history has perpetuated a centralised, bureaucratic tradition carried over from its English heritage: this may have contributed to socialised attitudes to work and the organisation of labour (management).

Jamaica's network of banks is fairly well-developed and diversified consisting of the Bank of Jamaica (BoJ – the Central Bank), commercial banks, merchant banks, non-banking financial firms (finance houses, building societies, credit unions, trust companies), and development banks. In Jamaica's liberalised financial environment, banks operate within a

[2] http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20535285~menuPK:1390200~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html (retrieved March 30, 2009).

relatively small market and therefore face tough competition. Table 1 outlines the population of banks in Jamaica for selected periods. Even when fewer in number overall, the 'traditional' commercial banks dominate merchant banks, both in terms of their geographical presence through branches scattered across the island and in terms of share of total assets of the sector.

Table 1 Number of Commercial and Merchant Banks 2002-2007

Banks	Dec 2002	Dec 2003	Dec 2004	Dec 2005	Dec 2006	Dec 2007
Banks	6	6	6	6	6	6
Merchant	10	7	5	5	5	4
Total	16	13	11	11	11	10

Source: http://www.boj.org.jm/supervised_deposit.php

The past decade has evidenced significant changes in Jamaica's banking sector. Apart from international and internationally directed events such as financial crisis in South-East Asia and accounting changes resulting from the adoption of International Financial Reporting Standards (IFRS), the past post-crisis decade has also witnessed various attempts by the Jamaican bank regulators to enhance their intelligence as well as to foster a stronger banking sector through supervised mergers of weak (and failing or theoretically failed) banks.[3] At the end of 2007, 5 of the 6 commercial banks operating and 1 of the 4 merchant banks had majority foreign ownership.

Since banks serve as the primary vehicles for financial intermediation in Jamaica, they play a pivotal role in economic development. Policy planning and strategy must, of necessary, involve enhancements to bank efficiency and productivity as key strategies to survival. Unfortunately, due to the relatively small number of banks in Jamaica and the inaccessibility of high-quality bank-specific data, there is a paucity of research on critical banking issues. That banking remains under-researched in Jamaica is an unfortunate restriction on empirical evidential information for policy development and strategy. While there has been relatively little work on the causes of the Jamaican banking crisis *per se*, this is

[3] 'Banks' refer to deposit-taking entities governed by the Banking Act (commercial banks) or the Financial Institutions Act (merchant banks). Bank failure is defined to include bailout and regulator-induced or supervised merger.

the first work to our knowledge to examine banking productivity in Jamaica using non-parametric bootstrap technology.

3. Bank productivity methodology and literature

The monitoring of productivity growth from one period to the next is particularly significant in the light of growing empirical support for the strong positive correlation between financial market development and economic growth in developing countries (see, for example, La Porta *et al.*, 1998). We utilize the Malmquist Productivity Index to analyse productivity changes within Jamaican banks as it allows for comparison of the inputs of a bank unit over two periods of time (t and $t + 1$) and to determine by how much the input in period t could be decreased while achieving the same level of output in period $t + 1$.[4] The bank that is able to produce the greatest number of outputs per unit of combined inputs is said to be most productive. In fact, an output efficient bank is also the most productive as it requires increases in one or more of its inputs in order to increase its output because it is already producing the maximum number of units possible with the current level of inputs. Where the bank is output inefficient, it is not the most productive and the current level of inputs could be more efficiently utilised to increase its output. By the same token, productivity can be evaluated in terms of input efficiency (inputs cannot be reduced without reducing output) or input inefficiency (a reduction in inputs should not result in a reduction in output).

DEA is widely used for the evaluation of relative firm efficiency and, by inference, productivity. DEA is a non-parametric technique grounded in linear programming that constructs an efficient frontier of firms based on those firms that are producing the maximum output for a given input (output efficient) or utilising the minimum inputs for a given level of output (input efficient). Firms that lie on the efficient frontier are assigned a score of 1 (or 100%), while less inefficient firms (not on the frontier) are assigned a score less than 1.

[4] Grosskopf (2003) provides a brief history of the Malmquist productivity index and discusses the theoretical and empirical issues related to the index. For the decomposition of the Malmquist productivity index, see Lovell (2003).

However, the measurement of productivity growth is constrained by the fact that scores obtained from a particular sample cannot be compared with another sample in a different time period.

The Malmquist Productivity Index is a combined index based on the DEA that may be extended to measure changes in productivity over time. Färe *et al*. (1994) developed a Malmquist Productivity Index (M) based on constant returns to scale (CRS) that enables productivity growth to be decomposed to identify how much of the change in the efficiency (and productivity) level of a bank over time relates to 'frontier shifts' (the movement by all banks due to technological innovation) or relative 'catch-up' shifts (by individual banks).[5] Briefly, for a vector of inputs $\{x\}$ and vector of outputs $\{y\}$, for each time period $\{t\}$ the production set $\{S_t\}$ describes all feasible input-output pairs at a given time such that:

$$y_t = \max\{\hat{y}_t : (x_t, y_t) \in S_t\} \tag{1}$$

However, observed output at any point of time $\{\hat{y}_t\}$ may not correspond to the maximum potential output for given input $\{x_t\}$. The appropriate method of accounting for the discrepancy between actual and potential maximum output (technical inefficiency) is the output distance function of Shephard (1970) or Färe (1988) defined as:

$$d_t(y_t, x_t) = \inf\{q : (y_t/q, x_t) \in S_t\} \tag{2}$$

To construct the Malmquist productivity index we specify the distance function for two adjacent time periods. For period {t+1} the distance function is defined as:

$$d_{t+1}(y_{t+1}, x_{t+1}) = \inf\{q : (y_{t+1}/q, x_{t+1}) \in S_{t+1}\} \tag{3}$$

[5] We use banks here but the principles could be applied to any decision-making unit (DMU). A further decomposition can be conducted by separating the change in efficiency into the change in pure efficiency × change in scale efficiency. The change in efficiency is constructed under CRS while the change in pure efficiency and scale efficiency is constructed under VRS (see, for example, Ray and Desli, 1997).

The Malmquist index (M) of total factor productivity change is the geometric mean of the two output distance function ratios based on the technology for period's t+1 and t respectively. In other words:

$$M = \left[\frac{d_{t+1}(y_{t+1}, x_{t+1})}{d_{t+1}(y_t, x_t)} \frac{d_t(y_{t+1}, x_{t+1})}{d_t(y_t, x_t)} \right]^{\frac{1}{2}} \tag{4}$$

In their study of productivity growth in industrialised countries, Färe *et al.* (1994) decompose (4) for changes in technical efficiency (catch up) and changes in frontier technology (innovation). This can be seen by expressing (4) as:

$$M = \frac{d_{t+1}(y_{t+1}, x_{t+1})}{d_t(y_t, x_t)} \left[\frac{d_t(y_{t+1}, x_{t+1})}{d_{t+1}(y_{t+1}, x_{t+1})} \frac{d_t(y_t, x_t)}{d_{t+1}(y_t, x_t)} \right]^{\frac{1}{2}} \tag{5}$$

or

$$M = E_{t+1} T_{t+1}$$

where

M = the Malmquist productivity index

E_{t+1} = a change in relative technical efficiency over the period t and t+1

T_{t+1} = a measure of technical progress measured by shifts in the frontier from period t to t+1

When $M > 1$ it means that there has been a positive total factor productivity change between period t and $t + 1$. When $M < 1$ it means that there has been a negative total factor productivity change.

The Malmquist index has been growing in importance as a method of evaluating the productivity performance of banks and has evidenced increasing academic enquiry utilising data from various types of economies. Using data from the United States of America Wheelock and Wilson (1999) employed Malmquist decomposition to examine bank productivity for the period 1984 to 1993. They utilised interest paying deposits as an input and non-interest paying demand deposits as output and reported a general drop in average productivity caused by failure to catch-up with outward shifts of the production frontier.

Alam (2001) found that the deregulation period resulted in a productivity surge in the first half of the 1980s followed by a productivity regress in the second half for large US banks. These results were confirmed by Mukherjee *et al*. (2001) who also used panel estimation to explain productivity growth in terms of bank size, product-mix and capitalisation.

Casu *et al*. (2004) find that productivity growth in European banking has been largely brought about by technological change rather than efficiency improvement. Berg *et al*. (1992) examined Norwegian banks 1980 to 1989 and found productivity regress prior to deregulation and strong productivity gains due to catch-up after deregulation. Other studies of bank productivity using the Malmquist method have been Drake (2001) for the UK, Grifell-Tatjéand and Lovell (1997) for Spain, Canhoto and Dermine (2003) for Portugal, Noulas (1997) for Greece and Isik and Hassan (2003) for Turkey.

Outside of the USA, UK and Europe, we also find a number of studies conducted on the productivity of banks in developing countries. Meza and Quintin (2005) note from recent evidence from Mexico and Asia that aggregate total factor productivity (TFP) falls markedly during financial crises, and 'precipitously' (p.3) following the crises and that this 'presents a difficult challenge for the standard small open economy neoclassical model' (p.1). In this paper, we examine changes in the productivity of Jamaican banks generally, and seek to identify whether there are classes of banks that are dissimilar.

4. Measuring bank productivity in Jamaica: model strategy and data

The design of the final four models was determined by data availability and the requirements of the estimation software. The intermediation approach of Sealy and Lindley (1977) is employed for the selection of the relevant variables as input and output vectors in the computation of *M*. The intermediation approach views the principal function of the bank as a financial intermediary transforming deposits into earning assets such as loans. Hence, the inputs and outputs are typically deposits along with labour and physical capital, and interest earning assets (loans and securities), respectively. The alternative production approach presented in the literature views the bank as producing loan services and deposits from physical labour and capital. Despite the lack of consensus in the literature as to the preferred approach, both approaches have generally resulted in similar conclusions (Mester, 1993).

For all models outlined in Table 2, we assume constant returns to scale (CRS) technology. All variables are defined in real terms where 1998 is the base year; values have been deflated by the Consumer Price Index.

Table 2 – Model Descriptions

NON-PARAMETRIC DEA (standard and bootstrap)	**MODEL DESCRIPTION**		
	Model	**Inputs**	**Outputs**
	Model 1	1.Operating Costs 2. Deposits	1. Total Net Interest Income 2. Non-interest income[6]
	Model 2	1.Operating Costs 2. Deposits	1. Gross Loans 2. Investments
	Model 3	1.Operating Costs 2. Deposits	1. Gross Loans – NPL (net)[7] 2. Investments
	Model 4	1.Operating Costs 2. Deposits	1. Net Loans + Investments 2. NPL (bad output)

First, we compute *M* using standard DEA. This study specifies two input and two output variables for each model.[8] For all the models we use total customer deposits and total non-interest expenses as the input vector (as in Hou, 2006 for China). Second, we employ a bootstrap procedure to the frontier models to address data inconsistencies as well as all the possibility of measurement errors in the standard models. Berger and Humphrey (1997) note that:

[6]See, for example, Mukherjee *et al*. (2001), Isik and Hasan (2003), Casu *et al*. (2004), Hou (2006) for the use of non-interest income as a measure of bank output.

[7] The importance of adjusting loan stock for NPL is to mitigate the effect of the large loan portfolios of larger banks on the efficiency calculation. The unadjusted loan portfolio would bias the efficiency score upwards for those banks which have the largest share of loans but may also hold a high proportion of NPL. Park and Weber (2006) found that adjusting loans for NPL accentuated their general finding for Korea.

[8] One of the reasons we do this is because of the lack of observations. With linear programming there is a constraint as the number of inputs/outputs that can be utilised with the number of observations.

> A resampling technique, such as bootstrapping, is one way of obtaining an empirical approximation to the underlying sampling distribution of DEA efficiency estimates. Once the underlying distribution is approximated, statistical inference can be conducted (1997:10).

Bootstrapping is based on the notion that if the data can be viewed as a random sample from an underlying population under a model, then the process of continuous random draws from the sample under the model generates also random draws from the population.[9] We generate 2,000 bootstraps for productivity growth for each bank for each pair of years for each of the four models.[10] Selected results from these models are summarised in the Appendix.

We utilise annual audited unconsolidated financial data for all Jamaican commercial and merchant banks during the period 1998 to 2007 for which data are available.[11] Data were obtained from publicly available resources, including Bankscope, financial statements and Annual Reports, the website of the respective banks, the website of the Central Bank, and media reports.[12] Notably, all the banks now use International Financial Reporting Standards (IFRS) to report their financial information.[13] In a few instances where data were not consistently available a number of working assumptions had to be made to fill the gaps.[14] In the final analysis we used an unbalanced panel of 12 banks with 111 bank-year observations. In this exercise, the requirement for a fully balanced panel between each pair of years meant that only 11 banks were used for estimates of productivity change between 1998-1999 and 2001-2002. For estimates between 1999-2000, 2000-2001 and 2005-2006, 10 banks were used. Nine banks were used for all other pairs of years, including 1998/2007 when we examine the change in the productivity of banks over the entire period.

[9] For a brief description of the bootstrapping procedure, please refer to Simar and Wilson (2000).
[10] Hall (1986) suggests that 1,000 bootstraps to ensure adequate coverage of the confidence intervals.
[11] Unconsolidated means individual bank level data, excluding other group company data.
[12] Bankscope database, maintained by Bureau Van Dijk, provides financial and other data for over 29,000 banks worldwide.
[13] IFRS were adopted in Jamaica for financial year-end reporting on or after July 2002. Some financial statements have therefore been reported using the local accounting standards (Local GAAP) previously in use for a part of the period under consideration. Daley (2004) and Daley (2002) discuss the likely impact of the change.
[14] While these assumptions are 'conditioning' factors that should be taken into account when interpreting the results, they are not pervasive.

5. Empirical Results

Perhaps the most notable finding from a comparison of the model results is the fact that of 444 estimates for the four models over the 10-year period, less than 10% of the pure DEA estimates are statistically significantly different[15] from the bias-corrected median of the bootstrap estimates (refer Appendix A for selected results). The bootstrap therefore gives confidence in the standard estimates.

The bias adjusted bootstrap estimates of the decomposed productivity results for each bank by models reflects movements in productivity growth for each year in the Malmquist productivity index, as well as the change in efficiency (catch-up) and technical progress for each model. We separate our analysis here between model 1 and all others. What we observe from model 1 is that there was significant productivity growth in all banks at some point during the period but not consistent periods of growth (see Appendix B).[16] BNS experienced significant growth during 1998/9 and again in 2004/5, driven mainly by efficiency progress which outpaced technological regress. Similarly, growth registered for CITIBANK, FCIB and RBTT was driven by stronger gains in efficiency over the respective years that mitigated any regress in technology. Model 1 also suggests that productivity growth experienced by FGB, NCB and PCMB from 2004 to 2007 was largely driven by technological advances.[17]

We separate the remaining models between models 2 and 3, (which are qualitatively similar in definition), and model 4 and interpret the results in the following way. For models 2 and 3 the banks that registered productivity growth seemed to have been driven largely by technological progress whereas for model 4, the growth seems to have been driven more by efficiency (catch-up) gains. The difference between models 2 and 3 is that model 2 includes non-performing loans. The exclusion of NPLs in model 3 does not seem to have influenced

[15] At the conventional 5% level of significance.
[16] For brevity, we do not report decomposition for all models. Details available from the authors upon request.
[17] The trend towards improved efficiency for NCB was anticipated from a banking system overhaul (http://www.sun.com/software/cluster/NB-Jamica.pdf) and may have lead to the achievement in 2009 as a "Most Innovative Bank" (http://www.jncb.com/corp_info/news.asp?Story=337)

the results much. What we observe from these two models in general is that strong growth was registered for CCMB, CITIBANK, FGB and to a lesser extent for PCMB. Generally speaking, the other banks recorded productivity regress. For the period 2006/7 all banks registered positive or zero growth with the exception of MF&G and NCB.

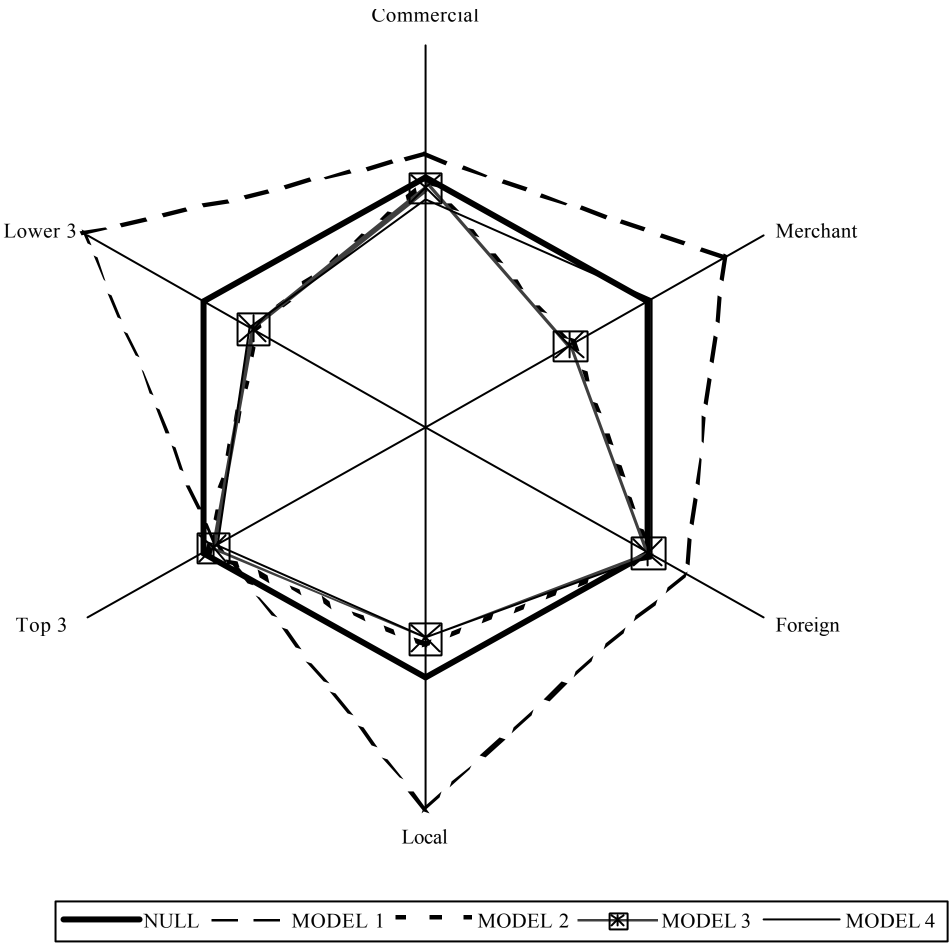
The result of model 4 is similar to those of models 2 and 3. The difference between the two sets of models is the inclusion of NPLs as bad output in the former model. The results are much sharper with this adjustment and those banks that showed productivity growth register even stronger growth implying that the banks that recorded the strongest improvement also had the lowest NPLs. The similarities between the results for models 2, 3 and model 4 suggest that the levels of NPL recorded were not significant enough to bias the efficiency scores although the inclusion as a bad output influenced the strength of the growth recorded. The reporting of such data accurately and consistently is therefore a key factor to analyses such as this one and should be considered as part of further research.

Of the weighted median values (by asset share) of the bias-adjusted bootstrap estimates for all models for six bank categories constructed showing the movements in productivity for each year and the overall change in productivity for the full period, the results for the full period are more telling.[18] The results for Model 1 show that all categories of banks experienced productivity growth driven by technical progress (frontier shifts) over the period except for the top 3 banks. The results of models 2 and 4 show foreign banks recording productivity growth due to efficiency gains, while model 4 also showed merchant banks reflecting growth in total factor productivity (TFP) due to technical progress. No category recorded growth on the basis of Model 3. Overall, foreign banks have shown a

[18] We construct bank categories as follows: Top 3 = BNS, NCB, RBTT; Lower 3 = CCMB, FCIB, FGB; Foreign = BNS, CIBC MB, CITI MB, CITIBANK, FCIB, NCB, RBTT; Local = CCMB, FGB, MAN SIG, PCMB, MF&G, NCB, RBTT (NCB has been majority foreign owned since March 2002; RBTT has been since March 2001); Commercial = BNS, CITIBANK, FCIB, FGB, NCB, RBTT; Merchant = CCMB, CIBC MB, CITI MB, MAN MB, PCMB, MF&G.

more consistent growth in productivity as reflected in the robust results from three of the four models.

Figure 1 Malmquist productivity by bank category



We depict the results in Figure 1 and show the performance of each bank category by model against the null hypothesis of zero productivity growth (M=1) for the entire period 1998/2007 as represented by the unbroken line. Evidently, all categories, with the exception of the top 3, show significant productivity growth in model 1 with the lower 3, local and merchant bank categories showing the most significant growth, in that order. There is, albeit modest, productivity growth for foreign banks in models 2 and 4 and for merchant banks in model 4. All other lines representing all other categories for all other models lie within the unbroken line, suggesting productivity regress and, in fact, show significant productivity regress for merchant and lower 3 banks in models 2 and 3.

In general, the growth reflected in models 2 and 4 where the output vector is represented by the stocks from the intermediation process (loans and investments) is markedly modest vis-à-vis the results for model 1, where the output vector is represented by the flows from the intermediation process (total income).[19]

We further examine the determinants of productivity via the yearly bootstrap median values of M for each bank based on the assumptions and definitions of each model. Table 3 shows selected results from panel corrected heteroskedastic adjusted estimation.[20] The bank specific variables are LSIZE, the natural logarithm of total assets, CAT, a zero-one dummy variables representing type of specialisation (commercial or merchant), and OWN, a dummy for ownership (domestic or foreign). RGDP, the rate of growth of GDP, was used as a macroeconomic environmental variable affecting the entire banking market and DUM02, a dummy variable taking the value of unity from 2002 onwards and zero in previous years, was used to test for a potential major structural break.

Table 3: FGLS panel regression test for association with Malmquist productivity index

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	-0.461	2.361	2.407	1.733
LSIZE	.118**	-.790***	-.793***	-.581***
CAT	.686***	-2.395**	-2.391**	-1.880**
OWN	-.534***	2.178***	2.190***	1.885***
COST	-.016***	.0715***	.0714***	.051***
GDP growth	-.204**	-	-	-
DUM02	-	1.90**	1.875**	1.355**
Log L*	-71.3	-185.9	-185.9	-163.07

***, **,* significant at 1%, 5%, and 10% respectively

The most consistent result to focus on is that the inference from the results of model 1 is different from the inference of the results of all other models as it relates to the association of the variables with bank productivity. Model l suggests that size, business emphasis (retail or merchant), ownership, cost and the rate of growth of GDP all show a statistically

[19] In all models, the results for Citimerchant Bank appeared spurious for 2006. We attribute this to the unusual (though accurate) amounts recorded during this year for the bank as it proceeded into liquidation. We believe that these results may have influenced the results for other banks in the bootstrap but is included for the sake of degrees of freedom. We were constrained from excluding this Bank when reporting our final results by the requirements of the estimation software and the unavailability of alternative data.

[20] The standard fixed effects model was rejected on conventional F test for each of the models.

significant association with total factor productivity for banks. In this model, the former two variables show a positive relationship while the latter three show a negative relationship, implying that larger, commercial, and locally-owned banks are more productive (overall).

The second important and consistent result from models 2, 3 and 4 is that size, business emphasis (retail or merchant), ownership, cost and the dummy variable for 2002 onwards all show a statistically significant association with total factor productivity for banks. The results suggest a negative association for the first two variables and a positive association for the latter three. The strong and positive coefficient for the dummy variable for 2002 onwards is strongly suggestive of a structural break worthy of further investigation.

6. Concluding Remarks

This paper has presented a number of Malmquist models for quantifying and decomposing bank productivity in Jamaica by individual bank as well as by bank category. The model results have been determined by rigorous bootstrap methodology and are indicative of robustness.

In common with other studies on developing countries, we find that foreign-owned banks outperform locally owned banks over the period. The individual bank results show that all banks experienced some productivity growth at some point during the period but that there was no consistent pattern of growth. In general, the top 3 banks showed zero productivity gains and, in fact, reflected efficiency regress towards the end of the crisis period in 1998/9. This could be reflective of the fact that although these banks were relatively poor producers at the time they were able to survive the crisis due to too-big-to-fail policies at work in Jamaica as suggested by Daley *et al.* (2008). The results also indicate marked growth for the second largest banks as well as merchant and locally-owned banks and modest growth for commercial and foreign-owned banks, in some models.

There is strong implication from all the models that growth experienced up to 2002 was primarily catch-up, but that technical progress has been the catalyst for any growth since then. This may be reflective of the efforts expended to improve the performance of the banks coming out of the crisis period and the subsequent enhancements to technologies such as internet banking. The pre- and post-2002 demarcation also coincides with the adoption of new accounting standards in Jamaica and regulatory reform.

Regression results show strong association between bank productivity and bank size, business focus and ownership, although the direction of association is not consistent for all models. The models presented in this paper are advantageous in that they separate efficiency gains from technological frontier shifts. As such, they provide valuable information for policy planning for Jamaican banks.

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Appendix A: DEA and Bootstrap Malmquist compared for selected years

	Model 1			Model 2			Model 3			Model 4		
i	DEA	Boot Median	0.025, 0.975 Bias Corr.	DEA	Boot Median	0.025, 0.975 Bias Corr.	DEA	Boot Median	0.025, 0.975 Bias Corr.	DEA	Boot Median	0.025, 0.975 Bias Corr.
1998/9												
BNS	1.221	1.232	1.220, 1.364	1.035	1.023	1.001, 1.062	1.009	0.993	0.970, 1.024	1.052	1.055	1.049, 1.064
CCMB	0.410	0.898	0.342, 1.917	2.188	2.314	1.424, 3.868	1.898	1.953	1.187, 3.185	2.650	14.314	2.820, 66.304
CIBC MB	0.912	0.995	0.662, 1.478	0.657	0.758	0.608, 1.003	0.678	0.822	0.668, 1.115	0.848	0.914	0.788, 1.189
CITI	0.981	1.131	0.985, 1.541	0.724	0.717	0.698, 0.725	0.727	0.743	0.725, 0.751	0.984	0.705	0.450, 0.977
CITI MB	2.425	1.646	0.985, 3.943	5.764	2.503	1.652, 4.532	5.511	2.548	1.564, 4.598	6.938	3.554	3.036, 6.442
FCIB	1.492	1.651	1.494, 2.267	0.961	0.971	0.889, 1.063	0.959	0.992	0.913, 1.096	1.445	1.460	1.388, 1.549
FGB	1.509	1.567	1.497, 1.826	1.216	1.100	1.012, 1.254	1.215	1.093	1.010, 1.258	1.569	1.439	1.178, 1.671
MAN MB	0.865	0.853	0.845, 0.935	0.997	0.886	0.881, 1.029	0.710	0.688	0.684, 0.745	0.803	0.856	0.807, 0.858
NCB	0.784	0.761	0.662, 0.785	0.994	0.997	0.983, 1.009	1.020	1.036	1.009, 1.060	0.970	0.971	0.960, 0.980
PCMB	0.958	1.039	0.904, 1.231	1.000	1.026	0.933, 1.146	0.931	0.958	0.850, 1.095	1.062	0.877	0.875, 1.146
RBTT	0.922	0.922	0.915, 0.936	0.838	0.893	0.819, 0.923	0.866	0.931	0.847, 0.983	0.781	0.784	0.775, 0.795
1998/2007												
BNS	1.228	1.193	1.136, 1.291	1.196	1.154	1.093, 1.233	1.189	1.113	1.057, 1.197	1.015	0.985	0.942, 1.017
CCMB	1.640	1.465	1.116, 1.747	0.900	0.603	0.509, 0.853	0.893	0.585	0.496, 0.795	0.979	0.820	0.725, 1.058
CITI	2.167	3.113	2.380, 3.484	1.444	1.476	1.093, 2.092	1.597	1.643	1.154, 2.408	1.031	0.641	0.197, 1.047
FCIB	1.384	1.454	1.295, 1.706	0.601	0.577	0.489, 0.687	0.629	0.642	0.541, 0.791	0.834	0.923	0.818, 1.182
FGB	1.732	1.854	1.547, 2.293	1.146	1.208	0.813, 1.880	1.047	1.173	0.742, 1.859	0.697	0.514	0.307, 0.880
NCB	0.875	0.799	0.707, 0.875	0.900	0.897	0.867, 0.947	0.877	0.858	0.821, 0.936	0.928	0.929	0.927, 0.939
PCMB	3.269	1.176	0.768, 2.455	0.845	0.875	0.706, 1.137	0.835	0.893	0.699, 1.245	3.929	1.866	1.020, 3.475
RBTT	0.640	0.662	0.628, 0.671	0.753	0.764	0.580, 0.986	0.743	0.745	0.551, 0.993	0.819	0.820	0.815, 0.835

Appendix B Bootstrap Malmquist Decomposition – Model 1

EFFICIENCY	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	1998/2007
BNS	1.287	2.140	0.401	2.755	2.461	0.168	1.273	0.708	0.891	0.882
CCMB	0.885	1.590	0.341	2.662	1.086	1.709	0.276	0.865	1.086	0.875
CIBC MB	1.777	0.532	0.682	0.925						
CITI	1.043	3.425	0.313	1.327	1.052	0.869	2.154	0.672	1.263	1.348
CITI MB	0.351	0.700	0.697	0.756	1.624	0.400	17.790	0.093		
FCIB	1.594	2.499	0.421	1.790	0.648	0.841	1.320	0.643	0.922	1.164
FGB	1.465	1.814	0.779	1.745	5.623	0.165	1.346	0.735	0.866	1.072
MAN SIG	0.860			0.681						
MF&G								0.931	0.921	
NCB	0.726	2.276	0.619	2.003	1.381	0.659	0.912	0.649	0.906	0.497
PCMB	0.854	0.556	1.330	1.395	0.917	1.444	0.548	0.747	1.073	0.180
RBTT	0.899	2.676	0.201	1.738	2.819	0.163	1.804	0.526	1.015	0.528
TECHNOLOGY										
BNS	0.965	0.440	2.330	0.381	0.656	4.163	0.825	1.400	1.095	1.362
CCMB	1.022	0.891	1.182	0.456	0.626	0.667	1.017	1.811	1.213	1.671
CIBC MB	0.564	1.552	2.103	1.309						
CITI	1.076	0.466	2.549	0.683	0.702	1.281	0.828	1.621	1.198	2.250
CITI MB	4.747	0.804	2.038	0.776	0.242	9.016	0.041	0.026		
FCIB	1.051	0.481	2.155	0.494	0.614	1.475	0.818	1.527	1.103	1.246
FGB	1.073	0.505	1.536	0.715	0.357	2.780	1.149	1.513	1.205	1.733
MAN SIG	0.995			1.374						
MF&G								0.832	1.369	
NCB	1.039	0.464	2.005	0.490	0.682	1.405	1.006	1.679	1.146	1.612
PCMB	1.221	1.648	0.904	1.326	0.714	0.457	1.889	1.657	0.988	6.530
RBTT	1.028	0.471	1.841	0.513	0.238	5.832	0.590	1.943	1.131	1.247
MALMQUIST										
BNS	1.232	0.943	0.932	1.053	1.641	0.691	1.055	0.988	0.972	1.193
CCMB	0.898	1.424	0.404	1.200	0.692	1.147	0.282	1.562	1.318	1.465
CIBC MB	0.995	0.818	1.492	1.153						
CITI	1.131	1.585	0.800	0.905	0.745	1.088	1.771	1.078	1.529	3.113
CITI MB	1.646	0.549	1.440	0.598	0.398	3.654	0.718	0.004		
FCIB	1.651	1.205	0.911	0.896	0.405	1.223	1.081	0.986	1.017	1.454
FGB	1.567	0.912	1.202	1.314	1.941	0.463	1.539	1.105	1.051	1.854
MAN SIG	0.853			0.973						
MF&G								0.767	1.264	
NCB	0.761	1.053	1.236	0.974	0.945	0.915	0.923	1.089	1.035	0.799
PCMB	1.039	0.918	1.175	1.813	0.651	0.658	1.010	1.231	1.067	1.176
RBTT	0.922	1.239	0.374	0.895	0.665	0.937	1.067	1.017	1.152	0.662