How do we know what the right price is (and does it matter)?

Paul Rouse
University of Auckland

David Tripe
Massey University

Abstract:

Paying too much for funding or failing to obtain adequate returns for lending and other interest-bearing assets due to inappropriate mix is just as much a source of inefficiency in banking as overutilisation of input resources. A focus on prices and thus on allocative efficiency has received much less attention in the academic literature on banking.

This paper uses an extensive quarterly data set from New Zealand, which allows a decomposition of interest costs and revenues into quantity and price effects, to explore the factors, including both technical and allocative efficiency, that impact on changes in banks' costs and revenues. We find that focusing solely on technical efficiency can give a misleading impression of banking performance in our New Zealand sample. The inclusion of allocative efficiency measurement shows greater variability of performance as well as highlighting changes in the mix of inputs and outputs needed for banks to improve performance.

Keywords:
Allocative efficiency, DEA, Banking, New Zealand

1 Introduction

Surveys of the efficiency literature (e.g. Liu et al, 2013; Lampe & Hilgers, 2015) often highlight banking as one of the most popular areas of study, and it is certainly an area in which a large number of studies have been undertaken (e.g. Berger & Humphrey, 1997; Fethi & Pasiouras, 2010). These have used both (non-parametric) DEA and (parametric) SFA (and sometimes both of them in comparisons), with a few studies that have used DFA, TFA and FDH.

One of the reasons for so much attention having been paid to the banking sector is that banks produce lots of data (Benston, 2004). We get balance sheets and income statements, which supposedly have an advantage of simplicity in that the banks' core business is in monetary amounts, giving us relatively straightforward financial statements. Making use of the data for efficiency analysis can be straightforward enough as long as one is happy to use the data in those financial statements, and there are numerous studies using a basic intermediation model (as per Sealey and Lindley, 1977), which sees resources such as labour and fixed assets (and sometimes deposits or borrowed funds) being converted into loans and income elements (and sometimes deposits).

Looking at the quantities only without regard to the prices being paid would clearly omit a potential source of inefficiency: a bank can usually make more loans if it reduces their price, or collect more deposits if it increases their price. If an operating unit is paying too much for its inputs, or not being paid enough for its outputs, how can it be efficient? In an SFA study, prices are often created by dividing the relevant income statement flow by a balance sheet quantity, but this does not always result in prices that are meaningful in the generally accepted sense of the term, in that the relevant balance sheet item used as the numerator is often total assets. Prices estimated in this way sometimes appear to be somewhat surprising, as can be seen in the prices shown in Table 1 of Weill (2013), even though Weill's approach is in accordance with the prior literature. Does it seem reasonable that the price of labour in Lithuania should be more than 13 times its price in Luxembourg, or that physical capital is 7 times more expensive in the Netherlands than in Germany?

Mountain & Thomas (1999) and Koetter (2006) identify a further issue with this approach, in that bank specific prices for factors of production are contrary to what one would normally expect, where participants in banking markets should be expected to face more or less the same prices for their inputs and outputs. Relative differences in aggregate cost or revenue would then be a reflection of differences in the mix of inputs and outputs (and would thus relate to allocative efficiency). The solution to this conundrum has been to look for independent sources of price information, such as surveys to establish prevailing costs in particular markets – an approach followed by Koetter (2006) and Berger & Bonaccorsi di Patti (2006).

A somewhat different approach has been followed in those DEA studies where prices have been considered, by using the aggregate cash flows for income and expense elements to develop what Drake et al (2009) have described as a profit/revenue approach. This approach typically uses interest and non-interest expense as inputs, and interest income and non-interest revenue as outputs. This should give a better view of efficiency than just using funds and loans, but it is not yet providing any basis for measurement of allocative efficiency. Berger & Mester (1997) commented that "non-parametric techniques generally ignore prices and can, therefore, account only for technical efficiency in using too many inputs or producing too few outputs."(p 905). This is often used to argue that DEA cannot measure allocative efficiency, and a key contribution of this paper is to attempt to measure allocative efficiency using DEA.

The next section of the paper describes our data and the related effort to specify a meaningful set of prices. Section 3 describes the method we have used, and presents the results of our analysis. Section 4 seeks to summarise some of the problems we have faced and presents a conclusion.

2 Our data and prices

An ideal approach would allow a full decomposition of all income statement and balance sheet items into quantities and prices, although this is not always easy to achieve in practice. Interest costs, measured relative to interest-bearing liabilities and interest revenues, measured relative to interest-bearing assets, look straightforward enough. A cost might also be able to be estimated for shareholders' equity, although that is a potentially more challenging exercise if banks do not have share market listings in their own right.

More challenging issues arise with non-interest revenue and expense. If data on personnel costs are available, and if personnel numbers are known (noting that these are not a balance sheet item), it is feasible to estimate a figure for personnel cost per employee. Challenges may then arise with outsourcing, however, in that a bank can reduce its personnel numbers and personnel costs by outsourcing particular types of activities. Personnel costs will be replaced by other costs.

Banks publish data on the value of their fixed assets (physical capital), but it is then often difficult to attribute costs or prices directly to those fixed assets. Which items of other non-interest expense relate to fixed assets? Moreover, the amount of fixed assets and fixed asset costs will be impacted by choices around whether those fixed assets are owned or leased. Approaches to the valuation of fixed assets may vary from bank to bank. If one has figures for personnel costs and personnel numbers, what physical quantities can the other expenses be related to? In these authors' experience, the typical breakdown of bank non-interest cost would be something like 50% for personnel, 10% related to fixed assets, and 40% other. These other costs undoubtedly contribute to the production process, so it would be wrong to just ignore them.

Similar issues can arise with non-interest revenue, which is generated from a wide range of activities that banks undertake. Banks profit from foreign exchange, interest rate and derivative trading. They earn fees for managing customers' accounts and from processing payment transactions on customers' behalf. They earn fees and sometimes penalties from loans. They earn commissions from sales of insurance and other products, while they may also accrue regular fees for managing assets on customers' behalf. They can earn merchant and interchange fees on credit card transactions. If a bank owns buildings, it may also receive rent. Non-interest revenues have sometimes been ascribed to off-balance sheet items, but many of the items in the foregoing list are on-balance sheet. Once again, as with non-interest costs, non-interest revenue is usually too big a part of banks' overall revenue stream to be able to be just ignored.

For this study we use data for New Zealand banks, which is available quarterly. This reflects New Zealand banking system oversight being based on public disclosure of information to allow counterparties to assess banks' soundness, with the information including a year-to-date balance sheet and income statement. Our study covers 3 (ANZ, ASB and Westpac (abbreviated to WST)) out of 4 major banks and 3 smaller banks (Kiwibank (abbreviated to KWB), SBS and TSB), which together accounted for 74% of the assets of the New Zealand banking system as at December 2014. We chose not to include the fourth major bank as its non-interest revenue figures were unusually volatile because of its marking to market of significant portions of both its assets and liabilities on a frequent basis.[1]

Our study covers a five-year, 20-quarter period from the March quarter of 2010 through until the December quarter of 2014. The data are analysed as a balanced panel, which provides us with 120 observations in total, sufficient for the numbers of inputs and outputs that we use. We do not

[1] Although it is possible to identify the effect of the mark-to-market adjustments for that particular bank's non-interest revenue, this is not possible for other banks in the study, and we would then be comparing a set of banks with inconsistent data.

consider that technical change over the period would have been sufficient to invalidate our assumption of a common frontier over the five-year period. Our study start date of the March quarter of 2010 means that the worst effects of the GFC would have abated, while changes in interest rates over the period of the were also small. Neither of these should have led to any distortions in our results.

Under the disclosure rules applying in New Zealand, banks are required to report interest-bearing assets and interest-bearing liabilities, which makes relating these to interest revenues and costs very straightforward for estimation of the relevant prices. Figures for shareholders' equity are also able to be obtained from the disclosure statements. As a cost of equity, we apply a figure of 10.5%, which was at one recent time reported as the rate that the major Australian banks were using for Economic Value Added (EVA) calculations (although their actual returns on equity are rather higher than this – more like 15%).

For non-interest expense, we chose branch numbers as a proxy. Although these are reported only once a year, they change very little from one year to the next (often not at all), and there was therefore little risk in interpolating numbers for the end of each quarter. We thus have a figure for non-interest expense, number of branches, and what is in effect a price of branches. Number of personnel, as a potential alternative proxy, shows much more variation from one year to the next, and would be likely to have led to less reliable results. Fixed assets would be unlikely to be a useful proxy, as they comprised only 0.25% of banks' assets as at 31 December 2014. We would also argue that, despite the reducing importance of branches for bank service delivery, they provide a fair proxy for the scale of bank activity and the likelihood that they will incur non-interest expense.

For non-interest revenue, we chose as a proxy (denominator for the price ratio) the sum of liquid assets, trading and other securities, investments in associates, fixed assets, intangibles, and other assets (the major component of which is usually the positive mark-to-market adjustments of banks' off-balance sheet derivatives portfolios). This might alternatively be described as non-lending assets, but not including future tax benefits. All of these items are likely to make some contribution to a bank's non-interest revenue stream. At one time, prior to the adoption of Basel II, it would have been possible to use the total of risk-weighted off-balance sheet assets, but this data is no longer being reported, following changes to the disclosure regime in 2008. The resulting price may not have any particular economic meaning, but it would seem to be as good a proxy as is available for the New Zealand banking sector.

3 What we did

Our choice of inputs and outputs and their relationship to the production process has been outlined above. Equity is included to adjust for risk, and because it is, in fact an important element in the production process in banking (Hughes & Mester, 1993). Our analysis was undertaken on a variable returns to scale basis to control for differences in size and so that any necessary data transformations could be undertaken. This requires that the data be inflation adjusted, but for our preliminary analysis this correction has not yet been applied.

We undertook a number of separate analyses. We first examined our data for pure technical efficiency, with no price (or income statement) information, looking only at the physical quantities of inputs and outputs. We then used an output-oriented revenue approach, an input-oriented cost approach, and a non-oriented profit approach.

Table 1 provides summary statistics of the data set.

Table 1: Summary Statistics

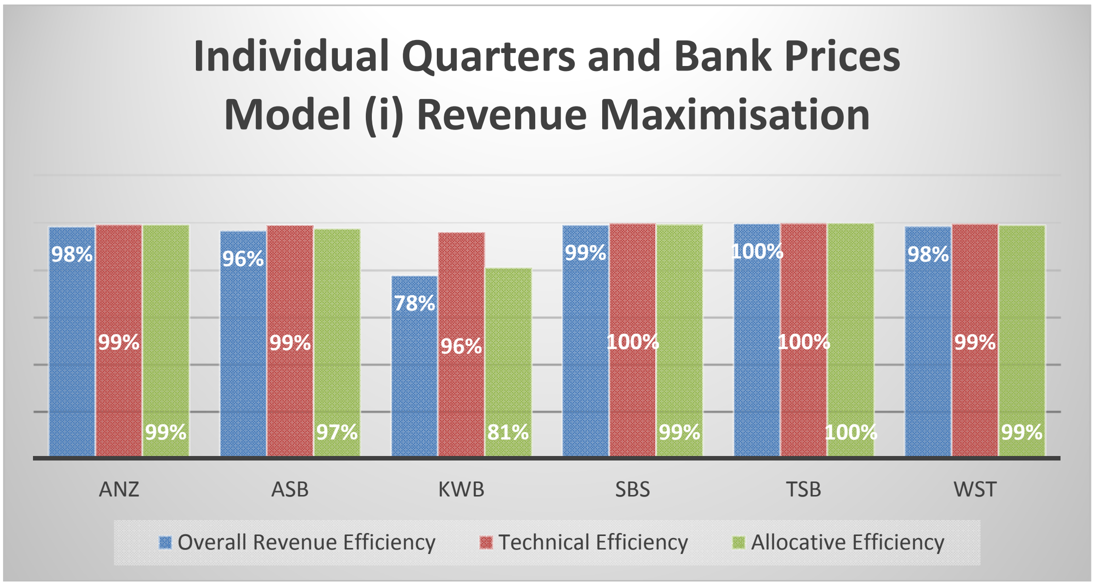
	Inputs			Outputs		Prices				
	Interest-bearing liabilites	Branch Nos	Equity	Interest-bearing assets	Total non-lending assets (not including deferred tax)	Interest Cost (%)	Price of branches	Cost of Equity (%)	Interest revenue (%)	Price of other assets (%)
Mean	$ 38,134	161	$ 3,187	$ 43,061	$ 10,445	4.0%	$ 0.89	10.5%	5.8%	4.4%
Std Deviation	$ 33,398	113	$ 3,861	$ 38,149	$ 10,949	0.4%	$ 0.42	0%	0.5%	3.5%
Minimum	$ 2,361	15	$ 178	$ 2,538	$ 108	3.3%	$ 0.18	10.5%	4.3%	0.5%
Median	$ 34,346	170	$ 1,185	$ 38,430	$ 5,250	3.9%	$ 0.99	10.5%	5.7%	3.6%
Maximum	$ 99,802	317	$ 12,211	$ 116,137	$ 35,263	5.5%	$ 1.66	10.5%	7.0%	25.9%
Means By Bank Sorted By Size										
ANZ	$ 89,985	293	$ 11,197	$ 103,456	$ 31,157	3.9%	$ 1.37	10.5%	5.9%	2.9%
WST	$ 61,866	203	$ 2,649	$ 69,261	$ 16,825	4.0%	$ 1.06	10.5%	5.8%	3.4%
ASB	$ 56,580	142	$ 3,878	$ 63,116	$ 9,693	4.1%	$ 1.31	10.5%	5.9%	4.1%
KWB	$ 13,306	287	$ 767	$ 14,626	$ 2,209	3.9%	$ 0.25	10.5%	5.3%	7.9%
TSB	$ 4,522	24	$ 415	$ 5,156	$ 2,382	3.9%	$ 0.50	10.5%	5.5%	0.7%
SBS	$ 2,548	16	$ 217	$ 2,755	$ 403	4.3%	$ 0.83	10.5%	6.5%	7.2%

There is considerable variation across all inputs and outputs reflecting the differences in size and focus of the banks in the sample. There is also considerable variability in the prices on inputs and outputs again reflecting size and ability to access favourable borrowing and lending rates. The smaller banks tend to have more extensive networks of generally smaller branches, which accounts for lower prices per branch. Kiwibank (KWB) was established by the Government through New Zealand Post in a political move in 2002, and operates out of post shops throughout New Zealand, hence its lower price per branch. Note that the TSB has the lowest price for Other Assets, reflecting a higher holding of investment securities and relatively low levels of non-interest revenue, which will explain its performance in revenue maximisation in the analysis below when comparing different sets of prices. The two smallest banks are owned by a community trust in the case of TSB while SBS is a mutually-owned institution. The three large banks are Australian owned.

Three DEA models are used: revenue maximisation, cost minimisation and profit efficiency. In each model, five sets of prices are used: i) individual prices by bank per quarter, ii) average prices by bank, iii) average prices for the three large banks, iv) average prices for the three smaller banks, v) average prices across all banks. Average prices were across the most recent four quarters or twelve months.

Figure 1 reports the overall revenue maximisation efficiency using the first set of prices decomposed into technical and allocative efficiency.

Figure 1: Efficiency scores by bank using i) individual prices per bank per quarter.



Technical efficiency is very close to 100% for all banks, suggesting that it is not an effective measure for discriminating between banks' performance. KWB shows significantly lower allocative efficiency, making its overall efficiency significantly lower.

Table 2 provides a more incisive analysis of specific changes in inputs and outputs required for each bank to improve its overall revenue efficiency. Note that changes encompass both outputs and inputs. Some of these changes would involve significant shifts in strategic investments. For example, the ASB would need to increase its Other Assets by 37% which would not be an option in the short term. The changes required for KWB are quite dramatic and almost involve closing the bank down by reducing its number of branches by 80%. Table 2 also indicates that KWB needs to more than double its investment in Other Assets to achieve revenue maximisation. Reference to Table 1 shows that

KWB has the highest price for Other Assets of all the banks, reflecting a transfer of agency business to the bank from New Zealand Post, but relatively low levels of non-lending assets. The relatively higher price of Other Assets for the ASB and SBS banks also drives the change in revenue mix suggested in Table 2: 37% and 10.2% respectively.

Table 2: Changes in Individual Inputs and Outputs to improve overall Revenue Efficiency.

Mean original values						
	Revenue	**Liabilities**	**Branches**	**Equity**	**IBAssets**	**OtherAss**
ANZ	$ 7,032	$ 89,985	293.3	$ 11,197	$ 103,456	$ 31,157
ASB	$ 4,089	$ 56,580	141.9	$ 3,878	$ 63,116	$ 9,693
KWB	$ 943	$ 13,306	287.0	$ 767	$ 14,626	$ 2,209
SBS	$ 200	$ 2,548	16.1	$ 217	$ 2,755	$ 403
TSB	$ 300	$ 4,522	24.5	$ 415	$ 5,156	$ 2,382
WST	$ 4,575	$ 61,866	202.6	$ 2,649	$ 69,261	$ 16,825
Mean change to maximise revenue						
ANZ	$ 105	$ -	(9.2)	-$ 182	$ 776	$ 1,852
ASB	$ 140	-$ 480	-	$ -	($475)	$ 3,597
KWB	$ 248	$ -	(234.9)	$ -	$ 342	$ 2,848
SBS	$ 2	-$ 0	(0.3)	($1)	$ 5	$ 41
TSB	$ 1	$ -	-	($0)	$ 23	($6)
WST	$ 76	$ -	(1.0)	$ -	$ 254	$ 1,669
Mean Percentage change required						
ANZ	1.5%	0.0%	-3.1%	-1.6%	0.8%	5.9%
ASB	3.4%	-0.8%	0.0%	0.0%	-0.8%	37.1%
KWB	26.3%	0.0%	-81.8%	0.0%	2.3%	128.9%
SBS	1.2%	0.0%	-1.9%	-0.4%	0.2%	10.2%
TSB	0.4%	0.0%	0.0%	0.0%	0.4%	-0.2%
WST	1.7%	0.0%	-0.5%	0.0%	0.4%	9.9%

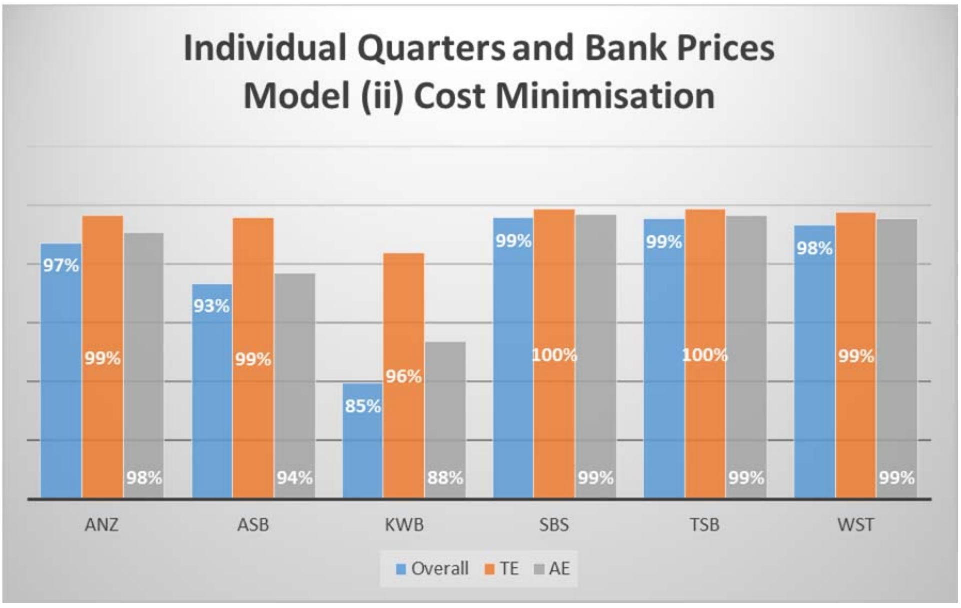
As the price sets change, the efficiency scores change as shown in Appendix 1. The biggest change is for KWB when the prices are set by the other banks e.g. large and small banks and across all banks. When its own prices are used either individually or averaged over 12 months, KWB has overall efficiency of 78% most of which is due to allocative efficiency of 81% with technical efficiency 96%. This is due to its high price on Other Assets which is reduced when combined with prices from the other banks.

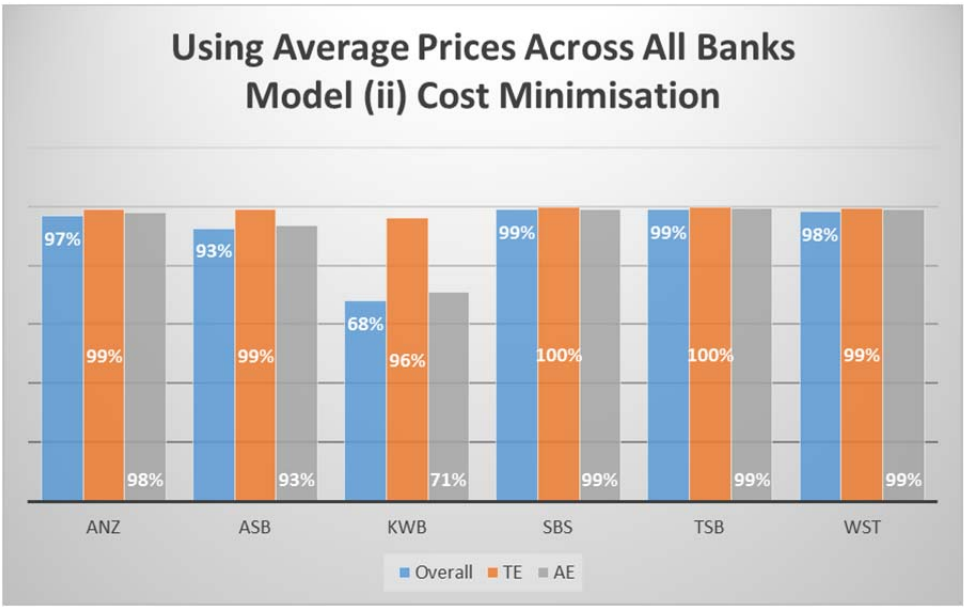
We turn next to the second model: cost minimisation again using five sets of prices. Looking first at the top panel of Figure 2, the ANZ, ASB and KWB have some allocative inefficiency, with KWB being the lowest in terms of overall efficiency, most of which is due to allocative inefficiency. It should be apparent that relying solely on technical efficiency to evaluate bank performance for this sample, would provide a misleading impression of reasonably high structural efficiency.

The lower panel of Figure 2 shows the results when using the average prices across all banks for the most recent 12 months. There is no change for most of the banks but KWB is significantly affected with a reduction in overall efficiency from 85% to 65%, all of which is due to allocative inefficiency.

An analysis similar to Table 2 (not reported here) shows that the source of its inefficiency is the number of branches and an apparent excess funding from Equity. Similar to the revenue analysis, KWB is supposed to reduce its branches by over 80% which is paramount to closing the bank.

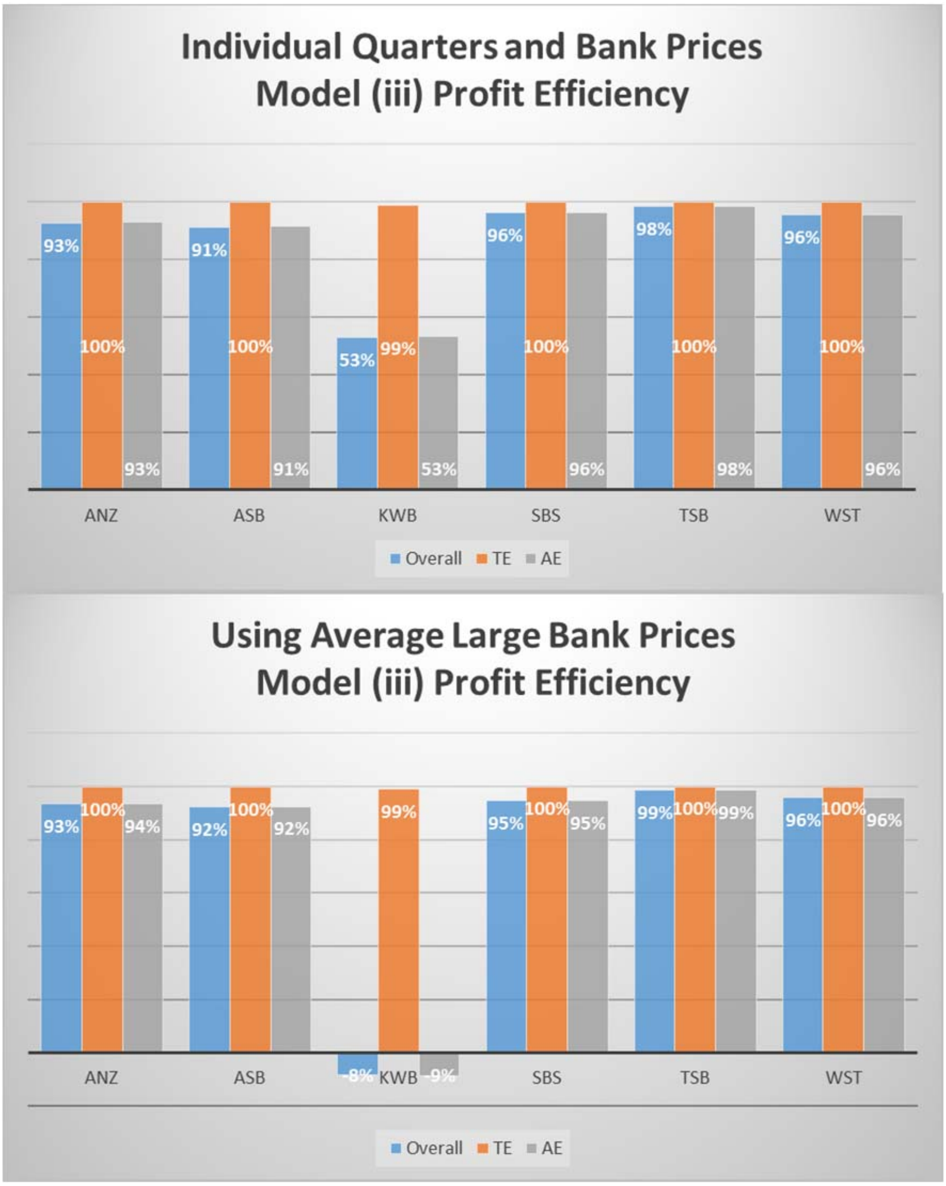
Figure2: Efficiency scores by bank using i) individual prices per bank per quarter and ii) average prices across all branches





The third model is profit efficiency where both inputs and outputs can be changed in the light of prices faced by each bank. For the revenue and cost models above, technical efficiency was calculated using an output and input oriented radial VRS model respectively. For the profit efficiency model, we calculated technical efficiency using a hyperbolic model whereby outputs are expanded and inputs contracted using a single scalar. As this is a non-linear model, we experimented with different models including a linear approximation suggested by Fare *et al.* (1985) and linear transformations of the data. The efficiency scores varied considerably with some scores being less than 50% which did not meet with our expectations and knowledge of the NZ banking sector. Finally we used the non-linear option in the Excel Solver with a lower bound of one on the efficiency scalar which provided scores fairly close to 100% which seemed more likely than the alternatives[2].

Figure 3: Profit Efficiency using i) individual prices per bank per quarter and ii) average prices across the large branches



[2] We checked these results with a log linear model which provided almost identical results with the exception of three bank quarters where the differences in technical efficiency scores were less than 2%.

Figure 3 reports the results for profit efficiency decomposed into technical and allocative components. The upper panel uses the first price set, namely prices for each quarter and bank.

Technical efficiency is high across all banks but there is more variability in allocative efficiency with KWB being the lowest. Ignoring KWB, allocative efficiency varies from 91% to 98%. When the prices for the large banks are used, the effect on KWB is dramatic with losses now being incurred mainly because of the higher price for its branches. The lower panel of Figure 3 shows this with all of it attributed to allocative inefficiency.

Table 3 repeats the analysis carried out in Table 2 for the profit efficiency model but shows only the percentage changes required in inputs and outputs. As previously noted in the above analyses, KWB is the most affected bank with substantial reductions in branches and increase in Other Assets. ANZ however is also affected in terms of reductions in branches and Equity. ASB, SBS and WST show required increases in their Other Assets in order to improve efficiency.

Table 3: Percentage changes in inputs and outputs under the Profit Efficiency Model using individual prices for quarters and Banks

		Mean Percentage change required				
	Profit	Liabilities	Branches	Equity	IBAssets	OtherAss
ANZ	7.9%	0.0%	-9.4%	-5.8%	0.6%	1.1%
ASB	10.5%	-0.2%	0.0%	0.0%	0.1%	26.0%
KWB	92.8%	0.0%	-72.0%	-0.5%	2.9%	104.1%
SBS	4.4%	0.0%	-1.4%	-0.1%	0.2%	9.4%
TSB	1.8%	0.0%	0.0%	-1.0%	0.3%	0.2%
WST	4.8%	0.0%	-0.4%	-2.4%	0.4%	8.9%

We performed these analyses using both DEA Solver (Cooper, Seiford and Tone, 2007) and Excel with our own model constructions. This revealed that DEA Solver uses the prices supplied in the data to calculate the actual revenue or actual cost which correspond to the actual figures when the individual prices for each bank are used but change when the other four price sets are substituted for these. Accordingly we can identify a form of price variance which is the difference between the actual revenue or cost (actual prices multiplied by actual quantity) and the “standard” revenue or cost (standard prices multiplied by actual quantity). Table 4 shows these for each of the four price sets.

The upper panel shows how the actual revenue compares with the calculated revenue when price sets ii) to v) are used. For example, the actual revenue for KWB is 95 percent of revenue calculated using the actual quantity multiplied by its own average prices over twelve months. This is because its interest revenue price and price of Other Assets were 5.23% and 8.05% over the whole sample period compared with an average of 5.34% and 9.45% respectively over the most recent 12 month period. In other words, its revenue prices were on average higher in the period preceding the last 12 months.

Table 4: Price variances for the revenue, cost and profit analyses

Comparison of Actual Revenue = Actual prices * Actual quantity	ANZ	ASB	KWB	SBS	TSB	WST
With Revenue using Actual Quantity and:						
Ave 12 month prices per bank	99%	100%	95%	102%	102%	100%
Average large bank prices	99%	102%	102%	116%	78%	99%
Average small bank prices	99%	105%	104%	119%	77%	100%
Average all bank prices	99%	103%	102%	116%	78%	99%
Comparison of Actual Cost = Actual prices * Actual quantity						
With Cost using Actual Quantity and:						
Ave 12 month prices per bank	100%	107%	98%	105%	104%	102%
Average large bank prices	101%	106%	68%	102%	94%	102%
Average small bank prices	107%	111%	96%	115%	104%	109%
Average all bank prices	103%	108%	76%	106%	97%	104%
Comparison of Actual Profit = Actual prices * Actual quantity						
With Profit using Actual Quantity and:						
Ave 12 month prices per bank	97%	85%	89%	98%	95%	97%
Average large bank prices	91%	95%	-3810%	175%	48%	93%
Average small bank prices	81%	91%	131%	128%	40%	86%
Average all bank prices	89%	93%	621%	154%	46%	91%

TSB suffers from its very low price for Other Assets when using prices other than its own for its revenue income. In contrast, SBS enjoys a price advantage over the other banks resulting in a "favourable" price variance. This is largely a consequence of it having a larger higher risk portion in its loan portfolio, which causes it to record higher interest revenues (as was seen in Table 1).

The middle panel of Table 4 compares the actual cost with cost calculated using the price sets ii) to v). KWB's actual cost is much lower than the other banks mainly due to its branch low costs (see Table 1). TSB also enjoys lower costs again due to its lower branch costs.

The lowest panel compares actual profit with profit calculated using the four other price sets. This shows considerable variation for each bank under different price settings. KWB in particular suffers catastrophically if the large banks' prices are used but gains when either the average small bank or overall average bank prices are used. Reference to Table 1 shows that KWB has the lowest branch cost of all the banks, causing its costs to increase substantially when using a different, higher price.

SBS has favourable prices for both inputs and outputs so its actual profit exceeds what it would obtain using prices faced by the other banks in the banking sector.

In the first section of the paper we noted that a common approach in the DEA context was to use aggregate cash flows for income and expense elements to develop what Drake et al (2009) described as the profit/revenue approach. We undertook an analysis on this basis with this data set, using interest and non-interest expense and equity as inputs, and interest and non-interest revenue as outputs. Our results from an input-oriented variable returns to scale model are shown in Table 5 below.

Table 5: A more traditional profit/revenue model

	ANZ	ASB	KWB	SBS	TSB	WPT
Average efficiency score	.980	.975	.944	.982	.976	.978

This is showing us negligible inefficiency, which demonstrates that the inclusion of prices in this way, using this profit/revenue approach, does not take full account of the effects of prices in the way we have done in our main analysis. Decomposing the cash flows into prices and quantities, rather than just including the cash flow numbers directly into the analysis, is a preferable approach.

4 What we found

Analysing performance using technical efficiency only in the New Zealand banking sector gives a misleading impression of high performance. However, if meaningful prices can be identified or calculated, a more incisive analysis can be obtained where performance can be decomposed into allocative and technical efficiency components. We believe that our prices for interest revenue and cost are correct and appropriate; we also argue that our prices for branches, other assets and equity are reasonable approximations of their unobservable “true” price. Of course, these could be calculated using a different asset base or more sophisticated asset pricing model but this forms the basis for future research avenues.

The worst performance was from a Government owned bank, KWB, which has a more political objective than the narrower profit focus of the other banks. It also has more branches throughout the country which could be seen as providing greater access to more communities. While its technical efficiency is comparable to the other banks, its allocative efficiency is considerably worse under all three revenue, cost and profit models. It is rather disturbing that in order to improve its performance, it needs to close a substantial number of branches which we believe would be politically unacceptable.

The other major change required for performance improvement for four of the banks is the shift to improving revenue streams from Other Non-Lending Assets which comprise cash and investments, fixed assets, intangibles and other assets. How realistic such a shift in strategy is would depend on each bank's strategic focus and positioning.

We found that performance does change depending on the prices faced by each bank. SBS appear to have positioned themselves into favourable prices on both the input and output side. KWB has favourable branch costs but these still do not overcome their performance relative to the other banks. As an aside, any analysis exploring the use of alternative price sets needs to be aware of how these will be treated in commercial software which will use the prices provided to calculate the actual revenue, cost or profit.

Insofar as there is a weakness in our paper, it lies in the assumptions we have had to make in decomposing the prices and quantities: possibly this has penalised Kiwibank because of its large number of branches. The opportunity to develop a better decomposition might give us the scope to produce more robust results.

References:

Benston, G, J. (2004). What's special about banks? *The Financial Review.* 39 (1). 13-33.

Berger, A. N. & Bonaccorsi di Patti, E. (2006). Capital structure and firm performance: a new approach to testing agency theory and an application to the banking industry. *Journal of Banking and Finance.* 30. 1065-1102.

Berger, A. N. & Humphrey, D. B. (1997). Efficiency of Financial Institutions: International Survey and Directions for Future Research. *European Journal of Operational Research.* 98 (2). 175-212.

Berger, A. N. & Mester, L. J. (1997). Inside the black box: what explains differences in the efficiencies of financial institutions? *Journal of Banking and Finance.* 21. 895-947.

Cooper, W. W.; Seiford. L. M. & Tone, K. (2007). *Data Envelopment Analysis.* (Second Edition). New York: Springer

Drake, L.; Hall, M. J. B. & Simper, R. (2009). Bank modelling methodologies: a comparative non-parametric analysis of efficiency in the Japanese banking sector. *Journal of International Financial Markets Institutions and Money.* 19. 1-15.

Färe, R., Grosskopf, S. and C.A.K. Lovell. (1985). *The Measurement of Efficiency of Production*. Kluwer-Nijhoff Publishing

Fethi M. D. & Pasiouras F. (2010). Assessing bank efficiency and performance with operational research and artificial intelligence techniques: a survey. *European Journal of Operational Research.* 204. 189-198.

Hughes, J. P. & Mester, L. J. (1993). A quality and risk-adjusted cost function for banks: evidence on the "Too-big-to-fail" doctrine. *The Journal of Productivity Analysis.* 4. 293-315.

Koetter, M. (2006). Measurement matters – alternative input price proxies for bank efficiency analyses. *Journal of Financial Services Research.* 30. 199-227.

Lampe, H. W. & Hilgers, D. (2015). Trajectories of efficiency measurement: a bibliometric analysis of DEA and SFA. *European Journal of Operational Research.* 240. 1-21

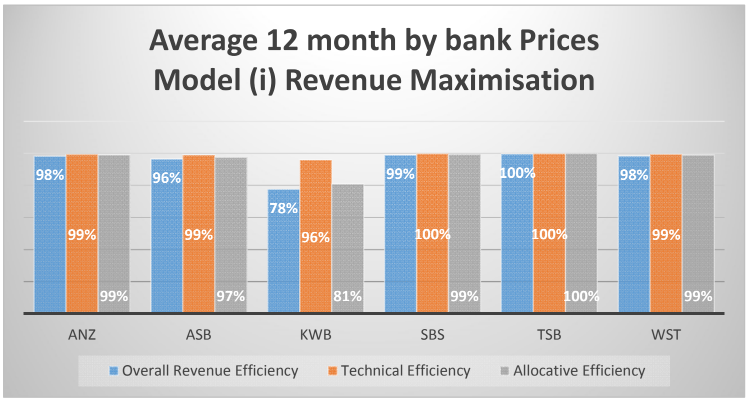
Liu, J. S.; Lu, L. Y. Y.; Lu, W-M. & Lin, B. J. Y. (2013). A survey of DEA applications. *Omega.* 41. 893-902.

Mountain, D. C. & Thomas, H. (1999). Factor price misspecification in bank cost function estimation. *Journal of International Financial Markets, Institutions and Money.* 9. 163-182.

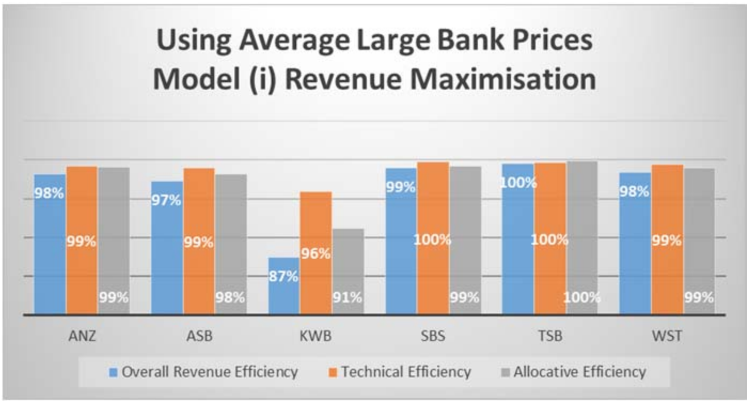
Sealey, C. W. & Lindley, J. T. (1977). Inputs, outputs, and a theory of production and cost at depository financial institutions. *Journal of Finance.* 32 (4). 1251-1266.

Weill, L. (2013). Bank competition in the EU: how has it evolved? *Journal of International Financial Markets, Institutions and Money.* 26. 100-112.

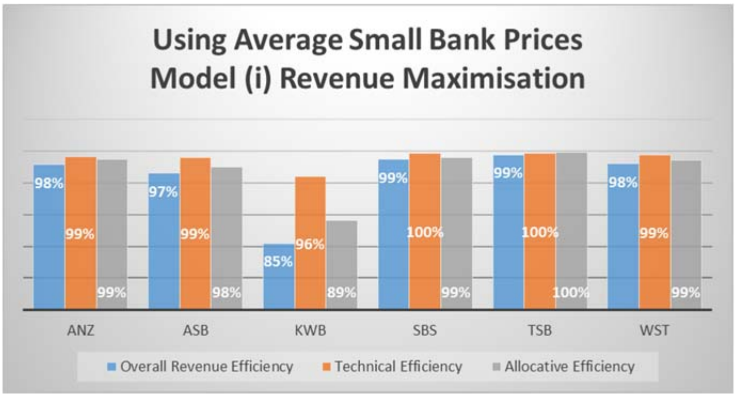
Appendix I



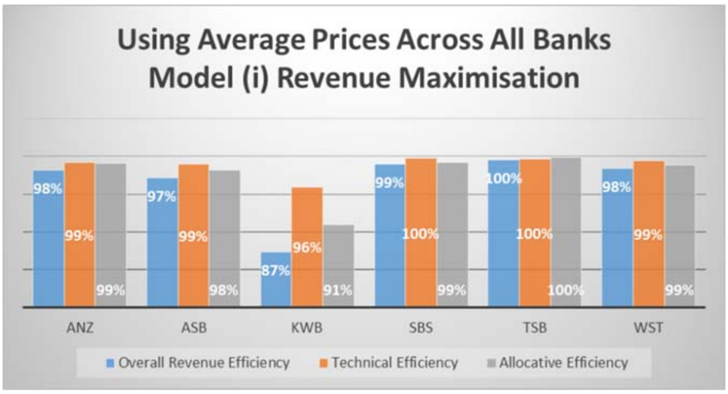
Average 12 month by bank Prices
Model (i) Revenue Maximisation
98%
99%
99%
96%
99%
97%
78%
96%
81%
99%
100%
99%
100%
100%
100%
98%
99%
99%
ANZ
ASB
KWB
SBS
TSB
WST
Overall Revenue Efficiency
Technical Efficiency
Allocative Efficiency



Using Average Large Bank Prices
Model (i) Revenue Maximisation
98%
99%
99%
97%
99%
98%
87%
96%
91%
99%
100%
99%
100%
100%
100%
98%
99%
99%
ANZ
ASB
KWB
SBS
TSB
WST
Overall Revenue Efficiency
Technical Efficiency
Allocative Efficiency



Using Average Small Bank Prices
Model (i) Revenue Maximisation
98%
99%
99%
97%
99%
98%
85%
96%
89%
99%
100%
99%
99%
100%
100%
98%
99%
99%
ANZ
ASB
KWB
SBS
TSB
WST
Overall Revenue Efficiency
Technical Efficiency
Allocative Efficiency



Using Average Prices Across All Banks
Model (i) Revenue Maximisation
98%
99%
99%
97%
99%
98%
87%
96%
91%
99%
100%
99%
100%
100%
100%
98%
99%
99%
ANZ
ASB
KWB
SBS
TSB
WST
Overall Revenue Efficiency
Technical Efficiency
Allocative Efficiency