Total Quality Management
Vol. 20, No. 11, November 2009, 1153–1172

Routledge
Taylor & Francis Group

An integration of balanced scorecards and data envelopment analysis for firm's benchmarking management

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Management performance measurement is a complex task since multiple inputs and multiple outputs are involved in the process. This study attempted to develop an integrated framework to encompass the basic concepts of balance scorecards (BSC) and data envelope analysis (DEA) for measuring management performance. BSC and DEA are complementary to each other. On the one hand, BSC can provide appropriate outputs of performance for DEA. On the other hand, DEA can set benchmarking for companies based on their inputs and outputs, as well as transform performance measures into managerial information. Accordingly, the synergy of BSC and DEA can translate the appropriate performance indices into managerial implications. This study selected auto and commercial bank industries as the targets for empirical investigation. The results indicated that the interrelationships among four perspectives of BSC were empirically valid. However, the most crucial indicators in each perspective were distinct in different industries. About 46% of auto companies and 57% of commercial banks are located at efficiency frontiers. Managerial implications and research limitations are addressed as well.

Keywords: balanced scorecard; data envelopment approach; benchmarking management; quality management; performance management

Introduction

The increasing use of organisational measurement systems is changing the way managers run their companies (Bojnec & Latruffe, 2008; Prajogo, 2007; Soltani et al., 2007). The balanced scorecards (BSCs) are a formal management system that provides a realistic framework linking performance measurements to strategic objectives (Hasan & Tibbits, 2000). The BSC integrates the interests of the key stakeholders including owners, customers and employees (Bach et al., 2001; Kaplan & Norton, 1996). The term 'balance' reflects the attempt to capture both financial and non-financial measurements with emphasis on lagging and leading indicators, long-term strategic objectives and short-term actions, external and internal performance perspectives, as well as quantitative-objective and qualitative-subjective measures (Ahn, 2001; Bach et al., 2001; Denton & White, 2000; Gautreau & Kleiner, 2001; Green et al., 2007; Kaplan & Norton, 1996; Papalexandris et al., 2005; Phusavat, 2007; Phusavat & Kanchana, 2008).

Although BSC has received wide acceptance from academics and practitioners (Butler et al., 1997), there are several major limitations of the BSC approach discussed in the literature (Othman et al., 2006). First, it is a top-down approach only (Kanji & Moura, 2001;

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ISSN 1478-3363 print/ISSN 1478-3371 online
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DOI: 10.1080/14783360903248286
http://www.informaworld.com

Malina & Selto, 2001). Therefore, the interactions between top management team and working level employees are limited. Lohman et al. (2004) found that the BSC did not provide an opportunity to develop, communicate and implement strategy in a corporate setting. Although BSC has been adopted widely by different industries, there is no formal implementation methodology. This lack of formal implemented methodology and subjective measures often leads to focusing on short-term financial measures. Finally, according to Fletcher and Smith (2004), the BSC lacks a single focus for accountability. What the BSC does not do but what managers need is one comprehensive index to summarise the interaction between these leading and lagging measures of performance. While the BSC may tell us what measures to look at, it does not tell us how to look at them or their relative importance.

Although BSC has some limitations, it serves as a basis for resource deployment and improving internal process (Pock et al., 2004). A BSC enhances the quality of a firm's controlling system in various ways. The purpose of this study is to integrate data envelope analysis (DEA) with output factors based on the BSC approach and expand the concept of benchmarking to solve those problems. DEA is a tool to calculate efficiencies with non-parametric approach based on a set of inputs and outputs (Narasimhan & Graham, 2005; Serrano-Cinca et al., 2005; Wang, 2006). BSC and DEA are different concepts but complementary to each other. On the one hand, DEA is capable of improving the limitations of BSC and providing more useful information for managers. The performance measurement system is wasted unless the data can offer managerial implications and inform management's actions (Franco & Bourne, 2003; Lin et al., 2008; Wu et al., 2008). While BSC can measure an organisation's performance from brief but comprehensive perspectives (Braam & Nijssen, 2004), DEA can evaluate overall management performance based on inputs and outputs, and set appropriate benchmarks for each company (Rickards, 2003). Benchmarking is a management technique used broadly by an organisation or a department to improve performance. Many companies have engaged in benchmarking practice and made great progress.

In addition to benchmarking, DEA can provide information related to either the most efficient or the most inefficient companies (Mostafa, 2007). Furthermore, it can analyse multiple inputs and outputs simultaneously, as well as show by what percentage the inputs should decrease in order to achieve a given output level and by what percentage the outputs should increase given original levels of inputs in order to reach efficiency (Rickards, 2003). Hence, DEA can transform performance measures into managerial information. On the other hand, BSC can provide appropriate outputs for DEA. Serrano-Cinca et al. (2005) argued that different combinations of inputs and outputs would produce different efficiency. Hence, the results of DEA depend on the selection of inputs and outputs. Serrano-Cinca et al. (2005) also stated that the DEA model could not involve redundant information. BSC is able to resolve these two concerns in that it not only minimises information overload by limiting the number of measures used (Kaplan & Norton, 1992) but also develops the scorecard by linking to key success factors (Frigo & Krumwiede, 2000). Accordingly, BSC and DEA complement each other.

In short, management performance measurement is a complex task since multiple inputs and multiple outputs are involved in the process. The balanced scorecard is one approach to measuring management performance. When the efficiencies of multiple performance organisations are to be compared quantitatively, however, DEA will be appropriate because DEA enables management to integrate dissimilar multiple inputs and outputs to make simultaneous comparisons (Avkiran, 2002). DEA rests on the economic notion of the production technology transforming inputs to outputs. It is a non-parametric

approach for estimating maximum output level for given inputs or minimum input levels for given output levels (Thanassoulis, 1996). Its advantage is the ability to deal with aggregate information rather than detailed information (Chang & Lo, 2005). Therefore, DEA is viewed as a methodology that provides a valid starting point for specifying balanced performance. The main purpose of this study is to fill the research gap and develop a comprehensive framework to encompass the basic concepts of BSC and DEA to measure management performance. On the one hand, BSC is a widely acceptable performance measurement system. As Kaplan and Norton (1992) stated, 'what you measure is what you get' (p. 71), BSC can provide appropriate outputs of performance for DEA. BSC is able not only to minimise information overload by limiting the number of measures used (Kaplan & Norton, 1992) but also to develop the scorecard by linking to key success factors (Frigo & Krumwiede, 2000). On the other hand, DEA can set benchmarking for companies based on their inputs and outputs, as well as transform performance measures into managerial information. Thus, BSC and DEA are complementary to each other. As BSC is commonly used in traditional industries and creates too many numbers to deal with easily, this study seeks to combine BSC with DEA to evaluate management performance in the manufacturing sector (i.e. the auto industry) and the service sector (i.e. the national commercial bank industry). The results of this study could also assist governmental administrators and business managers to make decisions on investment and management.

Literature review

Balanced scorecard (BSC) approach

The BSC approach offered by Kaplan and Norton (1992) addresses the issues of divergent stakeholder goals and gauging managers' effectiveness. Kaplan and Norton (1992) proposed four balanced perspectives to measure performance comprehensively including financial, customer, internal business processes, and learning and growth perspective. These perspectives reflect the interests of the key stakeholders of companies involving shareholders, customers and employees (Gautreau & Kleiner, 2001; Mooraj et al., 1999).

The performance measurements from the financial perspective indicate 'whether the company's strategy, implementation, and execution are contribution to bottom-line improvement' (Kaplan & Norton, 1992, 77). The performance measurements from the customer perspective indicate the company's sources of demand (Denton & White, 2000). This perspective can force the company to view its performance through customers' eyes (Kaplan & Norton, 1992). The emphasis on customers should take care of satisfaction, loyalty, retention and acquisition of customers (Kaplan & Norton, 1996). Moreover, Mooraj et al. (1999) argued that the internal business process perspective of BSC focused on the internal processes required for excelling in efficiently providing the value expected by customers. To satisfy customer needs and to achieve better competitive advantage, many firms have concentrated their efforts on the improvement of internal business processes. In terms of the learning and growth perspective, Kaplan and Norton (1992) stated that the firm's ability to innovate, improve and learn could tie in to the firm's value.

Interrelationships among four perspectives of the BSC

Kaplan and Norton (1996) proposed the cause-and-effect relationships among the four perspectives of BSC by measuring the strength of the linkages among measures in different

perspectives. Additionally, the cause-and-effect relationships among measurement in different perspectives of BSC are essential in that the performance measurement system can act as a feed-forward control system because of the non-financial indicators (Nørreklit, 2003). Accordingly, the interrelationships among different perspectives of BSC favour selection of appropriate measurements for the company and enhancement of advantage of the performance measurement system (Mooraj et al., 1999).

Fletcher and Smith (2004) suggested that the learning and growth perspective was the leading indicator of internal business process, which was in turn the leading indicator of customer satisfaction. A degree of improvement of internal business process and level of customer satisfaction will in turn affect the financial perspective. The BSC takes a balanced look at the firm because it focuses on leading and lagging indicators of performance measurement, financial management, and quantitative and qualitative measures of performance.

Based on the above literature review, it seems that the interrelationship among four perspectives of the BSC have attracted management attention. However, researchers seem not to reach a consistent agreement on the interrelationship between the four perspectives of the BSC. Rusjan (2005) pointed out that the relationships between the difference performance areas were not clear. This study would like to go further by integrating the opinions of previous studies to evaluate more specifically the interrelationship between the four perspectives of the BSC and between the individual indicators of each BSC perspective, especially in the auto and national commercial bank industries.

Research hypotheses

Based on the previous studies described above of Denton and White (2000), Fletcher and Smith (2004) and Kaplan and Norton (1996), hypotheses on the interrelationships between the four perspectives of the BSC are developed as follows:

Hypothesis 1: The factors of the learning and growth perspective of the balanced scorecard will significantly impact on the factors of the internal business process perspective of the balanced scorecard.

Hypothesis 2: The factors of the internal business process perspective of the balanced scorecard will significantly impact on the factors of the customer perspective of the balanced scoreboard.

Hypothesis 3: The factors of the customer perspective of the balanced scorecard will significantly impact on the factors of the financial perspective of the balanced scorecard.

The objects of DEA are decision-making units (DMUs). In practice, there are branch stores, business offices, company divisions, diverse sites manufacturing a particular product, product groups, subsidiary corporations, work teams, and so forth. One can investigate various kinds of efficiency on the basis of a DEA.

Based on the previous studies on DEA of Banker et al. (1984), Banker and Thrall (1992), Charnes et al. (1978), and Sueyoshi (1997), hypotheses of efficiency frontier are developed as follows:

Hypothesis 4: The most efficient DMUs are ones that allocate on the efficiency frontier. The DMUs that allocate below the regression line are less efficient and in reverse, the DMUs that allocate above the regression line are more efficient.

Hypothesis 5: The differences between the two industries (i.e. auto and national commercial bank) tend to perform differently on all research variables, including input variables and output variables such as financial, customer, internal business process, learning and growth perspectives of the balanced scorecard.

Methodology

Research model

The purpose of this study is to evaluate the performance in two distinct industries (i.e. auto and national commercial bank) by means of BSC and DEA. According to the purpose and hypotheses of this study, a research framework is developed as shown in Figure 1. Managers must adopt the BSC to evaluate their management performances from four perspectives including the financial perspective, customer perspective, internal business process perspective, as well as learning and growth perspective. In addition, in order to evaluate the competitive position of the firm, managers need to apply DEA to identify the efficiency frontier, benchmarking partners and inefficient slacks for the firms. DEA is a non-parametric approach for estimating maximum output level for given inputs or minimum input levels for given output levels (Thanassoulis, 1996), which has been applied to evaluate benchmarking and identify best practice frontiers (Chang & Lo, 2005). DEA can indicate and compare relatively inefficient and efficient units and suggest how to reduce the inefficiencies (Wang, 2006). Therefore, by using DEA, the results of this study intend to provide competitive information and benchmarking partner, which are essential for firms to design long-term strategies and objectives.

Construct measurement

DEA methodology is a non-parametric approach to performance measurement on the basis of a set of inputs and outputs. For the input measurement, this study adopted four factors as input variables comprising employees, costs, materials and assets. However, there was no 'materials' item for the national commercial bank industry. Thus, 'materials' was replaced with operating expenses as to national commercial banks. For the output measurement, four major sections are operationalised including financial perspective, customer perspective, internal business process perspective, and learning and growth perspective.

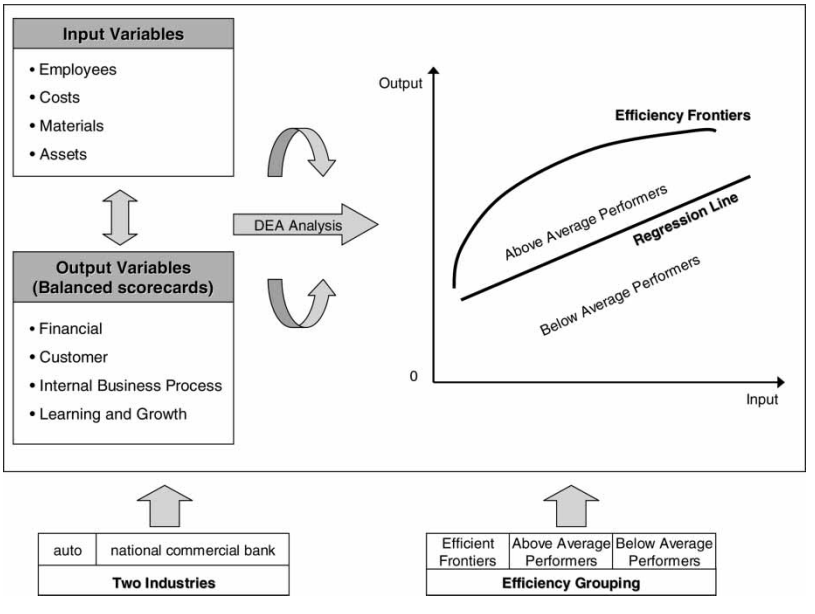


Figure 1. The research conceptual framework.

Several scholars have suggested various sets of indicators with respect to the perspectives of BSC. Based on the past literature, this study selected measurements for the sake of parsimony and accessibility of indicators. In terms of the financial perspective, there were four indicators involving total revenue, operating income, cash flow and accounts receivable. In terms of the customer perspective, there were two indicators involving relative market share and market share growth. The relative market share was the percentage of sales for the company relative to total sales for the industry, whereas the market share growth was calculated on the basis of relative market share of current year and previous year. In terms of the internal business process perspective, there were three indicators including total assets turnover, inventory turnover, and property plant and equipment turnover. Turnover rate is the objective indicator to measure the efficiency with respect to internal process. The high turnover rate represents high efficiency. However, the inventory turnover was deleted for the national commercial banks, because there was no inventory for banks.

In terms of the learning and growth perspective, there were three indicators: the research and development expenses per employee, administrative expenses per employee and intangible assets. However, most national commercial banks did not disclose the research and development expenses and intangible assets. In this regard, the research and development expenses per employee indicator was replaced with average salary per employee, and intangible assets were deleted as to the national commercial bank industry.

This study further used principal component factor analysis, item to total correlation analysis, and Cronbach's alpha to evaluate the dimensionality and reliability of outputs, that is, four perspectives of BSC. Factor analysis examined the basic structure of the data, and item to total correlation analysis assessed the degree of multicollinearity among variables. Cronbach's alpha measured the internal consistency of each identified dimension. The results of these analyses are shown in Table 1. Following the suggestions of Hair et al. (2006), with the criteria of factor loadings greater than 0.6, item to total correlation coefficients greater than 0.5, and Cronbach's alpha greater than 0.6, it is shown that the dimensionality and reliability of all research constructs are quite reliable and acceptable. Therefore, each dimension of BSC could be calculated by the average of its indicators.

Sampling plan and data collection

This study chose two distinct industries for the purpose of comparison, comprising of the auto and national commercial bank industries. The Mergent database is the primary source of samples and data. Specifically, we picked the sample companies as well as their financial statements and annual reports from the Mergent database. One of the conditions imposed by DEA is the requirement of homogeneity of the data (Serrano-Cinca et al., 2005). In order to ensure the homogeneity of samples with respect to these two types of industries, this study employed SIC as the criteria to select companies in each industry (i.e. SIC is 3711 for auto industry; SIC is 6021 for national commercial banks).

For the purpose of parsimony, this study only picked the top 50 companies for each industry category according to the total revenue in the latest annual reports. However, we deleted several sample companies which were merged or acquired, or did not provide the recent financial reports in the Mergent database. The final valid sample contains 39 companies for the auto industry and 30 companies for the national commercial bank industry. According to Golany and Roll (1989), the number of DMUs required for DEA should be double or more the total research variables. Since this study contained eight factors (four input variables and four output variables), 30 or 39 samples in each industry would be appropriate. All of the research variables were offered in the companies' financial

Table 1. The measurements of constructs of BSC.

Construct	Indicator	Factor loading	Item-to-total correlation	Cronbach's alpha
Auto industry				
Financial perspective	Total revenue	0.968	0.902	0.835
	Operating income	0.724	0.590	
	Cash flow	0.782	0.791	
	Accounts receivable	0.796	0.647	
Customer perspective	Relative market share	0.808	0.505	0.877
	Growth of market share	0.808	0.505	
Internal business perspective	Total assets turnover	0.902	0.691	0.713
	Inventory turnover	0.830	0.598	
	Property plant and equipment turnover	0.653	0.567	
Learning and growth perspective	Intangible assets	0.696	0.501	0.618
	R&D expenses per employee	0.908	0.518	
	Administrative expenses per employee	0.650	0.573	
Commercial bank industry				
Financial perspective	Total revenue	0.944	0.891	0.771
	Operating income	0.698	0.589	
	Cash flow	0.923	0.794	
	Accounts receivable	0.591	0.560	
Customer perspective	Relative market share	0.714	0.620	0.740
	Growth of market share	0.714	0.620	
Internal business perspective	Total assets turnover	0.810	0.611	0.774
	Property plant and equipment turnover	0.810	0.611	
Learning and growth perspective	Administrative expenses per employee	0.975	0.900	0.947
	Salary and wages per employee	0.975	0.900	

statements and annual reports. Since the scale of variables was based on national monetary units, this study adjusted each variable of all samples to US$ scale (million). The characteristics of variables and samples are shown in Table 2.

The national origins of the majority of our sample were Japan for the auto industry and the United States for commercial banks. In terms of the input variables, the auto industry had the most number of employees and highest direct costs, whereas the commercial banks had the most total assets. Nevertheless, the commercial bank industry had the least total assets turnover.

Results of analysis

Interrelationships between research variables

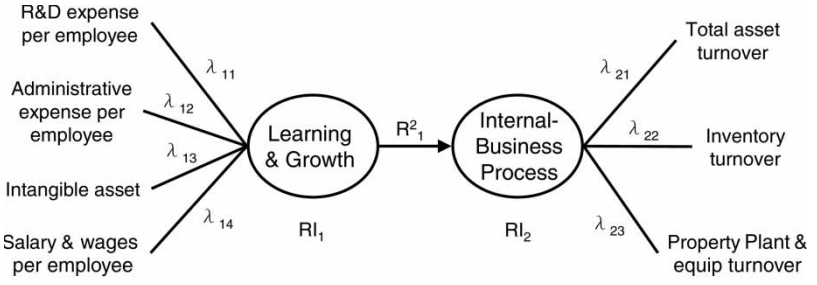
In order to achieve the purpose of this research and test the hypotheses, SPSS 10.5 and DEA 2.1 software were employed to analyse the data. In order to examine the interrelationships between four perspectives of BSC, this study used canonical correlation analysis to test Hypotheses 1, 2 and 3. The detailed information of canonical results is shown in Figures 2 to 4. For relationships between the learning and growth perspective and the internal business process perspective of BSC, Figure 2 demonstrates that levels of indicators of the learning and growth perspective tended to significantly influence

Table 2. The characteristics of samples.

	Auto industry (n = 39)	Commercial bank industry (n = 30)
Nationality	China: n = 2 Europe: n = 9 Indian: n = 3 Indonesian: n = 1 Japan: n = 16 Korea: n = 3 Swedish: n = 1 Taiwan: n = 1 United States: n = 3	Brazil: n = 1 Canada: n = 1 China: n = 5 England: n = 1 Europe: n = 4 Hong Kong: n = 1 Indian: n = 1 Japan: n = 1 Taiwan: n = 4 Thailand: n = 2 United States: n = 7 Venezuela: n = 2
Number of employees	86490.51 (110261.39)	73539.20 (107320.94)
Direct costs	33632.43 (46659.54)	9531.97 (12921.01)
Raw material/operating income	2205.56 (5621.14)	8076.73 (12180.51)
Total assets	57898.17 (99358.47)	319520.06 (435755.23)
Total revenue	41649.78 (56341.48)	20004.11 (30155.05)
Operating income	1133.022 (2053.86)	4300.41 (7960.10)
Cash flow	5974.18 (10936.61)	79055.79 (150677.82)
Accounts receivable	9115.84 (18550.77)	18646.96 (27749.79)
Total assets turnover	1.31 (0.78)	0.06 (0.03)
Inventory turnover	18.78 (23.67)	–
Property plant and equipment turnover	4.68 (2.50)	5.58 (4.55)
Intangible assets	1522.13 (2480.35)	–
R&D expenses per employee	0.011 (0.012)	–
Administrative expenses per employee	0.068 (0.095)	0.037 (0.039)
Salary and wages per employee	–	0.064 (0.059)

Note: Numbers in parentheses are means, numbers without parentheses are standard deviations.

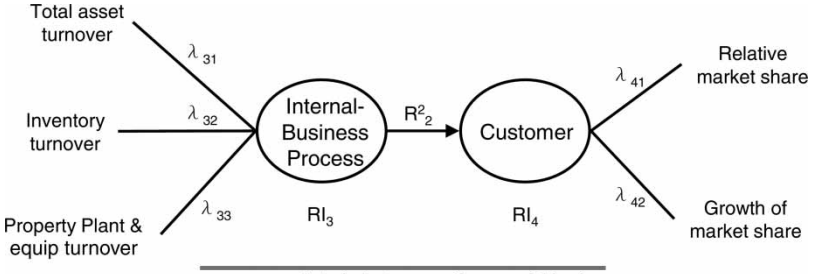
total assets turnover, inventory turnover, and property plant and equipment turnover for the auto industry ($Can\ R^2 = 0.388$; $F = 80.46$; $p < 0.05$). Additionally, levels of indicators of the learning and growth perspective tended to significantly influence total assets turnover and property plant and equipment turnover for the commercial bank industry ($Can\ R^2 = 0.382$; $F = 52.00$; $p < 0.05$). Therefore, the results were consistent with Hypothesis 1 that the factors of the learning and growth perspective of the BSC had significant influence on the factors of the internal business process perspective of the BSC.



	Auto industry (n=39)	Commercial bank industry (n=30)
R^2_1	0.388	0.382
RI_1	22.395%	18.991%
RI_2	14.088%	15.460%
λ_{11}	0.677*	–
λ_{12}	0.480*	0.437*
λ_{13}	0.633*	–
λ_{14}	–	0.786*
λ_{21}	0.977*	0.327*
λ_{22}	0.632*	–
λ_{23}	0.615*	0.942*

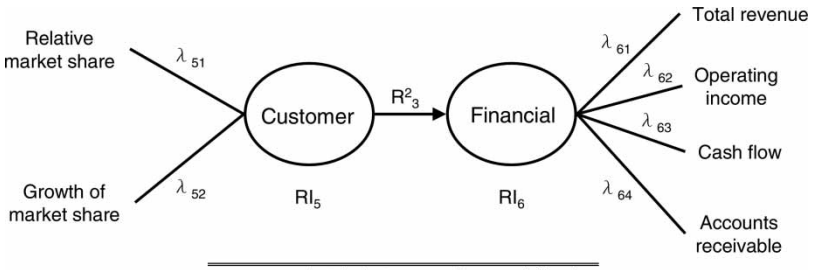
Figure 2. The interrelationships between the learning and growth perspective and the internal business process perspective of BSC.

Hypothesis 2 proposed that the factors of the internal business process perspective of the BSC had significant influence on the factors of the customer perspective of the BSC. Figure 3 reveals the detailed information of canonical correlation. Specifically, levels of indicators of the internal business process perspective tended to significantly influence relative market share and the growth of market share for the auto industry ($Can\ R^2 = 0.239$; $F = 68.00$; $p < 0.05$) and commercial bank industry ($Can\ R^2 = 0.294$; $F = 62.00$; $p < 0.05$). Thus, Hypothesis 2 was supported.



	Auto industry (n=39)	Commercial bank industry (n=30)
R^2_2	.239	.294
RI_3	13.220%	14.925%
RI_4	9.929%	19.211%
λ_{31}	.923*	.760*
λ_{32}	.405*	–
λ_{33}	.480*	.854*
λ_{41}	.989*	.904*
λ_{42}	.358*	.446*

Figure 3. The interrelationships between the internal business process perspective and the customer perspective of BSC.



	Auto industry (n=39)	Commercial bank industry (n=30)
$R^2_{.3}$	.997	.990
RI_5	64.819%	55.307%
RI_6	54.557%	54.761
λ_{51}	1.000*	1.000*
λ_{52}	.307*	.326*
λ_{61}	1.000*	.999*
λ_{62}	.607*	.567*
λ_{63}	.861*	.892*
λ_{64}	.701*	.346*

Figure 4. The interrelationships between the customer perspective and the financial perspective of BSC.

For relationships between the customer perspective and the financial perspective of BSC, Figure 4 demonstrates that levels of indicators of customer perspective tended to significantly influence total revenue, operating income, cash flow and accounts receivable for the auto industry ($Can\ R^2 = 0.997$; $F = 66.00$; $p < 0.000$) and the commercial bank industry ($Can\ R^2 = 0.990$; $F = 48.00$; $p < 0.000$). Therefore, the results were consistent with Hypothesis 3 that the factors of the customer perspective of the BSC had significant influence on the factors of the financial perspective of the BSC.

According to the variables with higher levels of canonical loading, R&D expenses per employee and intangible assets are two of the most promising factors that would be positively related to total assets turnover which in turn are positively related to relative market share for the auto industry. And the relative market share would be positively related to total revenue. In terms of the commercial bank industry, the salary and wages per employee are the most promising factors that would be positively related to property plant and equipment turnover which in turn positively relates to relative market share. And the relative market share would be positively related to total revenue. As a result, the cause-and-effect relationships among BSC perspectives (Fletcher & Smith, 2004; Kaplan & Norton, 1996) were supported for the auto and commercial bank industries.

Measuring the efficiency of each industry

This study used DEA with output orientation to calculate the relative efficiency for the auto and commercial bank industries. Through the application of DEA, the results would show the peer partners and the slacks of inputs for each company, as well as the efficiency frontiers of companies in each industry. The detailed results with respect to the auto industry are shown in Tables 3 and 4. The production efficiency (Constant returns to scale, CRS) was calculated based on CCR model developed by Charnes, Cooper, and Rhodes 1978. The production efficiency which equalled to one represented that the DMU was efficient relative to other DMUs, whereas the production efficiency which was smaller than one represented that the DMU was inefficient relative to other DMUs. Table 3 reveals that the majority of DMUs in the auto industry had good

Table 3. The efficiency and the benchmark peers of each DMU for auto the industry.

DMU	CRS	VRS	Scale[a]		Peers						Peer count	DMU	CRS	VRS	Scale[a]		Peers						Peer count
1	0.867	0.944	0.918	drs	27	4	18	28			0	21	0.798	0.932	0.856	drs	9	4	15	27			0
2	1.000	1.000	1.000	–	2						0	22	0.731	0.816	0.895	drs	20	24	9	27			0
3	1.000	1.000	1.000	–	3						2	23	0.729	1.000	0.729	irs	23						0
4	1.000	1.000	1.000	–	4						6	24	0.821	1.000	0.821	drs	24						4
5	0.441	0.509	0.866	drs	27	3	4	32			0	25	1.000	1.000	1.000	–	25						3
6	1.000	1.000	1.000	–	6						0	26	1.000	1.000	1.000	–	26						0
7	0.828	1.000	0.828	irs	7						0	27	1.000	1.000	1.000	–	27						11
8	0.896	0.913	0.981	drs	32	18	35	34	9	20	0	28	1.000	1.000	1.000	–	28						6
9	1.000	1.000	1.000	–	9						8	29	1.000	1.000	1.000	–	29						2
10	0.841	0.871	0.965	drs	29	24	28	27	9		0	30	0.775	0.827	0.937	irs	39	3	28	18	4	27	0
11	0.769	0.983	0.783	drs	16	25	18	9	15		0	31	0.828	0.944	0.877	drs	20	24	28	27			0
12	0.799	0.800	0.999	–	28	9	4	39	20	27	0	32	1.000	1.000	1.000	–	32						2
13	0.715	0.958	0.747	drs	18	25	35	9	15		0	33	0.891	0.985	0.905	drs	18	27	28	25			0
14	0.911	0.991	0.919	drs	24	29	27	9	20		0	34	1.000	1.000	1.000	–	34						1
15	1.000	1.000	1.000	–	15						4	35	1.000	1.000	1.000	–	35						2
16	1.000	1.000	1.000	–	16						2	36	0.753	1.000	0.753	drs	36						0
17	1.000	1.000	1.000	–	17						0	37	1.000	1.000	1.000	–	37						0
18	1.000	1.000	1.000	–	18						6	38	0.926	1.000	0.926	drs	38						0
19	0.806	0.853	0.945	drs	20	4	16	27	15		0	39	1.000	1.000	1.000	–	39						2
20	1.000	1.000	1.000	–	20						6												

Note: [a] Scale of efficiency. The scale equal to one represented that the DMU was in the condition of optimal return scale, otherwise, the scale unequal to one represented that the DMU was inefficient in the condition of decreasing or increasing return scale (i.e., drs or irs). When the DMU was in the condition of decreasing return scale (drs), the DMU should decrease its inputs accordingly in order to enhance performance or efficiency. On the other hand, when the DMU was in the condition of increasing return scale (irs), the DMU should increase its inputs accordingly to expand its operating scope.

Table 4. The slack of inputs of each DMU.

Auto industry					Commercial bank industry				
DMU	Number of employees	Direct costs US$ (million)	Material US$ (million)	Total assets US$ (million)	DMU	Number of employees	Direct costs US$ (million)	Operating expenses US$ (million)	Total assets US$ (million)
1	688.927	0.000	0.000	0.000	1	463.899	0.000	26677832.429	0.000
2	0.000	0.000	0.000	0.000	2	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	4	0.000	0.000	0.000	0.000
5	14642.577	0.000	81710.307	0.000	5	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	6	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	7	64.943	89.873	6316457.284	255868.844
8	0.000	0.000	0.000	0.000	8	124.808	447.812	9384214.706	0.000
9	0.000	0.000	0.000	0.000	9	40.130	0.000	7696067.860	0.000
10	0.000	0.000	0.000	0.000	10	0.000	0.000	0.000	0.000
11	0.000	30759056.565	2046868.193	84120987.708	11	0.000	96.252	0.000	0.000
12	0.000	0.000	0.000	0.000	12	0.000	0.000	0.000	0.000
13	0.000	31596971.136	3374501.672	0.000	13	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	14	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	15	2.969	392.977	0.000	0.000
16	0.000	0.000	0.000	0.000	16	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	17	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	18	0.000	0.000	0.000	0.000
19	0.000	0.000	1567409.292	0.000	19	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	20	0.000	340.895	0.000	324152.849
21	0.000	0.000	7039490.662	0.000	21	0.000	0.000	0.000	0.000
22	0.000	0.000	2072262.617	0.000	22	0.000	0.000	0.000	0.000

23	0.000	0.000	0.000	0.000	23	10.022	53.092	193833.472	0.000
24	0.000	0.000	0.000	0.000	24	0.000	0.000	0.000	0.000
25	0.000	0.000	0.000	0.000	25	0.000	0.000	0.000	0.000
26	0.000	0.000	0.000	0.000	26	101.868	0.000	0.000	9193318.289
27	0.000	0.000	0.000	0.000	27	0.000	0.000	0.000	244721.751
28	0.000	0.000	0.000	0.000	28	0.000	0.000	0.000	0.000
29	0.000	0.000	0.000	0.000	29	0.000	471.331	0.000	6542514.936
30	0.000	0.000	0.000	0.000	30	67.725	0.000	0.000	12156886.580
31	0.000	0.000	2648853.363	0.000					
32	0.000	0.000	0.000	0.000					
33	135.503	984200.690	0.000	0.000					
34	0.000	0.000	0.000	0.000					
35	0.000	0.000	0.000	0.000					
36	0.000	0.000	0.000	0.000					
37	0.000	0.000	0.000	0.000					
38	0.000	0.000	0.000	0.000					
39	0.000	0.000	0.000	0.000					

performance, such as Nos. 2, 3, 4, 6 DMU. For these efficient DMUs, they were located at the efficiency frontier. In addition, there were 19 inefficient DMUs which were necessary to refer to other efficient benchmarks. Table 3 also reveals each inefficient DMU's benchmarks in the column of peers.

Table 3 also shows that there were three DMUs in the condition of increasing return scale (irs), and there were 15 DMUs in the condition of decreasing return scale (drs). The results of DEA also provided information indicating how to improve DMU's efficiency by adjusting inputs. Table 4 displays the slacks of inputs that represented the redundant amounts of inputs. Most of these DMUs in the condition of increasing return scale (irs) or decreasing return scale (drs) should adjust their quantities of materials. Only No. 11 DMU had excessive levels of total assets. Nos. 1, 5 and 33 DMU had too many employees.

In terms of the commercial banks, Table 5 reveals that 12 DMUs in the commercial bank industry had good performance and are located at the efficiency frontier, such as Nos. 2, 3, 4, 5 DMU. In addition, there were 18 inefficient DMUs which needed to refer to other efficient benchmarks to improve their performance. For example, No. 1 DMU should learn from Nos. 13, 25, 24 and 21 DMU. Table 5 also showed that there were no DMUs in the condition of increasing return scale (irs), and there were 18 DMUs in the condition of decreasing return scale (drs) in these inefficient DMUs. Table 4 displays that most of these DMUs in the condition of irs or drs should adjust their amounts of employees, direct costs, operating expenses and total assets.

Norman and Barry (1991) proposed that the DMUs could be classified according to the levels of efficiency. The first category was the robustly efficient unit. The DMU in this category was not only efficient but also other DMUs' benchmark. The second category was the marginal efficient unit, in which the DMU was efficient in that the value of CRS was equal to one, but it was not other DMUs' benchmark in that the DMU may have distinct characteristics from others in the same industry. The third category was the marginal inefficient units whose value of efficiency lay in between 0.8 to 1. If the DMUs in this category would adjust their inputs or outputs, they were more likely to achieve the status of efficiency. The fourth category was the distinctly inefficient units whose value of efficiency was lower than 0.8.

In addition, some DMUs belonging to the inefficient unit category did not have to refer to other DMUs, even they could be other DMUs' benchmarks due to the value 'one' of variable returns to scale (VRS). In this case, these DMUs also were located in the efficiency frontiers (Banker et al., 1984). Nos. 7, 23, 24, 36, and 38 for the auto industry, Nos. 2, 5, 13, 15, as well as Nos. 6, 10, 12, 16, 19, and 24 DMUs for the commercial bank industry were the cases in point. Thus, the DMUs located in the efficiency frontiers included the robustly efficient units and the inefficient units whose VRS equalled to one.

Table 6 displays the summary of the preceding discussion for each industry. The auto industry had the highest percentages of marginal inefficient units, and the lowest percentages of robustly efficient units and DMUs located in the efficiency frontiers. Although the commercial bank industry had the highest percentages of distinct inefficient units, it also had the highest percentages of DMUs located in the efficiency frontiers. According to Tables 3 to 6, Hypothesis 4 was supported.

The comparisons of inputs and outputs among industries

In order to examine Hypothesis 5, this study further employed t-test to compare the differences with respect to research constructs. Among other matters, the number of employees,

Table 5. The efficiency and the benchmark peers of each DMU for the commercial bank industry.

DMU	CRS	VRS	Scale[a]		Peers					Peer count	DMU	CRS	VRS	Scale[a]		Peers						Peer count
1	0.181	0.482	0.376	drs	13,	25,	24,	21		0	16	0.709	1.000	0.709	drs	16						0
2	1.000	1.000	1.000	–	2					3	17	1.000	1.000	1.000	–	17						0
3	1.000	1.000	1.000	–	3					4	18	1.000	1.000	1.000	–	18						1
4	1.000	1.000	1.000	–	4					1	19	0.747	1.000	0.747	drs	19						3
5	1.000	1.000	1.000	–	5					1	20	0.292	0.535	0.546	drs	2,	22,	21,	12			0
6	0.339	1.000	0.339	drs	6					1	21	1.000	1.000	1.000	–	21						6
7	0.683	0.870	0.785	drs	25,	13,	22			0	22	1.000	1.000	1.000	–	22						4
8	0.188	0.340	0.554	drs	25,	22,	24			0	23	0.913	0.930	0.982	drs	14,	21					0
9	0.498	0.780	0.638	drs	25,	13,	24,	22		0	24	0.802	1.000	0.802	drs	24						4
10	0.298	1.000	0.298	drs	10					2	25	1.000	1.000	1.000	–	25						8
11	0.266	0.961	0.277	drs	25,	3,	19,	10		0	26	0.283	0.452	0.627	drs	28,	25,	13,	21			0
12	0.927	1.000	0.927	drs	12					2	27	0.585	0.588	0.994	drs	5,	21,	3,	18,	4		0
13	1.000	1.000	1.000	–	13					6	28	1.000	1.000	1.000	–	28						2
14	1.000	1.000	1.000	–	14					1	29	0.311	0.706	0.441	drs	12,	28,	3,	13,	25,	2	0
15	0.398	0.826	0.481	drs	6,	13,	19,	24,	21	0	30	0.282	0.842	0.335	drs	25,	19,	2,	10,	3		0

Table 6. The summary of efficiency of DMU for each industry.

Category	DMU	Number	Percentage
Robustly efficient unit			
Auto (n = 39)	3, 4, 9, 15, 16, 18, 25, 27, 28, 29, 32, 34, 35	13	33.33%
Commercial bank (n = 30)	2, 3, 4, 5, 13, 14, 18, 21, 22, 25, 28	11	36.67%
Marginal efficient unit			
Auto (n = 39)	2, 6, 17, 26, 37	5	12.82%
Commercial bank (n = 30)	17	1	03.33%
Marginal inefficient unit			
Auto (n = 39)	1, 7, 8, 10, 14, 19, 24, 31, 33, 38	10	25.64%
Commercial bank (n = 30)	12, 23, 24	3	10.00%
Distinctly inefficient unit			
Auto (n = 39)	5, 11, 12, 13, 21, 22, 23, 30, 36	9	23.08%
Commercial bank (n = 30)	1, 6, 7, 8, 9, 10, 11, 15, 16, 19, 20, 26, 27, 29, 30	15	50.00%
Efficiency frontiers			
Auto (n = 39)	3, 4, 7, 9, 15, 16, 18, 23, 24, 25, 27, 28, 29, 32, 34, 35, 36, 38	18	46.15%
Commercial bank (n = 30)	2, 3, 4, 5, 6, 10, 12, 13, 14, 16, 18, 19, 21, 22, 24, 25, 28	17	56.67%

Table 7. Comparisons of constructs by industries.

	1. Auto industry (n = 39)	2. Commercial bank industry (n = 30)	*t*-value	*p*-value
Number of employee/sales	71.577	116.076	−0.361	0.719
Direct cost/sales	772.762	574.291	1.857	0.072
Material/operating income/sales	116.347	398.274	−5.313	0.000
Total assets/sales	1039.895	19772.140	−11.865	0.000
Financial/Sales	0.335	3.294	−4.921	0.000
Customer	3.990	4.370	−0.298	0.767
Internal business process	8.260	2.820	3.892	0.000
Learning & growth/sales	0.009	0.001	5.322	0.000

Note: The unit of measurements, such as sales, direct cost, income, etc. are calculated in US$ (million).

direct costs, materials or operating income, total assets, financial perspective, and learning and growth perspective of BSC were divided by sales of each company. Table 7 indicates that the number of employees dividing by sales, which refers to the necessary number of employees to gain one million of sales, were not significantly different for the auto and commercial bank industries ($t = -0.361$, $p = 0.719$). In terms of direct costs divided by sales which means the necessary direct costs to gain one million of sales, the commercial bank industry had lower scores than the auto industry, but the difference was not significant ($t = 1.857$, $p = 0.072$). In terms of the total assets divided by sales, which means the necessary total assets to gain one million of sales, the commercial banks had significantly higher scores than the auto industry ($t = -11.865$, $p = 0.000$).

In terms of BSC dimensions, the commercial bank industry had significantly higher levels of financial dimension ($t = -4.921$, $p = 0.000$), but had lower levels of internal business process ($t = 3.892$, $p = 0.000$), as well as learning and growth dimension ($t = 5.322$, $p = 0.000$) than auto industry. The results support Hypothesis 5 that the differences

between the auto and commercial bank industries tend to perform differently on most research variables, including inputs and outputs.

Conclusions and discussions

The primary objective of this study was to develop an integrated research framework for measuring the firms' management performance with the applications of balanced scorecard and data envelope analysis. The function of DEA was to identify efficiency frontiers, benchmarking partners, and inefficient slacks in term of the four inputs and four perspectives of BSC for the auto and national commercial bank industries. Although some past research employed DEA to measure the bank industry's performance and efficiency (e.g. Liu & Tripe, 2002; Sufian & Majid, 2006), the inputs and outputs for measuring the performance were narrowly defined. In this regard, BSC provides an appropriate tool to define performance index by providing appropriate outputs of performance for DEA. BSC is able not only to minimise information overload by limiting the number of measures used (Kaplan & Norton, 1992) but also to develop the scorecard by linking to key success factors (Frigo & Krumwiede, 2000). On the other hand, DEA can set benchmarking for companies based on their inputs and outputs, as well as transform performance measures into managerial information. Accordingly, the synergy of BSC and DEA can translate the appropriate performance indices into managerial implications.

This is the first study to develop a research framework based on an integration of DEA and BSC to identify the competitive position of a firm and its learning objectives to become a member of the efficiency frontier. Previous studies related to the evaluation of BSC using DEA, tended to take a piecemeal approach, and did not integrate different constructs into a more concrete concept. This study tried to integrate different perspectives into a comprehensive framework and verify the comprehensive framework through statistical analysis, rather than case studies that are proposed in most of the previous literature. Since previous studies lack empirical content, the results of this study could provide a solid empirical foundation to support the inductive hypotheses for the integration of BSC and DEA.

There were several conclusions drawn from our results. First of all, the interrelationships between the four perspectives of BSC proposed by Kaplan and Norton (1996) were further empirically shown to be valid in the auto and commercial bank industries. Specifically, the learning and growth perspective was significantly related to the internal business process perspective, which in turn was positively related to the customer perspective. And the customer perspective was positively related to the financial perspective. In addition, the relationship between customer perspective and financial perspective was the most significant among the interrelationships of BSC.

Although all the dimensions of BSC linked to each other in each industry, the crucial elements in each dimension varied for each industry. In terms of the auto industry, R&D expenses per employee and intangible assets were the most crucial indicators in the learning and growth perspective, which was positively related to total assets turnover in the internal business process perspective. The total assets turnover was positively related to relative market share in customer perspective, which in turn was positively related to total revenue in the financial perspective.

The auto industry had the highest levels of the learning and growth perspective relative to the commercial bank industry, but had lower levels of customer perspective. In order to augment the levels of customer perspective, the auto companies can focus on the levels of R&D expenses per employee and intangible assets. In terms of the commercial bank

industry, the salary and wages per employee was most crucial indicator in the learning and growth perspective, which was positively related to property plant and equipment turnover in the internal business process perspective. The property plant and equipment turnover was positively related to relative market share in the customer perspective, which in turn was positively related to total revenue in the financial perspective. The commercial bank industry had lower levels of learning and growth perspective and thus lower levels of internal business process perspective. Although the commercial bank industry had the highest levels of financial perspective, it had the highest percentages of distinct inefficient units. This seems to reveal the importance of cause-and-effect relationships between indicators of the four perspectives of BSC.

Moreover, Norman and Barry's (1991) classification could provide information about the conditions of compositions with respect to each industry. The auto industry had the highest percentages of marginal inefficient units, and the lowest percentages of robustly efficient units and DMUs located in the efficiency frontiers. The commercial bank industry had the highest percentages of distinct inefficient units, and the highest percentages of DMUs located in the efficiency frontiers. The related information implies that the companies of the auto industry should improve their performance to achieve efficiency, and a higher percentage of companies in the commercial banks sector should inspect themselves because they are located in the efficiency frontier but are inefficient.

Several limitations of this study must be highlighted. First of all, this study employed the cross-sectional research design to analyse the sample. The cross-sectional design leaves open the possibility for lagged effects between integration and performance measurements. Second, the long-term trends of the four perspectives of BSC cannot be obtained from our data. Future research can address this limitation by examining a longitudinal study with the integration framework of BSC and DEA. Third, other limitations concern possible biases in the data. Companies in the dataset are large and medium-sized, and the results may only be valid for other companies of similar size. Fourth, the analysis was performed on mainly auto firms and banking firms. Last, the sample size was small for each industry due to the accessibility of data. Although the sample size was enough to conduct DEA, the further multivariate analysis cannot be used to examine the data due to small sample size. For example, the comparisons of four categories based on Norman and Barry (1991) for each industry cannot be conducted where the sample size is smaller than 30 in each category. However, unless there are systematic differences in the excluded firms, this may not be a major concern.

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