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The Relation Between Productivity Measures And Financial Information

- Evidence from the Airline Industry

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ABSTRACT

The principal purpose of this thesis is to examine the existence of the relation between technical efficiency and financial information based on published annual reports. Also, the effect of annual changes in productivity to changes in financial information is of interest in the study. The distinction between efficiency change and technological change is made for evaluation of productivity improvements.

The empirical evidence from the airline industry is presented. 35 airlines from 25 countries for the period 1991 through 1999 are included into the study.

The support for relation between technical efficiency and operating expenditures is found. The results obtained suggest that decomposing of productivity change into technical change and efficiency change does provide supplementary information. The negative relationship between change in operating expenditures and technological change is established.

Moreover, we found operating expenditures to be negatively related to MTFP index. This evidence is confirmed with results obtained by Holmen et al (1998).

The study does not reveal any reflection of productivity changes into information on earnings or cash flow. Thus, the priority of cash flow information as well as the reverse has no support from this empirical evidence.

According to the demand, and, consequently, revenue movements within the industry, the results obtained in the study could be explained by a more clearly defined (and less revenue-influenced) connection between costs and productivity measures in comparison with productivity measures and earnings or cash flow.

The timing of reaction for financial items on productivity changes is investigated. The assumed lag of one year does not provide any evidence on the relation of interest. Rather, the immediate reflection of productivity changes into financial information within the year is empirically supported.

Keywords: *Operational Performance, Productivity, Technical Efficiency, Cash Flow, Accounting Reports, Airline Industry, International Performance, Data Envelopment Analysis (DEA).*

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Daria Kitaeva

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1. INTRODUCTION

The chapter gives a brief introduction to the research field of the thesis. The general aspects of firm's performance evaluation, which this thesis deals with, are presented. The discussion of the main problem is provided. Research questions are stated and the purpose of the study is formulated on the basis of these questions. Finally, the possible contribution of the study is pointed out.

1.1. Background

The performance of the firm could be evaluated in different ways. One way can be to look to the productivity of the firm. Another way can be firm's evaluation on the basis of annual accounting reports. Thus, one can look to the evaluation problem in different focuses, since each of the focuses may bear the additional information for the analysis.

Nowadays the technological progress leads to the number of developments in different industries. Companies implement innovations, which help to improve their efficiency. It is reasonable to suggest that users of published accounting reports anticipate productivity changes to be also reflected in the financial figures.

Therefore, without any doubt financial information[1] is an essential part of the world of economics. The general purpose of financial figures is to transfer the information to different groups of users: shareholders, creditors, potential investors, analysts etc. All of them have a main interest in companies' performance and use financial data in their decision-making according to their purposes.

The financial information could be received generally from two different valuation approaches. In the accounting approach, all that matters is the accounting earnings of the business. It primarily concerned with historical description. According to Copeland, Koller & Murrin (1996), the basic purposes of accounting are to measure for a firm its efforts (costs), its

[1] By the term "financial information" the author means information based on annual accounting reports. This is not exactly accounting information, since some financial measures are not directly included into the accounting reports, but, however, could be derived from them with the help of elementary computations.

accomplishments (revenues), its success (the difference) over time and its position (what it owns and owes) at any moment in time. Also, they notice that it attempts to develop a list of actual events and the actual profit that results from them.

In contrast to that, the economic approach is based on a set of expectations and an expected profit, which represents a summary of those expectations (Edwards & Bell, 1970).

The significance of accounting numbers and economic value has been the subject of a lively debate during the last twenty years. Financial statement should provide information to help users in forming rational expectations about the future cash flows of an enterprise. Supporters of economic approach argue that cash flow information could be used in order to overcome some of the limitations of accrual accounting, both conceptually and in accounting law. However, accruals have been considered by accounting regulators as superior to cash flow data in predicting future cash flow. According to FASB (1978), "information about enterprise earnings based on accrual accounting generally provides a better indication of an enterprise's present and continuing ability to generate cash flows than information limited to the financial aspects of cash receipts and payments".

Another important aspect of performance evaluation is productivity, or efficiency, measurement. The practice of measuring efficiency has become increasingly important over recent years. A number of diverse techniques are implemented for different measurement focuses. With a well-defined and appropriate measure, with respect to the industry being examined, a great deal of information concerning the companies' performance can be attained.

This thesis deals with the importance of financial information concerning its ability to reflect productivity changes of firms. More detailed, it examines in which way the productivity changes could affect the financial figures. Therefore, the thesis investigates the performance's changes from financial published data as well as from productivity. The way in which the changes in performance are reflected in productivity changes or in some financial figures is investigated.

Also, the thesis attempts to bring light to the problem of priority between earnings and cash flow in a firm's performance evaluation. This problem arises with the choice of financial estimators for firm's performance.

The analysis of the thesis is built on the empirical evidence from airlines. The industry has some individual features. Moreover, the thesis is provided with the assessment of international performance in the airline industry. Different accounting rules and dissimilar units of measurement are some of the problems in international performance estimation.

1.2 Problem discussion

We start the discussion by considering three different aspects in a firm's performance evaluation: stock market returns[2], productivity measures and, finally, financial information. Although all of them are indicators of a firm's performance, evaluation based on each of them has its own individual features. Contradictory to the theory, which anticipates identical results due to their unique property of measuring performance, the different ways of evaluation give unequal results on the empirical evidence. Thus, the connection between them is a relevant subject for investigation.

The associating between stock market returns and productivity improvements is widely explored and the support for the existence of interrelation is presented in the scientific literature. Holmen, Marton & Sjögren (2002) found, in particular, that stock market returns are positively related to the aggregate productivity score, and the efficiency score the year of and the two years after improved or worsened productivity. Since the production process relates to profitability, which in turn relates to firm valuation, a change in a firm's efficiency is relevant news and, under the semi-strong form of the efficient market hypothesis[3], should be reflected in the market price of the firm. Semenick Alam

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[2] Stock market return is the firm's market stock price. This measure is a market parameter of a firm's performance and is determined by the discounted present value of the future cash flows of the firm.

[3] The efficient market hypothesis states that securities are normally in equilibrium and the prices fair thus making it impossible to beat the market. The weak form of the EFM holds

& Sickles (1998) examined the link between its relative technical efficiency scores and its stock market price. The first measure evaluates a firm's competence at combining inputs and outputs in its production process while the second measure reflects a firm's fundamental value. A positive relationship between efficiency news and stock market performance is found. Also, Banker & Johnston (1994) using the airline industry as empirical application, showed that high positive correlations exists between profitability and productivity.

The general source of signals to the market about improvements in efficiency is contained in published financial information. A lot of research studied the problem of stock market using annual accounting reports. Mainly, they examined which figures from annual financial information reproduce better estimation of firm's valuation.

Economic theory ascribes to corporate earnings the crucial role of a signal optimally directing resource allocation in capital markets. Many equity valuation models, both theoretical and those used by practitioners, share a common element – expected earnings as an explanatory variable. Financial analysts express such beliefs almost exclusively in the form of earnings (rather than equity, sales, or total assets) forecasts. For instance, Govindarajan's research (1980) indicates that some groups of users like security analysts utilized earnings information more often in their professional reports than they used cash flow information.

The list of sceptics regarding the usefulness of reported earnings is also formidable[4]. Differences between economic and accounting earnings as well as the incidence of manipulation in reported earnings are often mentioned as major deficiencies in earnings. In the article written by Bowen, Burgstahler & Daley (1987) one can find an empirical result that cash flow has incremental information content relative to that contained in earnings. The research was built on the testing for an association between unexpected security returns and earnings (cash flows). Also, Staubus (1965) measured the association between

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that future stock prices cannot be predicted based on historical returns. The semi-strong form holds that, in addition to past returns, all publicly available information is reflected in the stock price. (Semenick Alam, Sickles, 1998)

[4] See Lev (1989)

several financial accounting variables and common stock values. His conclusion is that current flows were more reliable than accounting earnings.

Ball and Brown (1968) assessed the usefulness of existing accounting income numbers by examining their information content and timeliness. In contradiction with the evidence presented above, they found that, of all the information about an individual firm, which becomes available during a year, one-half or more is captured in that year's income numbers.

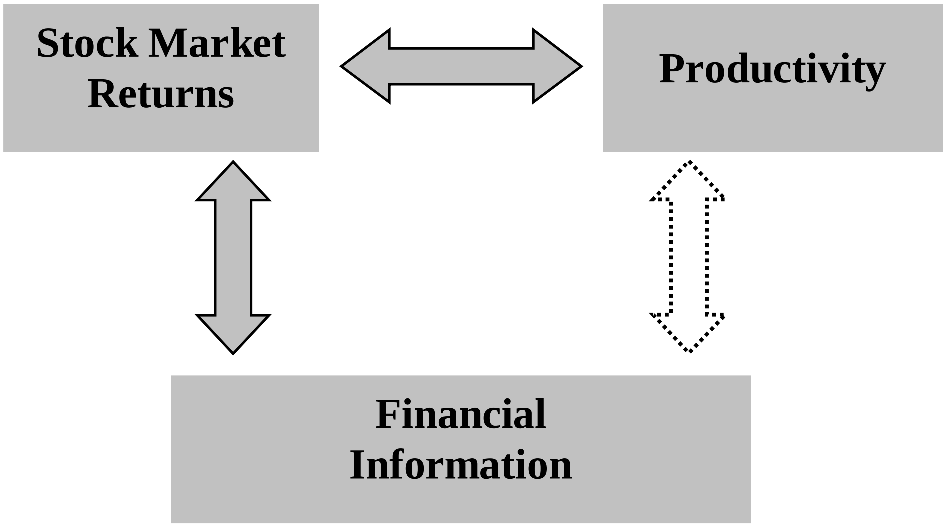
Another paper written by Beaver & Dukes (1972) presents some findings regarding the observed association between security prices and alternative income numbers. Cash flow was also examined because of the hypothesis that changes in cash flow are a better indication of wealth changes, since cash flow is not obscured by attempts by the accountant to measure depreciation and tax charge. They found earnings to be more consistent with the information set used in setting security prices than the cash flow.

Thus, although the evidence is contradictory, the problem of correspondence of annual reports and stock market returns is broadly examined.

On the other hand, the evidence of how the improvements of a firm's efficiency are mirrored in the annual reports is lacking. However, the importance of this problem could be explained by the fact that annual reporting is the main resource of published information users utilized to estimate market movements and the only basis which could throw light on the productivity changes within the company. Holmen, Marton & Sjögren (2002) consider the relation between technological innovations, firm value and accounting reports in the airline industry. In addition to the results concerning stock market returns and technological innovations, they found productivity measures to be negatively related to reported operating costs, suggesting that income statement does provide information about productivity improvements.

This thesis was written subject to decreasing the gap on information concerning the association of financial reporting and productivity improvements. Figure 1.1 below represents the research field of the discussion, with the broken-line arrow for lacking knowledge on relation between productivity and financial information:

Figure 1.1



The research focuses on the valuation of operational[5] performance of the firm. Analysis is carried out on changes in operation efficiency, which leads to either increase or decrease in firm's valuation. A broader conceptualisation of business performance would include financial performance in addition to operational performance. However, the financial performance will remain outside of the framework of current study.

We restrict the scope of productivity analysis by studying technical efficiency. Farrell (1957) defined technical efficiency as the ability of a firm to obtain maximum output from a given set of inputs. In what follows, the term "efficiency" refers to the technical efficiency measure, unless the other is stated explicitly.

Venkatraman & Ramanujam (1986) noticed, that it is logical to treat measures of technical efficiency within the domain of operational performance. Technical efficiency focuses on the resources firm use in its production process and on the result of that process. At the same time, we will give attention to

[5] Operational performance includes only operational activities of the firm. Such activities do not include the marketing or financing activities. (Schefczyk, 1993)

such financial information, as expenditures of the operational performance and operating result.

According to the previous discussion, we hypothetically anticipate figures in financial information to be affected by changes in productivity. Therefore, the first research question of the study is formulated as follows:

1) Does financial information reflect the changes in a firm's efficiency?

The term "financial information" possibly will be an essential issue since the accounting information as well as the cash flow information hypothetically could catch efficiency changes in the company. Efficiency depends on the result of firm's operational performance. We use both earnings and cash flow for the result proxy. The reason for that is that, although both measures are based on revenue and could be considered as the operation result, the contradiction on priority the approaches used for their measurement do not allowed us to choose one measure instead of other.

It is worthwhile mentioning that accounting reports contain information on earnings as well as on the other important issues. We argue for operating expenditures to be relevant for current research. As we mentioned above, the expenditures are linked directly with efficiency measurement. There is one more key detail that makes sense to consider them in the study separately from earnings. If the improvement in productivity operating efficiency is translated to the financial figures as the decrease in expenditures, then the influence of unpredictable changes in revenues could diminished the association between productivity changes and changes in earnings, while the connection between changes in expenditures and productivity changes will be kept.

Thus, the next question is:

2) Which type of financial measure replicates the productivity changes? Is it information on earnings, cash flows or on expenditures?

If any association between productivity and at least one of three measures mentioned above exists, the next step of the research is to see what is possible to derive about that relation. Consequently, the third question is:

3) What kind of relation does exists? Is it positive or negative? Does timing aspect play any role on the relation?

As one can see, the timing aspect of the problem is also included in the study. The reaction on efficiency change might not come immediately, and that leads to the importance of considering lag reaction in the financial data.

The research includes empirical evidence of international airlines. The main difficulties in international performance evaluation arise from distinctions in accounting rules among countries. The discussion on these subjects is included into the study.

Homogeneity in airlines' inputs and outputs allows us to use productivity measurement for operational performance in international sample. However, the absence of synchronism in deregulating process is too important to ignore.

The subject of the thesis based on problems which has been examined for decades, like earnings versus cash flow in a firm's valuation, as well, as on the research area which is relatively new (transportation of productivity changes information to the annual reports).

1.3 Purpose

Based on the previous problem discussion, the purpose of this assignment is to investigate the existence and nature of the association between financial information and productivity changes. The investigation is supported by empirical evidence of international airlines.

1.4 Contribution

The thesis is dedicated to the problem of efficiency changes' transformation to the information contained in the annual reports. A wealth of literature exists on the evidence of stock market returns and accounting reports, but the relation between efficiency changes and annual reports is not explored widely enough. According to the lack of knowledge on that research field, we believe this study could produce a fruitful contribution to the empirical evidence of the problem. If the association between financial information and productivity changes will be supported by empirical evidence, that could open the new perspective for the users of financial information in their decision-making process.

Also, there is a wide range of possibilities for future research. The research can be provided by modifying the model, or using other financial measures of a firm's performance. Another perspective is the study of an industry that is different from airlines.

2. THEORETICAL FRAMEWORK

2.1 Measuring Performance of the firm

The thesis is based on the two concepts of performance evaluation. The description of both productivity and financial concepts is given. Also, the subchapter represents the logical link between concepts.

According to Rappaport (1986) the principle that the fundamental objective of the firm's performance is to increase the value of its shareholders' investment is widely accepted. Nevertheless, he noticed that there is substantially less agreement about how this could be accomplished.

Financial concept of performance evaluation is based on the analysis of financial indicators. According to the corporate finance theory, this is a large number of different measures for corporate performance of the firm: earnings per share, return on equity or assets, cost of capital, etc. Copeland, Koller & Murrin (1996), among others, argued for discounted future cash flows to be the best measurement for a firm's performance.

However, in a world of risk and uncertainty there is no unique way of estimating future cash flows. As we have already discussed in the introduction chapter, one point of view is to estimate future cash flows on the base of current cash flows, while the other opinion is to use accounting accruals in the estimation.

The importance of including both earnings and cash flow in the study is explained by the fact that the contradiction of existing literature does not allow the unequivocal decision about the priority of accounting or economic approaches to be made. Also, expenditures could be a good indicator for a firm's performance. The expenditures are important in the study since the improvement of productivity ratio[6] can appear merely due to a decrease in its denominator, therefore, due to the reduction in expenditures. We will return to the debate on financial measures later in this chapter.

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[6] Productivity ratio of the firm is the ratio of its outputs to its inputs.

The productivity concept in performance evaluation is the other important aspect of the study. Copeland et al (1996) noted that the link between productivity and shareholder value maximization is too strong to ignore. If more output is produced with fewer inputs then the residual, the shareholder's value, is greater. Modern corporations give control over decision making to shareholders (or their agents), because shareholders are the only claimants that require complete information to make decisions in their self-interest. They have the incentive to make their companies into winners (Copeland et al, 1996).

The productivity concept is a kind of natural measure of performance. The larger values of productivity ratio are associated with better performance. According to Coelli, Prasada Rao & Battese, the performance of the firm is the activity, which convert inputs into outputs. They also pointed out the relative nature of performance: for instance, performance of the firm at date *(t)* could be measured relative to its performance at date *(t-1)* or it could be measured relative to the performance of another firm at date *(t)*. Some main details on productivity measurement will be given later.

2.2 Financial measurement of operational performance

The main issues of financial measurement are presented in following subchapter. More detailed analysis of the accounting and financial theory is performed. Also, the problem description of priority cash flow versus earnings in firm's performance evaluation is covered.

2.2.1 Two Items from Income Statement

According to Sorter (1969), every item on an income statement is the result of at least two processes – the underlying event and the accountants' allocation of the event to a particular time period. This allocation has the purpose of matching in order to derive "true" income figures.

In the framework of current study we focus on two items from income statement. Firstly, the object of interest is *Operating Expenditures*. This issue merely represents costs from operations of the company and excludes such expenditures from financial performance as interest expense.

Secondly, earnings in implication of this study refer to the *Earnings before Interest and Taxes*. This accounting figure represents the pre-tax operating income that a company would have earned if it had no debt[7]. It includes all types of operating income, including most revenues and expenses. Generally excluded are interest income, interest expense, the gain or loss from discontinued operations, extraordinary income or loss, and the investment income from non-operating investments. Depreciation of fixed assets should be subtracted in calculating earnings before interest and taxes (EBIT), but goodwill amortization should not.

2.2.2 Cash Flow

Although the thesis focuses on the *Pre-tax free cash flow* that is generated by a company, firstly the more general in theory approach of measuring *After-taxes cash flow* is given. *Free cash flow (FCF)* is a company's true operating cash flow. It is the total after-tax cash flow generated by the company and available to all providers of the company's capital, both creditors and shareholders. According to Copeland et al (1996), traditional measure of cash flow is represented as follows.

$$FCF = GrossCashFlow - GrossInvestment \quad ,$$

where *Gross Cash Flow* represents the total cash flow thrown off by the company, thus it is the amount available to reinvest in the business for maintenance and growth. Furthermore, *Gross Investment* is the sum of a company's expenditures for new capital, including working capital, capital expenditures, and other assets.

Capital Expenditures include expenditures on new and replacement property, plant, and equipment. Capital expenditures can be calculated from the balance sheet and income statement as the increase in net property, plant, and equipment plus depreciation expense for the period. Technically, this

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[7] The definition of EBIT is represented according to Copeland, Koller & Murrin (1996)

calculation results in capital expenditures less the net book value of retired assets.

The *Change in Operating Working Capital* is the amount the company invested in operating working capital during the period. In turn, operating working capital equals operating current assets minus non-interest bearing current liabilities.

According to Copeland et al (1996), another form of cash flow's illustration is the following:

$$FCF = (NOPLAT + Depreciation) - (NetInvestment + Depreciation),$$

where *NOPLAT* (*Net Operating Profit less Adjusted Taxes)* represents the after-tax operating profits of the company after adjusting the taxes to a cash basis.

As was mentioned above, *Depreciation* is one of the key elements in distinction between earnings and cash flow. According to Copeland et al (1996), depreciation includes all non-cash charges deducted from EBIT except goodwill amortization. It also includes the amortization of intangible assets with definite lives, such as patents and franchises.

The definition of cash flow presented above is usually called "traditional" measure of cash flow. The alternative measures incorporate more extensive adjustments. This thesis is restricted by traditional measurement[8] of pre-tax cash flow.

2.2.3 Cash Flow versus Earnings

According to the corporate finance theory, a firm's value is the net present value of the cash flows it is expected to create in future. Nevertheless, there is discrepancy in measurement of future cash flows. Managers, analysts and investors concentrate on the accounting figures in the valuation procedure. At

[8] More details on relationship of earnings and modified cash flows measures could be found, for example, in Bowen, Burgstahler & Daley (1986).

the same time, an amount of financial literature advocates cash flow valuation. (Mitchell, Goh &Forman, 1995; Feltham & Ohlson, 1995; Hawkins, 1977)

Beaver (1981) describes the purpose of financial statement as the ability to provide a report to capital suppliers to facilitate their evaluation of management's stewardship. A variety of reporting systems could conceivably fulfil this purpose. However, he noted that in financial accounting it has long been presumed that merely reporting cash flows is inadequate and therefore some form of accrual accounting is appropriate. A good illustration of that is FASB (1978) in its aspiration to shift from economic income measurement to an "information" approach states: "Financial reporting provides information that is useful to present for potential investors and creditors and other users in assessing the amounts, timing, and uncertainty of prospective cash receipts…Since investors' and creditors' cash flows are related to enterprise cash flows, financial reporting should provide information to help investors, creditors, and others assess the amounts, timing, and uncertainty of prospective net cash inflows to the related enterprise" (page 8).

Although the first steps towards information context of reports were taken, the FASB remains its position on *earnings* to be superior to cash flows: "Information about enterprise earnings based on accrual accounting generally provides a better indication of an enterprise's present and continuing ability to generate cash flows than information limited to the financial aspects of cash receipts and payments"(page 9). Nevertheless, empirical evidence shows ambiguous results. Bowen et al (1986) describe in their article empirical relationships between signals provided by accrual earnings and cash flow. They conclude *cash flow* to be the best estimation of future cash flow from operations. Thus these results are not consistent with the FASB's. Also, Graham and Knight (2000) found the cash flow from operations as the better measure of market price than accrual earnings in the valuation of equity REITS[9]. Studying REITS, authors naturally magnify the distinction between net income and cash flow.

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[9] Real estate investment trusts (REITs) purchase, hold and sell income-producing real properties and pass the rental income and capital gains on to investors. The asset structure of these funds is composed almost entirely of fixed assets. Further magnifying the divergence between earnings and cash flows is the fact that depreciation expense depends on the

The other opinion on that question argues for cash flows. For example, Sloan (1996) noted that the main argument is that earnings suffer from three limitations. First, realization and matching principles cannot always be easily and objectively applied. The second limitation is that the application of the realization and matching principles often requires accountants and managers to incorporate subjective estimates into earnings. Whether by mistake or design, these subjective estimates may be incorrect. Finally, Sloan (1996) argued that the periodic earnings number makes no attempt to measure the expected effects of events occurring in the current period on the free cash flow to be derived from sales expected to take place in subsequent periods. Thus, he pointed out, that expectations of the reductions in production expenditures from technological innovations are not reflected in current earnings. While there is little doubt that such *innovations* will lead to revised expectations about future free cash flow and future earnings, the accountant makes no attempt to measure them in current earnings.

Besides, Rappaport (1986) showed several important reasons why earnings fail to measure changes in the economic value of the firm:

1) *Alternative accounting methods may be employed.*
2) *Risk is excluded.*
3) *Investment requirements are excluded.*
4) *Dividend policy is not considered.*

According to Rappaport (1986), the first statement notes that earnings numbers can be calculated using alternative and equally acceptable accounting methods. The accountant's earnings result from attempts to match costs against revenues. This process involves allocating costs of assets, for example by depreciation, over their estimated useful life. Accounting allocations often differ among companies and for a particular company over time. In any event, these allocations are arbitrary because there is no sound basis for choosing one method over alternative methods.

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historical costs of the real estate assets, while the rents produced by the assets fluctuate with the market. (Graham & Knight, 2000)

The second reason is risk. The level of risk is determined both by the nature of the firm's operations and by the relative proportions of debt and equity used to finance its investments. As financial leverage is increased, the risk associated with shareholders likewise increases. As long as the incremental earnings generated by debt financing exceed interest expense, debt financing will increase net income. But since debt also increases risk, the increase in earnings may not necessarily lead to an increase in economic value.

Thirdly, Rappaport (1986) pointed out, that investment requirements are excluded with accruals approach. The relationship between the change in economic value and earnings is further obscured by the fact that investments in working capital and fixed capital needed to sustain the firm are excluded from the earnings calculations. When we move from earnings to cash flow, this shortcoming is removed. Depreciation is added back to earnings and capital expenditures are deducted from earnings.

The last reason Rappaport (1986) mentioned is, that the dividend policy is not considered in the earnings concept. If the objective is to maximize earnings, one could argue persuasively that the company should never pay any dividends as long as it expected to achieve a positive return on new investment. But if the firm invested shareholders' funds at below the minimum acceptable market rate, the value of the firm would decrease.

Ijiri (1975) suggested approach to look at the cash flow-versus-earnings problem in another dimension. He suggested the hypothesis that cash flows are not superior to earnings since cash flow can be viewed as a more primitive number than earnings. The earnings calculation engages every issue involved in cash flow with the additional items such as depreciation and accruals.

Thus, the important aspect is whether or not earnings contain more information than cash flow does. Or, alternatively, does the addition of knowledge of changes in depreciation provide additional explanatory power with respect to price changes, after the explanatory power of cash flow has already been considered? (Beaver, 1981) Nowadays, this is still an open question.

2.3 Efficiency and Productivity Measurement

The productivity concept of performance evaluation is in the focus. The subchapter gives some useful definitions of productivity measurement. The difference between efficiency and productivity is discussed.

2.3.1 Some useful definitions

The economic efficiency is an important characteristic of firm's performance. According to Färe, Grosskopf & Lovell (1985), the informal definition of economic efficiency is that efficiency is the quality or degree of producing a set of desired effects. Thus, a company is efficient if the company's behavioural objectives are achieved, and inefficient if they are not.

Farrell defines total economic efficiency as the composition of both technical efficiency and allocative, or price efficiency. The first measure may be conducted in terms of quantities (inputs or outputs), and the second refers to values (cost, revenue and profit).

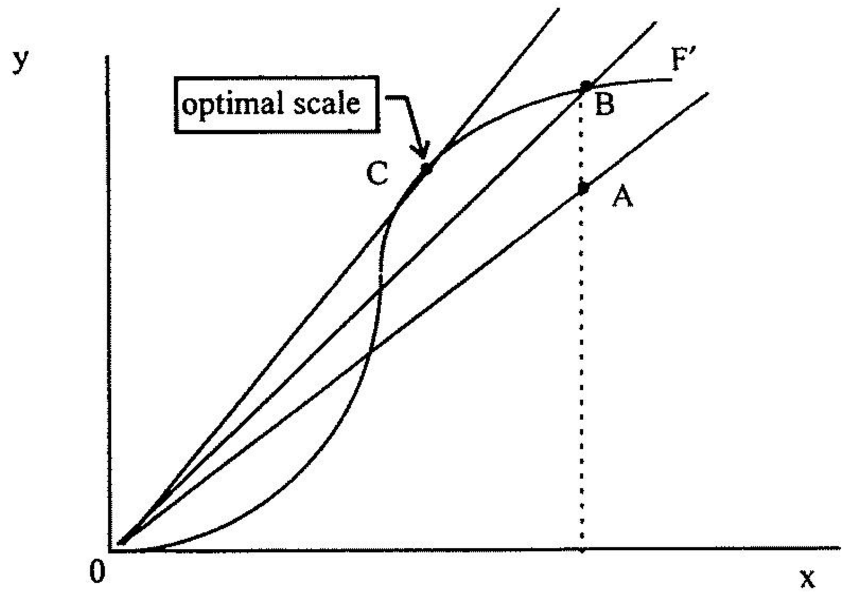
Allocative efficiency is the ability of a firm to use the inputs in optimal proportions, given their respective prices. It requires knowledge about price structure whereas technical efficiency operates with the quantities of inputs and outputs. The price efficiency measurement requires information on prices. This information may lose homogeneity from perspective of international analysis. Therefore, as we have argued above, it is relevant to focus on technical efficiency in the framework of the international operational performance evaluation.

The representation of firm's efficiency measure through the set and frontier definitions lies at the background of modern productivity theory (Coelli, Prasada Rao & Battese, 1998). In expressions of more precise definition, a firm is said to be technically efficient if production occurs on the boundary of the firm's production possibilities set, and technically inefficient if production occurs on the interior of the production possibilities set. The measure of technical efficiency is independent of the objectives claimed by the firm. The boundary of the firm's production set is frequently called "production frontier".

It represents the maximum output attainable from each input level. Hence it reflects the current state of technology in the industry (Coelli et al, 1998).

In the following Figure 2.1 there are a single input (*x*) and a single output (*y*):

Figure 2.1



Source: Coelli, Prasada Rao & Battese (1998)

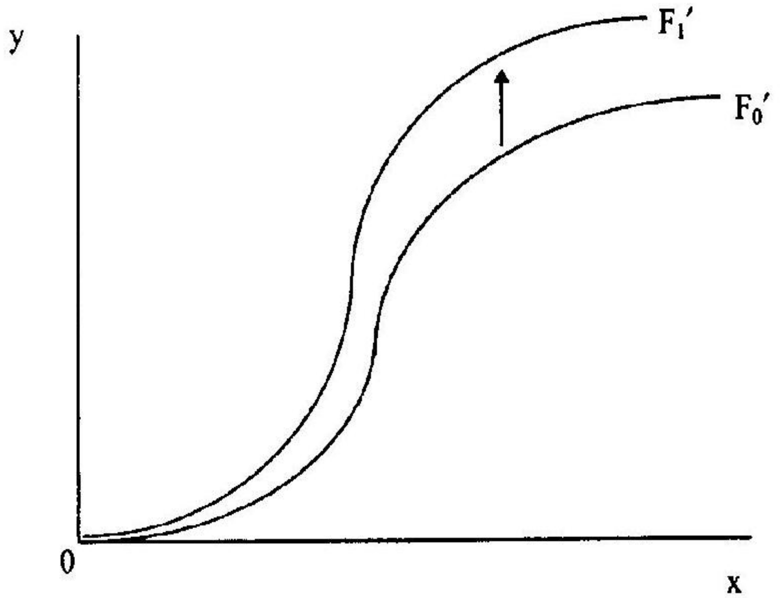
The curve line *OF'* represents a production frontier, which defines the relation between the input and the output. The feasible production set is the set of all input-output combinations that are feasible. It is presented by all points between the production frontier, *OF'*, and the *x*-axis (inclusive of these bounds). The points along the production frontier define the efficient subset of this feasible production set.

2.3.2 Efficiency versus Productivity

The term efficiency, as well as the term productivity, is frequently used in the media over the last decade. They are used interchangeably, while they are not precisely the same things. The difference is shown in Figure 2.1, which is represented above. Productivity measure is the output-input ratio and one can use a ray through the origin to measure productivity at a particular data point. If the firm operating at point *A* were moved to the technically efficient point *B*, the slope of the ray would be greater, implying higher productivity at point *B*. Nevertheless, by moving to point *C*, the ray from the origin is at a tangent to the production frontier and thus defines the point of maximum possible productivity. This latter movement is an example of exploring scale economies. Point *C* is the point of technically optimal scale. Operation at any other point on the production frontier results in lower productivity. Consequently, a firm may be technical efficient but may still be able to improve its productivity by exploiting scale economies.

Another important aspect in productivity measurement is the time factor. When one considers productivity comparisons through time, an additional source of productivity change, called technical or sometimes technological change, is possible. This engages the innovations in technology, which may be represented by an upward shift in the production frontier. Figure 2.2 shows the shift in production frontier caused by technological change between two periods:

Figure 2.2



Source: Coelli, Prasada Rao & Battese (1998)

At first period production frontier is represented by line OF_0', and in the second period the frontier shifts to the line OF_1'.

It is important to note that if a company has increased its productivity from one year to the next, the improvement need not have been from efficiency improvements alone, but may have been due to technical change or the exploitation of scale economies or from some combinations of these three factors.

2.4 Airline Industry

Because of all of the equipment and facilities involved in air transportation, it is easy to lose sight of the fact that this is, fundamentally, a service industry[10]. Airlines perform a service for their customers - transporting them and their belongings (or their products, in the case of cargo customers) from one point to another for an agreed price. There is neither physical product given in return for the money paid by the customer, nor inventory created and stored for sale at some later date[11].

Unlike many service businesses, airlines need more huge investments to get started. They need an enormous range of expensive equipment and facilities, from airplanes to flight simulators to maintenance hangars. As a result[12], the airline industry is a capital-intensive business, requiring large sums of money to operate effectively. Most equipment is financed through loans or the issue of stock. Airlines also lease equipment, including equipment they owned previously but sold to someone else and leased back. Whatever arrangements an airline chooses to pursue, its capital needs require consistent profitability. Because airlines own large fleets of expensive aircraft, which depreciate in value over time, they typically generate a substantial positive cash flow[13] (profits plus depreciation). Most airlines use their cash flow to repay debt or acquire new aircraft. When profits and cash flow decline, an airline's ability to repay debt and acquire new aircraft is jeopardized[14].

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[10] Source: Air Transport Association, web page http://www.airlines.org/public/industry
[11] Ibid
[12] Source: IATA, web page http://www1.iata.org/index.htm
[13] Ibid
[14] Ibid

Airlines' revenues react heavily to shifts in demand. The airline business historically has been very seasonal. The summer months demand boosts, as many people take vacations in that season. Winter, in contrast, has low demand, with the exception of the holidays. The result of such peaks in travel patterns is that airline revenues also rise and fall significantly through the course of the year. There is a number of other factors, which have a large influence on demand, and, consequently, to the airline's revenue. The precedents of crashes are one of these factors. The 11th of September 2001 brought more passengers to mistrust this kind of transportation. Threat of terrorism represents an actual and vital problem for the industry. Development of IT-technology also results in decreasing demand since it improves the human possibilities to do business at a distance.

Airline's costs are less influenced by demand than revenues. According to the industry's characteristics represented above, namely to the large proportion of fixed assets and, therefore, fixed costs comparing to many others industries, airlines are more predictable in sense of their expenditures rather than revenues.

2.5 Some Aspects of International Study

The thesis involves empirical evidence of *international* airline industry. The significance of fair evaluation of airlines' international operating performance is hard to overestimate. In recent years, with the process of globalisation, this problem has become more complicated and sharp.

International performance assessments of airlines from published financial information are difficult. The standards of annual reports vary extremely among different countries (Marton, 1998). In general, presentation of income statement and balance sheet information is obligatory. The situation with the international cash flow statements seems to be more adverse. The international differences in cash flow statements and its unimportance in annual reporting, as well as its non-required presence for some countries' reporting, are subject to its identification as irrelevant in the framework of this study. On the other hand, the figures on operation cash flow of the company might be derived from the income statement and balance sheet information.

Copeland et al (1996) pointed out some problems concerning worldwide valuation. The first one is the differences in accounting standards that also affect the estimation of cash flows. The second problem is the cultural differences that are relevant for valuations. The third one is differences in the cost of capital across national borders, which could be an impediment to business activities. They also argued that with economic valuation, free cash flows are the same regardless of the accounting standards of the country. Cash is cash, and any accounting system that has complete information made publicly available can be used to estimate the future cash flows of a company.

Schefczyk (1993) stated next problems for assessing airlines' international performance from accounting reports: most companies lease a substantial fraction of their aircraft; different accounting and taxation rules in various countries result in different impacts of leased assets on profit and balance-sheet information.

However, the idea of performance analysis is to make a fair estimation of real levels of achievement of specific goals in the company. The possible goal is to maximise the productivity.

This is intuitively acceptable that, for instance, the number of available ton kilometres may reflect aircraft capacity much more accurately than flight equipment depreciation and amortization (Schefczyk, 1993). Moreover, as was mentioned before, technical efficiency measure is independent of a firm's objectives. The empirical evidence from international airlines is described in scientific literature. For instance, we mention the Coelli, Perelman & Romano paper (1999), in which the efficiency of international airlines is measured. They obtained measures of technical efficiency from stochastic frontier production functions, which have been adjusted to account for environmental influences such as geographical factors.

One important aspect is still out of our consideration. This is the ownership structure of international airlines. Large investments, national prestige, trading benefits and existence of risk are some other arguments in support of government regulation. However, the competition environment brought efficiency improvements to the industry. The first wave of deregulation processes started in United States. The similar process in Europe began in late 1980s with the some liberalisation reforms. On the other hand, some countries do not hasten to deregulate the industry. A number of papers (Fethi, Jackson & Weyman-Jones, 2000; Good, Nadiri & Sickles, 1991) examined deregulation effects on the efficiency within the airlines.

The liberalisation movement in European airlines was initiated in the late 1980s to create a more competitive environment. This has aimed to result in an increase of efficiency and productivity. Several studies (Fethi et al, 2000; Good et al, 1991) have compared efficiencies of European and American airlines and show that the deregulated US airlines are more efficient than their highly regulated European counterparts.

Although the question of benefits from deregulation is widely examined for Europe and US, there is a lack of information about the rest of the world. The possible explanation is that US and Europe are pioneers in deregulation process and also hold sufficient number of airlines required for the empirical analysis.

3. METHODOLOGY

The objective of this chapter is to describe the approach applied in order to answer the research questions stated above. The methods and data used in the study are briefly presented. Also, the validity, as well as the reliability of the study, is discussed.

3.1 Scientific Approach

Research is not carried out to 'prove' something - research explores. The research of this study is classified as non-experimental. No manipulation of variables takes place since they are historical observations. Much of the research conducted in natural settings is non experimental because there is no possibility to manipulate the conditions that the subjects will experience.

The quantitative approach is applied to this study. By using a quantitative approach one can examine large sets of data and test different patterns of variables. A substantive finding, or hypothesis, is one that repeatedly survives through research probing. A single piece of work is simply neither complete nor conclusive. High quality of data is important. The data set was carefully chosen, so that all the characteristics actual in the total population are presented in the chosen sample.

3.2 Data

As was mentioned above, in quantitative studies, the "manner" in which data set units are selected is very vital. The empirical evidence of the thesis is built on the main sample of 35 international airlines. The airline companies were selected regardless of the geographical dislocation, ownership structure or size. Moreover, it includes 35 airlines from 25 different countries. Thus, this study contains the international data of the airline industry.

Secondary data was utilized since its nature permits analysis of large samples within a given restricted frame of time. Two main groups of data can be allocated. The first group contains data on annual financial reporting, whereas the second is used for measuring productivity among the industry. The study is restricted by time period 1991 through 1999. A frequent presents of such factors in the industry as mergers, acquisitions or merely bankruptcy cases within the airline industry creates impossibilities in analysing valid data for much longer periods.

Financial data is accumulated from annual reports. The accounting information is from International Civil Aviation Organization (ICAO) database. In order to make comparison meaningful, domestic currencies were translated into USD at the current rate. The thesis deals with the hypothesis that efficiency measures in the operations of airlines are reflected in the financial items; earnings before interest and taxes, operation expenditures and pre-tax cash flow from operations are included in the research. The information on earnings and expenditures was received from income statements. Further, cash flow's calculations both are based on income statement and balance sheet reports.

Information on productivity was kindly given to the author in a form of digital database by Dr Stefan Sjögren. Initially it was collected from IATA Yearly Statistics. Data includes fuel consumed in thousands of tonnes (*F*), number of labour (*L*) and aircraft capacity (*AC*). The latest can be found as the quantity of tonnes the airline can take on simultaneously with the assumption of working on the full capacity. This set of productivity data reflects the costs of the company and, therefore, may be considered as an input of production process.

The data on the number of passengers carried (*PC*) and amount of freight carried (*FC*) is also included in the study. *PC* and *FC* represent the indicators of output quantities of the airlines. An application of data to this study will be considered in model description in more detail.

Given that there are a number of gaps in accounting data for the full period, meaningful subsets of data will be applied in order to provide valid results. However, data represents a sample of companies over a period of years and, hence, is defined as combination of time-series and cross-sectional data sets. This combination is frequently called panel data. Three main subsets of 35, 29 and 15 airlines are presented in Appendix I.

Also, there are a few gaps in production data. The reason why the application of productivity data with gaps does not affect the results of the study is shown in the next chapter.

The literature review was generally built on sources from the Economics Library at the School of Economics and Commercial Law of Gothenburg. Its connection with other libraries in Sweden gives ample opportunities for exploring the existing literature on the research problem.

Also, the comprehensive study of a number of digital databases is done. The key words for the general search are "*Technical Efficiency*", "*Productivity Measurement*", "*Accounting Reports*", "*Operational Performance*" and "*Free Cash Flow*". The main databases the author uses in the research are *Econlit, JSTOR* and *Academic Search Premier*. In addition, the information from e-journals of the Economics Library is used. Other valuable knowledge is achieved by working with World Wide Net searching system "*Google*". The key words "*Airline Industry*" and "*Aviation*" were examined.

3.3 Method description

Research is an empirical investigation between or among several variables. The core method used to fulfil the objective of this research is statistical analysis. However, examining sub problem of productivity measurement requires methodological knowledge also. This section gives a brief overview of both methodology parts.

3.3.1 Statistical Method

Statistical approach of the research is provided with the regression analysis. The regression analysis based on least squares principle[15] is used in order to make comprehensive and complete analysis of whether or not financial figures reflect efficiency changes. Hill, Griffiths & Judge (2001) point out that the term

[15] The least squares principle asserts that to fit a line to the data values we should fit the line so that the sum of the squares of the vertical distances from each point to the line is as small as possible. This rule is arbitrary, but very effective, and is simply one way to describe a line that passes through the middle of the data. (Hill, Griffiths & Judge, 2001)

“linear” in “simple regression model” means not a linear relationship between the variables, but a model in which the parameters enter in a linear way. That is, the model is linear in the parameters, but it is not necessarily linear in the variables. However, taking into account the nature of our variables, it is appropriate to assume[16] that there is a linear association between variables.

In the study the simple regression with one independent variable as well as the multiple regression with a few independent variables are utilized. There are next assumptions for multiple regression model (Hill et al, 2001):

Assumption R1. The general form of regression model is

$$y_t = \beta_1 + \beta_2 x_{t2} + ... + \beta_k x_{tk} + e_t$$

where t is a number of observations from 1 to T, (k-1) is the number of independent variables in the model, y_t is the expected value of dependant variable, e_t is a random error term, x_{tk} are independent variables, parameter β_k measures the effect[17] of a change in the independent variable x_{tk} upon the expected value of y_t, with all other variables held constant.

Assumption R2. Each random error has a probability distribution with zero mean. This assumes that the average of all the omitted variables, and any other errors made when specifying the model, is zero. Hence, we are asserting that the model is, on average, correct:

$$E(y_t) = \beta_1 + \beta_2 x_{t2} + ... + \beta_k x_{tk} \Leftrightarrow E(e_t) = 0$$

where $E(y_t)$ is our average (expected) value of the dependant variable, and $E(e_t)$ is error mean.

[16] The tests on some other possible functional forms, namely “*quadratic*” form, reciprocal and natural logarithm (“*log-log*” form) did not provide any significant results. Thus, the author assumes linear relationship between variables.

[17] The parameter β_1 is the intercept term. The variable to which it is attached is x_{t1}=1. (Hill et al, 2001)

Assumption R3. Each random error has a probability distribution with variance σ^2. Also, the variance of the probability distribution of y_t does not change with each observation:

$$\text{var}(e_t) = \text{var}(y_t) = \sigma^2$$

The variance σ^2 is an unknown parameter and it measures the uncertainty in the model. It is the same for all observations. Errors with this property are said to be *homoskedastic*.

Assumption R4. The covariance between the two random errors corresponding to any two different observations is zero. Moreover, any two observations on the dependant variable are uncorrelated:

$$\text{cov}(e_t, e_s) = \text{cov}(y_t, y_s) = 0$$

for each *t*, *s* from observations 1..*T*, $t \neq s$.

Assumption R5. The values of x_{tk} are not random and are not exact linear functions[18] of the other explanatory variables.

Assumptions R1-R5 are also assumptions for simple regression model with one independent variable, thus, with $K=2$.

The significance of the independent variable in the model is proved with the test-statistic of a null hypothesis. The null hypothesis[19] stated that the independent variable has no effect on the dependant variable. According to Hill et al (2001), the sample information about the null hypothesis is embodied in the sample value of test statistics. Thus, the decision to reject or not to reject the null hypothesis is based on the value of the test-statistic, which itself is a random variable. The special characteristic of the test statistic is that its probability distribution must be completely known when the null hypothesis is

[18] This assumption is equivalent to assuming that no variable is redundant. If this assumption is violated, then the least squares procedure fails. This condition is called exact collinearity

[19] Tests of these important null hypotheses, which state that the independent variable has no effect upon the dependant variable, are called ***tests of significance***. (Hill et al, 2001)

true, and it must have some other distribution if the null hypothesis is not true. Let us assume the null hypothesis H_0: $\beta_2 = 0$. The alternative to it is H_1: $\beta_2 \neq 0$. If the null hypothesis is true, then under the assumptions R1-R5 of the regression model the test statistic has t-distribution with (*T-2*) degrees of freedom:

$$t = \frac{b_2}{SE(b_2)} \sim t_{(T-2)},$$

where t is test statistic (t-statistic); b_2 is the least squares estimator of β_2; $SE(b_2)$ is the standard error of b_2; and $t_{(T-2)}$ is t-distribution with (*T-2*) degrees of freedom. If the null hypothesis is not true and the independant variable affects in some way the dependant variable, then the t-statistic does not have a distribution with (*T-2*) degrees of freedom.

Significance of the model is tested with *F*-test. According to Hill et al (2001), the idea of the *F*-test is a comparison of sum of squared errors from the original, unrestricted multiple regression model to the sum of squared errors from a regression model in which the null hypothesis is assumed to be true.

Null hypothesis states that the value of the all parameters in the model is zero: $H_0 : \beta_2 = 0,..., \beta_k = 0$. The alternative hypothesis states that at least one of the parameters is different from zero. If the null hypothesis is not true, then constraints placed on the model by the null hypothesis have a large effect on the ability of the model to fit the data. The model in which the null hypothesis is assumed to be true is called restricted model. The restricted sum of squared errors from the hypothesis H_0 is designated by *SST*. The unrestricted sum of squared errors is the sum of squared errors from the unconstrained model, and is designated by *SSE*. Thus, *F*-test statistic is (Hill et al, 2001):

$$F = \frac{(SST - SSE)/(K-1)}{SSE/(T-K)},$$

where K is the number of independent variables and T is the number of observations. If the null hypothesis is true, F has the *F*-distribution with (*K-1*) numerator degrees of freedom and (*T*-*K*) denominator degrees of freedom. The null hypothesis is rejected, if $F \geq F_c$, where F_c is the critical[20] value.

According to Hill et al (2001), one can test the significance of simple regression using either *t*-test, or *F*-test. Both are equivalent for testing a single equality hypothesis. However, they notice that it is customary to test single hypothesis using a *t*-test in practice. The *F*-test is usually reserved for joint hypothesis.

Hill et al (2001) pointed out that with reporting the outcome of statistical hypothesis tests it has become common practice to report the *p*-values of the test. The *p*-value of a *t*-test (or *F*-test) is calculated by finding the probability that the *t*- (or *F*-) distribution can take a value greater than or equal to the absolute value of the sample value of the test statistic. Using a *p*-value, one can determine whether to reject a null hypothesis by comparing it to the level of significance α. The rejection rule for a hypothesis test is: when the *p*-value of hypothesis test is smaller than the chosen value of α, then the test procedure leads to rejection of the null hypothesis.

According to Hill et al (2001), one can use coefficient of determination R^2 as a measure of the proportion of variation in y explained by x within the regression model. The closer R^2 to the unit, the greater is the predictive ability of the model over all the sample observations. If $R^2 = 1$ then the model fits the data "perfectly". If the sample data for y and x are uncorrelated and show no linear association, $R^2 = 0$. When $0 < R^2 < 1$, it is interpreted as "the percentage of the variation in y about its mean that is explained by the regression model". However, by itself the coefficient of determination does not measure the quality of the regression model. Hence, it is not the objective of regression analysis to find the model with the highest R^2. Another note is that without intercept β_1 in the model, the measure of R^2 is no longer an appropriate measure of goodness of fit, and one should avoid its reporting.

Hill et al (2001) noticed, that the difficulty with R^2 is that it can be made large by adding more and more variables to the multiple regression model, even if

[20] Critical value leaves α% of the probability in the upper tail of the F-distribution. (Hill et al, 2001)

the variables added have no economic justification. Thus, the coefficient of determination R^2 is failed for multiple regression. In the multiple regression the measure of goodness of fit is adjusted R^2, which is adapted for number of variables in the model. Nevertheless, the adjusted R^2 is not the percentage of variation explained in the model.

According to Hill et al (2001), dummy variables allow constructing models in which some or all regression model parameters, including the intercept, change for some observations in the sample. Thus, this kind of variables is used to account for qualitative factors in economic models. Dummy variables are often called binary or dichotomous variables as they take just two values, usually 1 or 0, to indicate the presence or absence of a characteristic.

Dummy variables are included in regression for two main reasons. Firstly, the panel data requires taking into consideration time variables; hence the dummy variables for each year are introduced. Secondary, research, which deals with international sample, and the dummy variables in this context represent the region's distinctions.

Analysis on panel data has some specialities. Within usage of this type of data one possesses a time-series of data on cross-section of airlines' units. According to Hill et al (2001), the problem is how to specify a model that will capture individual differences in behaviour so that one may combine, or pool, all the data for estimation and inference purposes. They argue using a possible solution of the problem in terms of a dummy variable specification method called fixed effects method. This model of parameter variation specifies that only the intercept parameter varies, not the response parameters. Moreover, intercept varies only across airlines and not over time. Therefore, each dummy variable coefficient would be equal to the difference between the intercept for its firm and the intercept for the base firm for which a dummy variable is not specified.

3.3.2 Data Envelopment Technique

The methodology behind productivity measurement is extensively developed. Coelli, Rao & Battese (1998) describes four major methods of measuring productivity:

1) Least-squares econometric production models
2) Total factor productivity (TFP) indices
3) Data envelopment analysis (DEA)
4) Stochastic frontiers.

Methods 1 and 4 involve the econometric estimation of parametric functions, while methods 2 and 3 do not. These two groups are called "*parametric*" and "*non-parametric*" methods respectively. The first two methods (1 and 2) are most often applied to aggregate time-series data and provide measures of technical change and/or TFP. Both of these methods assume all firms are technically efficient. Methods 3 and 4, on the other hand, are most often applied to data on a sample of firms (at one point in time) and provide measures of relative efficiency among those firms. Hence, these latter two methods do not assume that all firms are technically efficient. However, multilateral TFP indices can also be used to compare the relative productivity of a group of firms at one point in time. Also DEA and stochastic frontiers can be used to measure both technical change and efficiency change for panel data.

Windle and Dresner (1995) gave an overview of productivity measurement in the airline industry. Moreover, the paper examines the empirical comparison of several different productivity measurements. The conclusion is that TFP index and DEA represent a middle ground between measures, being somewhat correlated with both the cost function results and the gross measures of productivity.

This study is performed with DEA. The main reason for this choice is that DEA fits to the purposes of the thesis more than other methods. The analysis is based on estimation either cross-sectional or panel data, while DEA also requires using cross-sectional or panel data. Further, DEA could be used to measure technical efficiency, scale efficiency and TFP change. The latter consists of technological and efficiency changes. The data required on variables is merely input and output quantities.

Efficiency is generally measured using either DEA or stochastic frontier methods. Although the latter take into account the noise, the advantages of the former in the framework of this thesis are clear: it does not require specification for distributional form for the inefficiency term; there is also no need to specify a functional form for the production function; and it is less difficult to accommodate multiple outputs (Coelli et al, 1998).

However, the method is sensitive to a couple of factors, which might influence the result, such as outliers (variables that are extreme in some sense), an increase in the number of inputs and outputs can cause increasing efficiency measures (Coelli, 1996). This means that small samples with many variables can produce misleadingly efficient measures. Thus, the model of present study is selected in order to avoid these weaknesses. The main argument for the industry choice is the homogeneity between airlines, which reflects homogeneity of inputs and outputs.

Generally speaking, DEA is a non-parametric mathematical programming approach to frontier estimation. The idea of measuring efficiency with production function frontier belongs originally to Farrell (1957). He used the non-parametric frontier approach to measure efficiency as a relative distance from the efficient production frontier. This measure was named a productive, or technical efficiency and later was extended by operational researchers, namely Charnes, Cooper and Rhodes (1978). They called the technique the Data Envelopment Analysis (DEA). Similarly, the output-increasing measure of technical efficiency shows the ratio between observed output and how much output could have been produced, with observed input and frontier technology. Efficient frontier units have a value of 1; inefficient are less than 1.

As was mentioned above, the study also involves time factors. Thus, the changes in productivity are also in focus of consideration. The changes are measured using Malmquist Total Factor Productivity Index. It measures total productivity change of the unit between two data points. The productivity change of the firm may be separated into the *efficiency* and *technological* changes. The first one is defined as the measured unit's ability to close the gap between the frontier and its own efficiency between time period (*t-1*) and *t* (also called *catch up effect*), and also represents the change in Farrell's technical efficiency between two corresponding periods of time. Technological change is the efficiency increase between (*t-1*) and *t* for a firm that is caused by a shift in the technology frontier. As was mentioned before, the shift in the frontier is explained as an increased productivity for the whole industry.

Accordingly, the method based on the geometric mean of two Malmquist indices, is able to account for changes in both technical efficiency (catching up) and changes in frontier technology (innovation) (Coelli et al, 1998). The production technology, output distance function, and the DEA linear programming problem for period *t* will be used for the index's calculation, as well, as another output distance function which is calculated between periods as follows:

$$OD_t(x_{t+1}, y_{t+1}) = \min\{\lambda; (x_{t+1}, {y_{t+1}}/{\lambda}) \in S_t\},$$

where S is the production technology, x_i and y_i represent the input and output levels in period (i) respectively. The output based on the Malmquist index is defined in the following way:

$$M(x_{t+1}, y_{t+1}, x_t, y_t) = \frac{OD_{t+1}(x_{t+1}, y_{t+1})}{OD_t(x_t, y_t)} * \left\{ \frac{OD_t(x_{t+1}, y_{t+1})}{OD_{t+1}(x_{t+1}, y_{t+1})} * \frac{OD_t(x_t, y_t)}{OD_{t+1}(x_t, y_t)} \right\} = E_{t+1} * A_{t+1},$$

where E_{t+1} reflects changes in relative efficiency and A_{t+1} reflects changes in technology between t and $t+1$ periods.

For the index, a value below 1 indicates productivity decline, while a value exceeding 1 indicates growth (Coelli et al, 1998). Similarly, for the index of components, values below 1 signify a performance decline, while values above 1 signify an improvement (Ibid). The decomposition of productivity change into efficiency change and technological change may provide additional information to the research.

3.4 Reliability and Validity of the Study

The reliability and validity of study are two key issues of scientific research. Reliability is supported by consistency and high quality of data used. Validity depends on the robustness of theoretical framework and how relevant the applying of chosen methodology to the research problem is.

With the objective to obtain significant results, the data is chosen subject to avoid a bias. Bias may be defined as any influence, condition, or set of conditions which singly or together cause distortion of the data from what would have been obtained by pure option. With this definition, any factor that impairs the unpredictability of the sample would be considered bias. Bias due to inadequate sampling impairs external validity. In order to avoid the bias, the data of the study was taken from reliable sources.

In the case of choosing accounting data, the annual reports of the companies were collected from such fundamental sources as the International Civil Aviation Organization (ICAO). ICAO[21] was established in the middle of the 1940s and for more than half of the century have the purpose of collaboration in the field of international civil aviation.

The reliable productivity data is collected from International Air Transport Association (IATA)[22]. Briefly described, it is the prime vehicle for inter-airline cooperation in promoting safe, reliable, secure and economical air services for the benefit of the world's trade. This pinnacle source of aviation data and information provides airlines, airports, financial institutions, and other related suppliers with the latest in innovative aviation offerings.

In addition, we believe the data is valid and useful in the frames of the quantitative model used in the research. The validity of the study contains the number of methodological and theoretical aspects of the study and is broadly discussed through the entire investigation. The high reliability of this study is

[21] More details about ICAO can be found on web page http://www.icao.int/index.cfm.

[22] The information about IATA can be found on web page http://www1.iata.org/index.htm.

the guarantee that if another researcher examines the same questions using the same data and scope, he will come up with the same results and conclusions.

4. MODEL SPECIFICATION AND PERFORMANCE

In this chapter, the specifications of the model used in research are described. The chapter starts with a sub-model for productivity measurement, goes through the proceeding of cash flow calculation and comes to the end with statistical models.

4.1 Productivity Measurement

4.1.1 Constant Return to Scale Assumption

Farrell (1957) introduced the definition of technical efficiency with respect to input orientation. In his focus, technical efficiency reflects the capacity of the firm to achieve a minimum level of inputs used in production process keeping the output unchanged. However, the output-oriented measure of technical efficiency was represented later and it could be described as the ability of a firm to obtain maximum output from a given set of inputs (Coelli, 1996).

The existing literature does not provide a unique answer on what measure fits better for the airline industry (Atkinson & Cornwell, 1994). An argument for output-oriented model is that the airlines of some countries still demonstrate a high degree of monopolization. Hence, in this case, monopolist has an opportunity to control the revenue and it is relevant to assume the productivity as the ability of the airline to maximize the revenue.

On the other hand, the support for input-oriented measure is that with the current increase in competition in the airline industry it is easier for a particular company to control its choice in input consumption than the outputs. Hence, the growing interest in the airline industry for reducing costs is important. In order to cope with the increasing competition, vast importance has been put on keeping prices low, and reducing costs is a good way to do it.

The difference in definitions takes place with variable return to scale. As was discussed above, a firm may demonstrate technical efficiency but may still be able to improve its productivity by exploiting scale economies. This scale inefficiency is significant under variable return to scale. However, if the level of inputs (in output-oriented model) used in two different periods is the same, scale issues do not arise.

Constant return to scale (CRS) assumes that all companies in the industry are producing at the optimal scale and the scale effect disappeares. One opinion is that constant return to scale created additional restrictions to the model. (For example, Charnes, Cooper, Lewin & Seiford, (1994))

Some extremely small and large firms in the sample will be efficient using CRS, but indicate inefficiency under variable return to scale, since the DEA allows to envelop the sample more closely using variable return to scale. However, the belief that extremes are only scale inefficient and not technically inefficient may be wrong.

There is a strong support for airlines' constant return to scale in existing literature. Caves, Christensen & Tretheway (1984) considered a general model of airline costs, which they estimate by using panel data on large and small airlines. Differences in scale are shown to have no role in explaining higher costs for small airlines. Kumbhakar (1990) found the support for increasing return to scale more likely to be small. Coelli, Pelerman & Romano (1999) were not able to reject the hypothesis of constant return to scale on the case of international airlines. Also, Good, Nadiri and Sickels (1991) noted the complex nature of airlines' outputs and stated that care must be taken for scale economy interpretation. Due to the strength of these arguments, we assume the constant return to scale for the model. Therefore, the difference between terms "*efficiency*" and "*productivity*" vanishes in the framework of this study.

4.1.2 Choice of Variables

According to the purpose of the thesis, we are interested in measuring the efficiency of the operational performance. One of the benefits of Data Envelopment Analysis is the adjustment for multiple inputs and outputs. Hence, the DEA model for evaluation efficiency scores includes 3 inputs and 2 outputs. The discussion of their reliability is represented below.

One of the inputs is the quantity of airline's labour. The importance of including labour is explained by the fact that airlines are labour intensive[23]. Each major airline employs a virtual army of pilots, flight attendants, mechanics, baggage handlers, reservation agents, gate agents, security personnel, cooks, cleaners, managers, accountants, lawyers, etc. Computers have enabled airlines to automate many tasks, but there is no changing the fact that they are a service business, where customers require personal attention. More than one-third[24] of the revenue generated each day by the airlines goes to pay its workforce. Labour costs per employee are among the highest of any industry. However, this input is not self-sufficient.

Fuel is the other essential airlines' cost. As far as airlines are a service industry, and the services carry out normally with the utilization of fuel, it could be considered as a proxy for operation performance. By minimizing fuel, a reduction in the consumption of fuel used per certain output produced is accomplished, which means an improvement in technical efficiency. The fuel consumption also depends on aircraft type. The reduction in fuel costs with the technological innovations is possible irrespective of output's level. The quantity of fuel consumed corresponds to the second input.

Further, aircraft capacity is the last, but not least input in the model. The key aspect to put aircraft capacity into the model is its dependence on maintaining costs. Maintenance programs keep aircraft in safe, working order; ensure passenger comfort; preserve the airline's valuable physical assets (its aircraft); and ensure maximum utilization of those assets, by keeping planes in excellent condition. An airplane costs its owner money every minute of every day, but makes money only when it is flying with freight and (or) passengers aboard. Therefore, it is vital to an airline's financial success that aircraft are properly maintained. This requires crucial expenditures, and the company, which could find a way to reduce the airline capacity with the same level of output, therefore reduces such expenditures and improves its own efficiency.

There are mainly two sources of revenue in the airline industry. It was estimated that about 75 percent of the airline industry's revenue comes from

[23] Air Transport Association, web page: http://www.airlines.org/public/home/default1.asp
[24] Ibid

passengers and about 25 percent from other transport-related services[25]. Thus, we suggest estimating output through both quantity of passengers and quantity of freight carried.

4.1.3 DEA Performance

In order to measure the efficiency and the efficiency (productivity) change within airlines the *Data Envelopment Analysis Program* (*DEAP*) version *2.0* is used. This version being adapted for Malmquist index computation, allows us to achieve more information by decomposing the productivity change into technical change and technical efficiency change (Coelli, 1996; Coelli & Prasada Rao, 2001). The limitation for using Malmquist index in this version of the program does not affect the study according to the assumption of constant return to scale (*CRS*) technology. The efficiency scores and annual changes in efficiency scores are computed on a yearly basis for main samples of 35, 29 and 15 airlines.

As it was mentioned above, there are some gaps in production data for three airlines, namely Canadian Airlines International, INDIAN AIRLINES and Olympic Airways. The information on fuel consumption for the years 1998 and 1999 is lacking. Since these airlines are inefficient for the length of full period 1991-1999 and do not affect the results on production scores[26], we decided to keep them in data set. The amount of fuel consumed is assumed to be in the same proportion to ton kilometres flown[27] as for the previous year with available data on fuel for each airline. Thus, 1997 year is used for the basis.

However, examining the relation between productivity and financial information, airlines with gaps in data are not included for the particular period 1998-1999.

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[25] Air Transport Association, web page: http://www.airlines.org/public/home/default1.asp

[26] The addition of inefficient units into a sample does not affect the frontier. Thus, it does not change the efficiency scores of other units. More details on data envelopment technique properties could be found in Coelli, Prasada Rao & Battese, (1998)

[27] This parameter shows the quantity (ton*kilometres), which airline company has performed in its operations

4.2 Cash Flow Computation

Cash flow calculation is performed in a one-way procedure with respect to all firms' accounting reports. Although this way forbids taking into consideration the details on personal performance of each airline, it provides a valid proxy for cash flow estimation on the base of international accounting reports.

The computation is done in *MS Excel*. The Copeland et al (1996) definition of cash flow is utilized. The cash flow computation starts with year 1992 since some accounting information on the previous year is needed, and the accounting data available for the study is for the period 1991-1999. Also, the annual change in cash flow is obtained as the residual of cash flow at date (*t+1*) minus cash flow at date (*t*) and the result is divided by cash flow at date (*t*).

Alternatively, information on cash flow could be collected from cash flow statements without any computation. However, the differences in accounting reports among countries discussed above make the one-way computation of cash flow more appropriate in the framework of the study. Furthermore, Jan Marton (1998) pointed out that since reported cash flows have different definitions, the analysts prefer to calculate cash flows themselves; moreover, the statement of cash flow is not used much, given that it often just consists of net income with depreciation added.

4.3 Statistical Model

4.3.1 Choice of Variables

A statistical model is created to investigate the existence of the relation between financial information and efficiency of the airlines. According to that aim, the choice of dependent and independent variables is made. An independent variable is one that is assumed to produce an effect on, or be related to, an object of interest. The role of independent variable belongs to productivity measures. In general, four independent variables are of interest: *technical efficiency (TE)*, *Malmquist Total Factor Productivity (MTFP) Index*, *technological change (T)* and *efficiency change (E)*. As was mentioned above, MTFP Index represents the technical efficiency change in time. Not all variables are considered simultaneously, the choice of applying each of these variables in sub-models depends on the context and will be described later.

The dependant variable is the object or characteristic analysed by the researcher, generally in regards to how the independent variable or variables affects or are related to it. Thus, the financial items, namely *EBIT*, operating expenditures (*Exp*.) and pre-tax operating cash flow (*CF*) will be used. The effect of each of these three items will be examined separately. Moreover, the changes of variables through time will be considered.

4.3.2 Simple Regression Models

Model SR1. The first model with simple regression involves relative changes in productivity and financial variables between years. The general form of the model is presented below:

$$\Delta Dep\_Var_t = \beta_1 + \beta_2 \Delta TE_t + e_t ,$$

where t is the number of observations from 1 to T, and the dependant variable ΔDep_Var is a change in *EBIT*, *Expenditures*, or *CF*, explained through their linear relationship with change in technical efficiency, ΔTE, which is represented by one variable from MTFP index, efficiency or technological change. Coefficients β_1 and β_2 are parameters of the regression. In the simple regression model with one independent variable, parameter β_1 represents intercept of the relation, and β_2 is the appropriate slope.

The changes are considered on the annual basis in the period 1991-1999[28] for 35 airlines. The gaps in accounting data limit the observation set. In Table 4.3.1, the number of observations (airlines) in regression for each annual change according to the dependant variable is shown:

[28] The period 1992-1999 for the CF variable

Table 4.3.1

Period	Dependant Variable:		
	EBIT	Exp.	CF
1991-1992	32	32	-
1992-1993	34	34	31
1993-1994	35	35	34
1994-1995	35	35	35
1995-1996	34	34	34
1996-1997	33	33	32
1997-1998	28	28	27
1998-1999	25	25	23

However, there is a deficit in the number of observations for regression in Model SR1. Therefore, the simple regression is applied to the full period 1991-1997 with the next model.

Model SR2. The sub sample of 29 airlines is examined in this model for the full period 1991-1997[29]. The essential gaps for years 1998 and 1999 in accounting data lead to the exclusion of these two years from consideration. The general form of the model for annual changes is the same as for Model SR1.

Also, the relation between absolute value of efficiency and financial values are examined on the same sample of 29 airlines for the same period according to the lack of information concerning the priority of *absolute* or *relative* values for the investigation of relation. The **Model SR2a** has the form of simple regression with absolute values instead of annual changes:

$$Dep\_Var_t = \beta_1 + \beta_2 TE_t + e_t \,,$$

where t is the observation from *1..T*, *Dep_Var* is a dependent variable, *TE* is technical efficiency score; coefficients β_1 and β_2 are parameters of the regression.

[29] The period 1992 -1997 for the CF variable

Model SR3. Moreover, the fact that the information on changes in efficiency could not be subject to immediate reaction in financial figures is taken into the account. The process of translation productivity changes into financial information may take some time. We assume the delay to be one year. The other features of the model are the same as for the Model SR2 with the relative values:

$$LAG(\Delta Dep\_Var_t) = \beta_1 + \beta_2 \Delta TE_t + e_t$$

where $LAG(\Delta Dep\_Var_t)$ is one-year delay for financial data annual change, other descriptions keeping constant.

4.3.3 Regression with Dummy Variables

Model DR1. According to Hill et al (2001), dummy variables are a powerful tool for capturing qualitative characteristics. In general, a dummy variable could describe any event that has only two possible outcomes. However, many qualitative factors have more than two categories. A separate binary variable could be created for each category (Hill et al, 2001). In this model we suggest introducing six[30] dummies, one for one annual change: the data set consists of 29 airlines for the years 1991 through 1997. Therefore, each dummy takes two values, 1 or 0, to indicate the presence or absence of a characteristic. We express dummy variable D_k, in the following way:

$$D_k = \begin{cases} 1, & if \quad observation \in k \\ 0, & if \quad observation \notin k \end{cases}$$

where $k \in [1,6]$ is the annual change from the period 1991-1997. Thus, now the annual observations of each airline are linked together. The model is represented below:

$$\Delta Dep\_Var = \beta_1 + \delta_1 D_1 + \delta_2 D_2 + ... + \delta_6 D_6 + \beta_2 \Delta TE + e,$$

[30] The model for cash flow contains five dummies, each for the annual change for the period 1992-1997.

where ΔDep_Var shows the change in financial variable; ΔTE is either MTFP Index or productivity and efficiency changes; D_k is the annual dummies described above and δ_k is the new parameters with respect to dummies . Hill et al (2001) pointed out that annual dummies capture year effects, which are not otherwise measured in model.

Model DR2. Although a special research on the international differences in the annual reporting is outside of the framework of the study, these differences are too large to be ignored. Thus, it is relevant to a create model with region as the qualitative factor. The same sample of 29 airlines for the period 1991 through 1997 is observed. We introduce three region dummies: first - for US, second – for Europe and third – for the rest of the world. US is represented by 6 airlines, Europe by 11, and 12 airlines belong to other countries. Hence, the model is given by the following:

$$\Delta Dep\_Var = \beta_1 + \delta_1 D_1 + \delta_2 D_2 + \delta_3 D_3 + \beta_2 \Delta TE + e ,$$

where D_k is the region dummy and other designations are kept the same.

Hill et al (2001) noticed one important moment with dummies. If one includes all separate binary dummy variables into the model, the least squares procedure fails to define estimators. The reason is that the year (or region), categories are exhaustive, and the sum[31] of the dummies is 1. Therefore, the intercept variable x_1=1 is an exact linear combination of the annual (region) dummies and the collinearity arises. According to Hill et al (2001), the usual solution to this problem is to omit[32] one dummy variable. Mathematically it does not matter which dummy is omitted in our models. Also, the intercept could be omitted instead of the dummy.

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[31] The sum is D_1+ D_2+ …+ D_6 in the case of annual dummies and D_1+D_2+D_3 in the case of region dummies.

[32] Failure to omit one dummy variable will lead to your computer software returning a message saying that least squares estimation fails. This error is sometimes described as falling into the dummy variable trap. (Hill et al, 2001)

4.3.4 Fixed Effects Model

Model FE1. The fixed effects method is common for panel data sets. Since the data contains a time-series of data on a cross-section of airlines. Thus, the fixed effects method is applied in the study to capture individual differences in performance so that all the data for estimation and inference purposes could be combined, or pooled. There is no one general intercept in the model. Rather, the number of intercepts, one for each airline in the sample is introduced. They are created in terms of dummies:

$$D_{ji} = \begin{cases} 1, & if \quad i = j \\ 0, & if \quad i \neq j \end{cases}$$

The quantity of dummies corresponds to the number of firms. In this model the 15 international airlines for the period 1991 through 1999 are considered. Structural form of the Model FE1 is the following:

$$Dep\_Var_{it} = \beta_{11}D_{1i} + \beta_{12}\ D_{2i} + ... + \beta_{1,15}D_{15,i} + \beta_2 TE_{2it} + e_{it}\ .$$

The coefficients β_{1i} are equal to the firm intercepts. The same idea of the model is applied for changes in the dependant variable (Model FE1a). In this case the additional parameter appears since two components of changes, technological and efficient, are examined:

$$\Delta Dep\_Var_{it} = \beta_{11}D_{1i} + \beta_{12}\ D_{2i} + ... + \beta_{1,15}D_{15,i} + \beta_2 \Delta TE_{2it} + e_{it}\ .$$

Again, the change in technical efficiency could be given by MTFP index, or technological change, or efficiency change.

4.3.5 Regression with Few Independent Productivity Variables

Model MR1. There is another way[33] to include a possible lag of financial data into the consideration. The financial variable at date (*t+1*) could be expressed

[33] The way, which is distinct from Model SR3

as the technical efficiency score at date (*t*) plus the change in technical efficiency from date (*t*) to date (*t+1*). The change in technical efficiency is either MTFP index or composition of efficiency and technological changes. Based on this reasoning, the sub-model is given by:

$$Dep\_Var_{i(t+1)} = \beta_{1i} + \beta_{2i}\ TE_{it} + \beta_{3i} T_{i(t;t+1)} + \beta_{4i} E_{i(t,t+1)} + e_{it}\ ,$$

where i is the number of the i-th airline, $Dep\_Var_{i(t+1)}$ is the dependant variable at date ($t+1$), TE_{it} is technical efficiency score at date (t), $T_{i(t;t+1)}$ and $E_{i(t,t+1)}$ are the technological and efficiency changes between date (t) and ($t+1$) respectively, and β_{ji} are the parameters of the model.

All regression models are performed in *MS Excel*. The advantage of this software could be explained by exhaustiveness of output and universality.

5. RESULTS AND ANALYSIS

The results obtained during the study are represented in this chapter. Further, the analysis of results is made according to the focus of the thesis. Different models are examined, thus a brief explanation for their importance in the framework of the study is given.

5.1 Analysis of Productivity Scores

The purpose of the productivity assignment of the study is to evaluate technical efficiency scores for airline industry. The technical efficiency scores for 35 airlines are presented in Appendix II. The firm's score is the maximal performance measure for this firm relative to all other 34 airlines with the sole requirement that each airline lies on, or below, the extreme frontier. Each firm score is the result of focus on the individual airline's observation in contrast to industry's averages. The score equal to 1 represents fully efficient firms in the sample. For example, one can see that such airlines as Japan Air System, Lufthansa and America West Airlines are technically efficient in first two years of observation, namely 1991-1992. This means that these units are lying on the frontier. On the other hand, inefficiency is expressed in scores below unit. The farther the score is from 1, the more inefficient the airline. An example of the most inefficient airline in the sample for 1991 is LOT with score equals to 0.233.

The MTFP index scores, as well as its decomposition to the technological and to the efficiency changes for years 1991-1999, are presented in Appendix III. The score of changes for any particular airline shows the change (total, technological, or efficiency) from date (t) to date ($t+1$). The value above 1 indicates a positive change, while the value below 1 shows the deterioration in efficiency. For instance, LOT improved its efficiency from 1991 to 1992, whereas America West Airlines had a productivity decrease.

Also, the additional information is obtained from index's decomposition. The Indian Airline, for example, has positive efficiency change and negative technological change in the same period.

5.2 Results and Analysis of Cash Flow Computation

We will consider detailed cash flow computation in the case of British Midland Airline. Let us assume we are interested in computation of pre-tax operational cash flow for year 1992. ICAO generalized the accounting items for the airline industry in its statistical base. ICAO's pattern of income statement and balance sheet is presented in Appendix IV on the case of British Midland Airline. The cash flow computation is separated into six parts according to the Copeland[34] definition of pre-tax operating cash flow. All financial figures are given in thousands of U.S. Dollars.

The computation is started with EBIT. It is represented in the income statement as the operating result between total operating revenues and total operating expenses. The first step of computation is to obtain *Gross Cash Flow* by adding back *Total Depreciation and Amortization* to EBIT. The procedure is presented in Table 5.2.1:

Table 5.2.1

PART 1 - Gross Cash Flow:	**1992**
EBIT	8034.37
Depreciation and Amortization (total)	16747.55
Gross Cash Flow	**24781.92**

Since $CF = GrossCashFlow - GrossInvestment$, the next step is to calculate *Gross Investment*. The first component of Gross Investment is *Increase in Working Capital* . The calculations on it are given in Table 5.2.2.

As one can see from Table 5.2.2, Increase in Working Capital is the change in *Operating Capital* between the years 1991 and 1992. This is the amount British Midland invested in operating working capital during the year. In its turn, the Operating Capital is the difference between *Operating Current Assets* and *Total Non-interest Bearing Current Liabilities*. We can observe the decrease of 1736500 U.S. Dollars in working capital for British Midland in the table.

[34] This is the definition of cash flow according to Copeland et al, (1996).

Table 5.2.2

PART 2 - Increase in Operating Working Capital:	**1991**	**1992**
Current Assets	120621.40	125340.30
Equipment Purchase Funds	0.00	0.00
Other Special Funds	0.00	0.00
Operating Current Assets	120621.40	125340.30
Current Liabilities	(0.00)	(115081.60)
Unearned Transportation Revenues	(108626.20)	(0.00)
Deferred Credits	(0.00)	(0.00)
Operating Reserves	(0.00)	(0.00)
Total Non-interest Bearing Current Liabilities	(108626.20)	(115081.60)
Operating Working Capital	*11995.20*	*10258.70*
Increase in Working Capital		**(1736.50)**

The second component of Gross Investment is *Capital Expenditures*. Some assets not included in current assets, namely *Flight equipment before depreciation less reserve for depreciation, Ground property and equipment before depreciation less reserve for depreciation* and *Land* are treated as *Net Property, Plant and Equipment* and are involved into Capital Expenditures calculation. The computation on Capital Expenditures is given in Table 5.2.3:

Table 5.2.3

PART 3 - Capital Expenditures:	**1991**	**1992**
Flight Equipment after Depreciation	85572.46	82202.60
Ground Property and Equipment after Depreciation	43592.82	45261.21
Land	0.00	0.00
Net Property. Plant and Equipment	129165.28	127463.81
Increase in Net Property. Plant and Equipment		(1701.47)
Depreciation and Amortization (total)		16747.55
Retirement of Property and Equipment		(2913.67)
Capital Expenditures		**12132.40**

In Table 5.2.3, Capital Expenditures include change in Net Property, Plant and Equipment (negative change in the case of British Midland gives the negative sign of that component) and Total Depreciation and Amortization. *Retirement of Property and Equipment* is deducted from the result since this item does not reflect real cash flow from a firm.

The third component of Gross Investment is *Change in Other Assets Net of Liabilities*. *Investment in affiliated companies* is assumed not to be concerned with operational performance of the firm. Table 5.2.4 shows the items included in computation:

Table 5.2.4

PART 4 - Increase in Other Assets Net of Liabilities:	**1991**	**1992**
Deferred Charges (total)	0.00	0.00
Development and Pre-operating Costs	0.00	0.00
Other Deferred Charges	0.00	0.00
Intangible Assets	0.00	0.00
Other Assets. net of Liabilities	0.00	0.00
Increase in other assets net of liabilities		0.00

There is no information in data source according to items included in *Other Assets net of Liabilities* for British Midland. We assume the changes to be zero.

In the fifth part of the computation, the Gross Investment is obtained as the composition of Changes in Operating Working Capital, Capital Expenditures and Changes in Other Assets Net of Liabilities. The result of computation is presented in Table 5.2.5:

Table 5.2.5

PART 5 - Gross Investment:	**1992**
Increase in Working Capital	(1736.50)
Capital Expenditures	12132.40
Increase in Other Assets net of Liabilities	0.00
Gross Investment	**10395.90**

The last step is to calculate Cash Flow as the difference between Gross Cash Flow and Gross Investment. The pre-tax operating Cash Flow for British Midland in 1992 is represented in Table 5.2.6:

Table 5.2.6

PART 6 - Pre-Tax Cash Flow:	**1992**
Gross Cash Flow	24781.92
Gross Investment	(10395.90)
Pre-Tax Operating CASH FLOW	**14386.02**

Thus, we see that pre-tax operating cash flow is greater than earnings before interest and tax for British Midland in 1992. The airline generated real cash flow, which exceeds the accounting earnings. This is not the only case. In contrast, a number of airlines in the sample report positive EBIT, while real pre-tax operating cash flow is heavily negative. The long recession in the industry does not allow it to make optimistic forecasts concerning airlines' operational performance. The present study looks for the relationship between productivity changes and financial information using EBIT, expenditures and cash flow as financial indicators of operational performance. As we stated before, the utilization of information on cash flows, obtained with the non-accounting approach, can give additional knowledge on the relation of interest.

5.3 Analysis of Statistical Results

5.3.1 Year by Year Analysis

The results of regression for Model SR1 are presented in Appendix V. The simple regression model SR1 for each annual change in period 1991 through 1999 for 35 airlines[35] does not reveal any kind of significant relation between annual changes in efficiency scores and earnings, as well as for expenditures and cash flow. The reason for that could be deficit in observations. The data do not satisfy all the assumptions[36] of the simple regression model. Although assumption R4 holds[37], there is violation of assumption R3 on the *homoskedasticity* of data. Even though data on earnings is homoskedastic for all eight annual changes, the data on expenditures and cash flows do not have this property for the whole period. Table 5.3.1 below shows the tests results for all annual changes, where *T* means that the hypothesis of homoskedasticity is true; otherwise the hypothesis is false, and the letter *F* appears in the column. Moreover, *F/T* indicated that although some of the annual changes show

[35] As we mentioned before, the sample varies from year to year according to availability of data.
[36] The theoretical description of tests using in testing the assumptions of the regressions for all models is presented in Appendix VI.
[37] There is no need for testing assumption R5, since the simple regression model contains one independent variable

homoskedasticity, the others do not satisfy the hypothesis, thus, the heteroskedasticity in the data exists:

Table 5.3.1. *Test for Homoskedasticity (period 1991 through 1999)*

	Change, Exp.	Change, EBIT	Change, CF
Technological Change	F/T	T	F/T
Efficiency Change	F/T	T	F/T
MTFP Index	F/T	T	F/T

Therefore, $\operatorname{var}(y_t) \neq \sigma^2$ and random variable as well as random error are heteroskedastic. According to Hill et al, the existence of different variables, or heteroskedasticity, is often encountered when using cross-sectional data. The consequences of heteroskedasticity are that the standard errors usually computed for the least square estimators are incorrect, and therefore, the hypothesis tests that use these standard errors may be misleading[38]. The model SR1 works with cross-sectional data for each of the annual changes in the period 1991-1999 and simple regression model for year-by-year investigation fails to recognise the relation of interest. Further analysis with other models is provided in order to investigate the relation.

5.3.2 Simple Regression Results for the Full Period

In order to expand the sample of observations, the annual changes of 29 airlines are considered for the full period 1991-1997 in Model SR2. Thus, 174 observations are used for EBIT and Expenditures. As we mentioned above, the CF changes start with year 1992, hence, there are 145 observations for the CF variable. The assumptions R3 and R4 of the simple regression hold. The results obtained are presented in Table 5.3.2:

[38] The least square estimators are no longer the best linear unbiased estimator from Gauss-Markov Theorem (see Hill et al, 2001)

Table 5.3.2. *Results from Model SR2*

Period	Independent Variable	Dependant Variable	Beta 1	Beta 2	R Square
91-97	MTFP Index	Change, EBIT	4.229 (4.372)	-4.106 (4.157)	0.006 (7.974)
91-97	Efficiency Change	Change, EBIT	2.245 (5.035)	-2.242 (4.888)	0.001 (7.991)
91-97	Technological Change	Change, EBIT	7.213 (7.359)	-7.119 (7.190)	0.006 (7.974)
91-97	Efficiency Change	Change, Exp.	0.107 (0.080)	-0.055 (0.078)	0.003 (0.128)
91-97	Technological Change	Change, Exp.	0.433*** (0.112)	-0.374*** (0.112)	0.061*** (0.124)
91-97	MTFP Index	Change, Exp.	0.228*** (0.069)	-0.170*** (0.065)	0.038*** (0.125)
91-97	Technological Change	Change, FCF	-9.587 (13.199)	7.447 (12.706)	0.002 (12.1444)
91-97	MTFP Index	Change, FCF	-7.011 (7.178)	4.878 (6.749)	0.004 (12.137)
91-97	Efficiency Change	Change, FCF	-5.090 (8.251)	3.159 (8.045)	0.001 (12.152)

The numbers in parentheses are the *standard errors* of the respective parameters, which are written above. *Beta 1* is a least square estimator of the intercept β_1 in the model. *Beta 2* is the least square estimator of the slope β_2 of the regression function. These parameters of the model are quantities that help characterize economic behaviour, and that serve as a basis for making economic decisions (Hill et al, 2002). As we mentioned above, the significance of the results is proved with *t*-test in the case of simple regression. One, two, and three stars above a number indicate the significance on $\alpha = 0.1$, 0.05, and 0.01 levels respectively. A negative number shows the negative relation between variables. These designations are carried out through the rest of the chapter.

As one can see from Table 5.3.2, the significant relationship exists between MTFP Index and Expenditures. Moreover, the results of decomposition allow us to conclude the influence of technological change to this relation. The second parameter in the model β_2 is negative, which means the negative type of the relation. Therefore, the evidence demonstrates that the improvements in technical efficiency reflect the decrease in expenditures. This evidence does not contradict common sense. New innovations are introduced within the company if it helps to improve the productivity, thus, reduce the costs. However, changes in earnings and in cash flow do not demonstrate any significant reflection of productivity changes.

The value of R^2 (*R Square* in Table 5.3.2) is 0.038 for the MTFP index and 0.061 for the technological change. Therefore, 3.8 (or 6.1) percent of the variation in expenditures variable about its mean is explained by the regression model. This is not a large percentage, since the financial information is affected by many other factors, not only productivity changes.

However, the priority of absolute and relative values has not been examined according to the relationship. It could be the case that absolute values catch the reflection of productivity changes to the financial information better, than relative figures. The Model SR2a explores the relation on the absolute values. The sample consists of 29 airlines from the period[39] 1991 through 1997. The assumptions R3 and R4 hold for the model. The results of investigation are given in Table 5.3.3:

Table 5.3.3. *Results from Model SR2a*

Independent Variable	Dependant Variable	Beta 1	Beta 2	R Square
TE	EBIT	163863 (111949)	-638317 (133248)	0.001 (326614)
TE	Exp.	3286459*** (1314422)	824843 (1564495)	0.001 (3834852)
TE	CF	-67237 (378297)	77984.77 (448531)	0.001 (990596)

There is no significant relation between absolute values, and the coefficient of determination is around zero. The standard error has large values. However, the assumptions of simple regression hold. The significance of intercept is explained by random work rather than by any rule. Thus, the simple regression

[39] Period 1992-1997 for Cash Flow consideration

model with absolute values shows no relation between technical efficiency scores and financial information.

As we mentioned above, the changes in financial information could reflect productivity changes not immediately. Rather, it is relevant to suppose a delay in financial information. We assume the lag of one year. The model SR3 involves 29 airlines in the years 1992-1997. Again, data satisfy the assumptions R3 and R4 for simple regression model. The annual changes in productivity and financial data are examined. Table 5.3.4 shows the regression result:

Table 5.3.4. *Results from Model SR3*

Dependant Variable	Independent Variable	Beta 1	Beta 2	R Square
Lag (Change, Exp.)	MTFP Index	0.012 (0.063)	0.025 (0.059)	0.001 (0.112)
Lag (Change, Exp.)	Technological Change	0.041 (0.112)	-0.003 (0.108)	0.000 0.112
Lag (Change, Exp.)	Efficiency Change	-0.002 (0.072)	0.039 (0.069)	0.002 (0.112)
Lag (Change, EBIT)	MTFP Index	-1.154 (4.769)	0.899 (4.496)	0.000 (8.445)
Lag (Change, EBIT)	Technological Change	7.294 (8.415)	-7.278 (8.133)	0.005 (8.423)
Lag (Change, EBIT)	Efficiency Change	-4.173 (5.410)	3.888 (5.263)	0.004 (8.430)
Lag (Change, CF)	MTFP Index	-7.085 (8.145)	4.754 (7.558)	0.003 (13.186)
Lag (Change, CF)	Technological Change	7.437 (16.881)	-8.978 (15.985)	0.003 (13.191)
Lag (Change, CF)	Efficiency Change	-10.881 (9.130)	8.753 (8.937)	0.008 (13.154)

However, Table 5.3.4 shows us no significant results. The conclusion is that there is no support for the hypothesis that productivity changes translate to the financial information with the delay of one year. Thus, on the basis of the previous results obtained in model SR2, we conclude the instant[40] reflection of

[40] By "instant" reflection the author means the reflection during the present year

productivity changes into the accounting information on expenditures. The productivity improvement occurs with the decrease in costs, and this decrease is immediately reflected in accounting reports.

5.3.3 Results from Regression with Dummies

In order to capture the yearly change effects, the annual dummies are introduced in Model DR1. The annual changes for the period 1991-1997 are considered for 29 airlines. The intercept is assumed to be zero for the computation purposes. The results of regression with six dummies, each for the change between two subsequent years are shown in Table 5.3.5:

Table 5.3.5. *Results from Model DR1*

Independent Variable	Dependant Variable	Beta 2	Adjusted R Square
Efficiency Change	CF	0.954 (8.455)	-0.031 (12.259)
Technological Change	CF	18.362 (16.015)	-0.021 (12.202)
MTFP Index	CF	4.524 (6.906)	-0.028 (12.241)
Efficiency Change	EBIT	-3.920 (5.115)	-0.024 (8.044)
Technological Change	EBIT	-2.706 (9.735)	-0.027 (8.057)
MTFP Index	EBIT	-3.390 (4.315)	-0.024 (8.044)
Efficiency Change	Exp.	-0.097 (0.078)	0.069*** (0.122)
Technological Change	Exp.	-0.344*** (0.146)	0.091*** (0.121)
MTFP Index	Exp.	-0.140** (0.065)	0.086*** (0.121)

According to Table 5.3.5, there is again the significant relationship between changes in expenditures and productivity changes. Moreover, the decomposition of MTFP Index into efficiency and technological change shows the relation of expenditures to productivity change. The type of relation is negative, which confirms the results from Model SR2.

The *Adjusted* R^2 is larger than R^2 of SR2, nevertheless, these coefficients are not subject to comparison, since *Adjusted* R^2 does not show what percentage of variation of the dependant variable about its mean is explaining by the model. However, in the multiple regression *Adjusted* R^2 is a measure of fit for the model, and it has significant value with the Model DR1. Thus, we confirm the significance of relation between expenditures and technological change.

Further, there is no evidence of the existence of the relationship between productivity changes and either cash flow or earnings. The regression does not reveal any significance, and the negative *Adjusted* R^2 with the large standard error supports that.

As it was broadly discussed above, the differences in accounting rules and other factors among countries could affect results of international study. The airlines of US have vital differences from Europe airlines. The separation of international sample to the geographical regions could provide additional information on how the productivity changes transform in to the financial information. We recall, that the main investigation was performed with sample separation into three general sub-sets with respect to US, Europe and the third category for the rest of the world. The results obtained by examining Model DR2 with region dummies are given in Table 5.3.6.

As we can see from Table 5.3.6, the results from model DR2 do not bring any new knowledge on the relation. The expenditures are negatively correlated with technological change as well as with MTFP Index. The value of adjusted R^2 is 0.048 for the technological change, and 0.024 for MTFP Index, which are lower than those for the DR1 model (0.091 and 0.086 for technological change and MTFP respectively). Also, the model DR2 with MTFP demonstrates significance only on level $\alpha = 0.1$ instead of 0.01 in DR1. *Adjusted R Square* is lower, than for the years-dummies, which indicates that this regression explains the relation less clearly than the previous one.

Table 5.3.6. *Results from Model DR2*

Independent Variable	Dependant Variable	Beta 2	Adjusted R Square
Efficiency Change	CF	3.279 (8.114)	-0.026 (12.233)
Technological Change	CF	7.360 (12.833)	-0.025 (12.226)
MTFP Index	CF	4.970 (6.817)	-0.024 (12.217)
Efficiency Change	EBIT	-3.072 (4.905)	-0.006 (7.974)
Technological Change	EBIT	-7.256 (7.208)	-0.002 (7.959)
MTFP Index	EBIT	-4.777 (4.165)	-0.001 (7.953)
Efficiency Change	Exp.	-0.061 (0.079)	-0.014 (0.128)
Technological Change	Exp.	-0.384*** (0.112)	0.048*** (0.124)
MTFP Index	Exp.	-0.178*** (0.066)	0.024* (0.125)

Therefore, the simple region separation of airlines does not give any new information. The problem of differences among countries is a more complex issue than was assumed in current study and needs to be examined more carefully. For instance, Rajan & Zingales (2001) argue that the accounting system of England is more close to US then to the German system. Thus, the region dummies with determination on only geographical principles are unsuccessful instruments for the present research[41].

It is important to notice that the regression assumptions hold for models DR1 and DR2. Hence, heteroskedastisity or autocorrelation in data cannot affect the results.

[41] The research paper written by Jan Marton (1998) could be the basis for more detailed research in that direction.

5.3.4 Results from Fixed Effects Method

Pooling time-series and cross-sectional data with the fixed effects model allows us to introduce intercepts for each airline. The sample consists of 15 airlines for the period 1991 through 1999. Thus, eight annual changes are analysed. The results are given in Table 5.3.7:

Table 5.3.7. *Results from Model FE1a*

Period	Independent Variable	Dependant Variable	Beta 2	Adjusted R Square
91-99	MTFP Index	Change, EBIT	-2.302 (2.431)	-0.009 (4.907)
91-99	Efficiency Change	Change, EBIT	-1.485 (2.974)	-0.016 (4.922)
91-99	Technological Change	Change, EBIT	-4.524 (4.840)	-0.010 (4.907)
91-99	Efficiency Change	Change, Exp.	-0.063 (0.081)	-0.114 (0.133)
91-99	Technological Change	Change, Exp.	-0.269** (0.129)	-0.077 (0.131)
91-99	MTFP Index	Change, Exp.	-0.118* (0.065)	-0.087 (0.131)
91-99	Technological Change	Change, CF	-0.191 (13.437)	-0.156 (12.131)
91-99	MTFP Index	Change, CF	4.068 (6.143)	-0.150 (12.101)
91-99	Efficiency Change	Change, CF	5.561 (7.485)	-0.149 (12.093)

The negative relation between technological change and change in expenditures can be observed. No presence of connection between changes either in EBIT or in CF and change in efficiency is investigated. Moreover, the probability of accepting null hypothesis is high, which is impressed in the non-significance of the model. Hence, the Model FE1a does not confirm the existence of the relation between productivity and financial changes on the sample of 120 observations.

The reason for that can be in violation of regression assumptions. Although there is no autocorrelation, and the homoskedastisity for earnings holds, the heteroskedasticity for expenditures and cash flow is revealed. As we noticed above, the existence of heteroskedasticity can heavily affect the results of hypothesis testing, and, therefore, can influence the general results of the model.

The method of identifying individual intercept for each firm gives some new aspects on the relation between technical efficiency and expenditures for the absolute values. Again, the sample of 15 airlines for the period 1991 through 1999 is examined. The data on earnings and expenditures satisfy the assumptions R3 and R4, while the data on cash flow indicates heteroskedasticity. The results of the method's application are presented in the Table 5.3.8:

Table 5.3.8. *Results from Model FE1*

Period	Independent Variable	Dependant Variable	Beta 2	Adjusted R Square
91-99	TE	EBIT	249278 (315135)	0.368*** (336181)
91-99	TE	Exp.	-1042261* (627537)	0.969*** (666627)
91-99	TE	CF	408659 (792387)	-0.113 (798282)

Although there is no support for existence of connection between EBIT, or CF variables and the technical efficiency measures, the expenditures show the negative relationship[42] to technical efficiency scores. Thus, the fixed effects model reveals the relation on absolute values[43], while the simple regression

[42] Fixed effects model for the same sample with lag in financial data was tested. The results show insignificance of beta coefficient, thus, there is no support for the hypothesis of delay in financial data. Regression assumptions R3-R4 and optional assumption on the normality of distribution hold.

[43] Dr Sjögren and the author tested the fixed effects model on the sample of 29 airlines through the period 1991-1997 (203 observations) using SPSS software. The regressions show non-equal results: Although *Adjusted* R^2 *(=0,741***)* is also high, *Beta2* is positive *(=0,136*)*. However, the assumption R3 does not hold. Thus, the presents of heteroskedasticity in the sample does not allow us to make any conclusions about the relation.

model failed. Assumptions R3 and R4 as well as the optional assumption of the normality of distribution (Jarque-Bera test) are valid. The evidence demonstrates that the information on expenditures from the income statement of the firm reflects the information on the efficiency score of the company. Moreover, the high Adjusted R^2 shows the good fitness of the model.

5.3.5 Results from Regression with Few Independent Variables

The multiple regression shows the influence of each independent variable to the dependant variable. The effects from the absolute value of technical efficiency as well as annual changes in efficiency are examined. The sample of 29 airlines in the years 1991-1997 is utilized. The results of model MR1 are given in Table 5.3.9:

Table 5.3.9. *Results from Model MR1*

Dep. Variable	**Indep. Variable 1**	**Indep. Variable 2**	**Indep. Variable 3**	**Beta 1**	**Beta 2**	**Beta 3**	**Beta 4**	**Adjusted R Square**
EBIT(t+1)	TE (t)	Techn.Change (t,t+1)	Efficiency Change (t,t+1)	11.499 (0.001)	-2.073 (15.130)	0.868 (38.538)	-2.579 (22.014)	0.119*** (31.859)
Exp.(t+1)	TE (t)	Techn.Change (t,t+1)	Efficiency Change (t,t+1)	21.715 (59.610)	7.398 (18.938)	21.496 (48.236)	-56.572 (27.554)	-0.043 (39.876)
CF(t+1)	TE (t)	Techn.Change (t,t+1)	Efficiency Change (t,t+1)	24.660 (0.001)	5.765 (46.347)	19.918* (11.794)	446.729 (67.371)	0.025 (97.499)

The results show no significant support for reflection of technical efficiency at date (*t*) and productivity changes between years (*t, t+1*) to financial information at date (*t+1*). Assumptions of regression R3, R4 and R5 hold.

The *correlation matrices* for testing collinearity (R5) are represented in Appendix VII. There is no high correlation between variables and we conclude validity of the assumption R5 for the model.

6. SUMMARY AND CONCLUDING REMARKS

This chapter presents the conclusion on investigation of the relation between productivity and financial data. The conclusion is based on the analysis of the results given in the previous chapter. Also, the summary of the research is done.

The thesis studies a role of financial information in reflecting productivity changes. The theory, as well as the existent empirical evidence, does provide contradictory information on the priority role of earnings or cash flow in firm's performance evaluation. Also, the importance of other accounting figures is not fully investigated. Therefore, three relevant for the study items of financial information, namely, earnings, cash flow, and expenditures were examined.

The empirical evidence from the international airlines was considered. The general finding is the existence of relationship between efficiency measures and operating expenditures. Thus, the published financial information does reflect the changes in firm's efficiency. Furthermore, the evidence shows negative reaction. This evidence confirms the result obtained by Holmen et al (2002).

Moreover, additional information was obtained by the decomposition of MTFP index into efficiency and technological changes. Although no support for the relation between expenditures and efficiency change was found, the negative correlation between costs and technological change exists. Thus, the reported operating expenditures do provide information on efficiency improvements within the whole industry. However, there is no support for decreasing expenditures with the efficiency change, or catch up effect. Thus, the cost reduction is more likely to occur with the technological improvements for the whole airline industry rather then for the productivity improvements within the separate airline.

The thesis does not reveal any reflection of productivity changes into information on earnings or cash flow. Thus, the priority of cash flow information in comparison with earnings, as well as the reverse, has no support from the relationship with productivity measurement.

Earnings and cash flow are both revenue-based measures. Any changes in revenue are immediately reflected in earnings and cash flow. The revenues within the airline industry seem to have more unpredictable values than costs. The nature of revenue makes it dependant on the demand in the industry, while the demand represents changeable character.

On the other hand, expenditures have less dependence on revenue. The airline industry is the industry with the large amount of fixed assets, thus the proportion of fixed costs is also high. Therefore, the results obtained in the study could probably be explained by more clearly defined (and less revenue-influence) connection between costs and productivity measures in comparison with productivity measures and earnings or cash flow.

The timing of reaction for financial items on productivity changes was investigated. The assumed lag of one year does not provide any evidence on the relation of interest. Rather, the immediate reaction within the year was empirically supported.

The attempt for involving an international aspect in the study was made. However, it does not provide additional information on the relation between productivity measures and financial figures. More comprehensive research on difference in accounting rules and other national factors among countries is needed.

7. SUGGESTIONS FOR FURTHER INVESTIGATIONS

This thesis can be used as a starting point for future investigation into the relationship between accounting reports and productivity measures. An industry less affected by revenue changes could be used. For example, we suggest exploring monopolies, whose demand has a slight effect on revenues. In such industries the influence of the productivity changes to the annual reports and cash flow could be more observable (with the assumption of its existence, of course).

Also, future research could reduce the limitation on financial variables. For instance, we believe that it would be interesting to provide investigation on such relatively newly defined items as modified cash flow.

The accent could be shifted to the problem of globalisation in the industry. A possible issue of the future study could be the influence of accounting distinctions, differences in culture, in geographical location to the evaluation of international operating performance. Finally, the effect from deregulation reforms to the productivity changes in the airline industry could be examined on the evidence from other countries instead of widely studied Europe and US. The deregulation process in Russia could provide a good example.

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APPENDIX

Appendix I

Three general samples considered in the study:

AIRLINE SAMPLE 35		AIRLINE SAMPLE 29		AIRLINE SAMPLE 15	
1	AEROMEXICO	1	AEROMEXICO	1	AEROMEXICO
2	AIR CANADA	2	AIR CANADA	2	AIR CANADA
3	AIR FRANCE	3	AIR FRANCE	3	Alaska Airlines
4	Alaska Airlines	4	Alaska Airlines	4	America West Airlines
5	Alitalia-Linee Aeree Italiane	5	Alitalia-Linee Aeree Italiane	5	American Airlines
6	ALL NIPPON AIRWAYS	6	ALL NIPPON AIRWAYS	6	Austrian Airlines
7	America West Airlines	7	America West Airlines	7	BRITISH AIRWAYS
8	American Airlines	8	American Airlines	8	BRITISH MIDLAND
9	Austrian Airlines	9	Austrian Airlines	9	Continental Airlines
10	AVIANCA	10	AVIANCA	10	Delta Air Lines
11	BRITISH AIRWAYS	11	BRITISH AIRWAYS	11	FINNAIR
12	BRITISH MIDLAND	12	BRITISH MIDLAND	12	IBERIA
13	Canadian Airlines International	13	Canadian Airlines International	13	IRAN AIR
14	Continental Airlines	14	Continental Airlines	14	JAPAN AIR SYSTEM
15	Delta Air Lines	15	Delta Air Lines	15	Japan Airlines
16	FINNAIR	16	FINNAIR		
17	IBERIA	17	IBERIA		
18	INDIAN AIRLINES	18	IRAN AIR		
19	IRAN AIR	19	JAPAN AIR SYSTEM		
20	JAPAN AIR SYSTEM	20	Japan Airlines		
21	Japan Airlines	21	LOT		
22	LOT	22	LUFTHANSA		
23	LUFTHANSA	23	Olympic Airways		
24	Northwest Airlines	24	Philippine Airlines		
25	Olympic Airways	25	SAS		
26	Philippine Airlines	26	Singapore Airlines		
27	SAS	27	THAI AIRWAYS		
28	Singapore Airlines	28	Turkish Airlines		
29	SWISSAIR	29	USAIR		
30	THAI AIRWAYS				
31	Turkish Airlines				
32	TWA- Trans World Airlines				
33	United Airlines				
34	USAIR				
35	VARIG				

Appendix II

Technical Efficiency Scores for 29 airlines in period 1991-1997(obtained from Data Envelopment Analysis)

	AIRLINE	1991	1992	1993	1994	1995	1996	1997
1	AEROMEXICO	0.704	0.792	0.849	0.81	0.933	0.849	0.841
2	AIR CANADA	0.605	0.657	1	0.892	0.869	0.667	0.672
3	AIR FRANCE	0.804	0.76	0.693	0.786	0.753	0.809	0.793
4	Alaska Airlines	0.724	0.742	0.797	1	0.964	1	1
5	Alitalia-Linee Aeree Italiane	1	1	0.969	0.813	0.858	0.892	0.96
6	ALL NIPPON AIRWAYS	1	1	1	1	1	1	1
7	America West Airlines	1	1	1	0.986	1	1	1
8	American Airlines	0.625	0.738	0.713	0.655	0.697	0.705	0.686
9	Austrian Airlines	0.777	0.731	0.7	0.774	0.73	0.652	0.674
10	AVIANCA	1	1	0.917	0.859	0.951	0.923	1
11	BRITISH AIRWAYS	0.567	0.593	0.598	0.582	0.58	0.542	0.602
12	BRITISH MIDLAND	1	1	1	0.961	1	1	1
13	Canadian Airlines International	0.512	0.555	0.506	0.478	0.611	0.59	0.628
14	Continental Airlines	0.665	0.745	0.787	0.726	0.721	0.703	0.653
15	Delta Air Lines	0.743	0.781	0.845	0.779	0.798	0.911	0.918
16	FINNAIR	0.511	0.481	0.498	0.526	0.596	0.664	0.734
17	IBERIA	0.795	0.754	0.652	0.649	0.738	0.683	0.762
18	IRAN AIR	1	1	1	1	1	1	1
19	JAPAN AIR SYSTEM	1	1	1	1	1	1	1
20	Japan Airlines	1	1	0.947	0.511	1	1	1
21	LOT	0.233	0.354	0.418	0.446	0.486	0.488	0.529
22	LUFTHANSA	1	1	0.949	1	1	1	1
23	Olympic Airways	0.824	0.856	0.772	0.76	0.848	0.753	0.866
24	Philippine Airlines	0.736	0.695	0.551	0.62	0.647	0.637	0.734
25	SAS	0.905	0.924	0.922	0.887	0.923	0.809	0.886
26	Singapore Airlines	1	1	1	1	1	1	1
27	THAI AIRWAYS	0.78	0.941	0.835	1	1	1	1
28	Turkish Airlines	0.648	0.74	0.684	0.774	0.839	0.81	0.918
29	USAIR	0.947	0.931	0.88	0.918	0.965	0.939	1

Appendix III

AIRLINE	1991-1992			1992-1993			1993-1994			1994-1995			1995-1996			1996-1997		
	MTFP	T_Ch	Eff_Ch	MTFP	T_Ch	Eff_Ch	MTFP	T_Ch	Eff_Ch	MTFP	T_Ch	Eff_Ch	MTFP	T_Ch	Eff_Ch	MTFP	T_Ch	Eff_Ch
AEROMEXICO	1	0.888	1.126	1.052	0.982	1.071	1.084	1.136	0.954	1.121	0.974	1.151	0.937	1.03	0.91	0.953	0.961	0.991
AIR CANADA	1.067	0.983	1.085	1.88	1.235	1.523	0.838	0.939	0.892	0.916	0.941	0.973	0.821	1.069	0.767	0.963	0.955	1.009
AIR FRANCE	0.949	1.003	0.946	1.026	1.125	0.912	1.233	1.087	1.134	0.985	1.029	0.957	1.12	1.043	1.075	0.949	0.967	0.981
Alaska Airlines	0.959	0.935	1.025	1.121	1.044	1.074	1.463	1.166	1.255	0.877	0.91	0.964	1.1	1.06	1.037	0.986	0.986	1
Alitalia-Linee Aeree	0.977	0.977	1	1.015	1.047	0.969	0.914	1.091	0.838	1.095	1.037	1.056	1.076	1.036	1.039	1.05	0.975	1.077
ALL NIPPON AIRWAYS	0.9	0.9	1	0.936	0.936	1	0.994	0.994	1	1.109	1.109	1	1.119	1.119	1	1.016	1.016	1
America West Airlines	0.971	0.971	1	1.018	1.018	1	1.02	1.034	0.986	1.045	1.031	1.014	0.992	0.992	1	0.952	0.952	1
American Airlines	1.044	0.885	1.18	0.977	1.011	0.967	1.064	1.159	0.918	1.032	0.97	1.064	1.046	1.033	1.012	0.947	0.973	0.973
Austrian Airlines	0.91	0.967	0.941	1.012	1.057	0.957	1.19	1.076	1.106	0.868	0.921	0.943	0.952	1.066	0.893	1.018	0.984	1.034
AVIANCA	0.979	0.979	1	0.967	1.054	0.917	1.02	1.089	0.937	1.058	0.956	1.107	1.048	1.08	0.97	1.052	0.971	1.084
BRITISH AIRWAYS	1.007	0.963	1.046	1.068	1.059	1.008	1.045	1.074	0.973	1.047	1.051	0.997	0.995	1.064	0.935	1.051	0.947	1.109
BRITISH MIDLAND	0.937	0.937	1	1.091	1.091	1	0.944	0.982	0.961	1.149	1.105	1.04	1.219	1.219	1	0.938	0.938	1
Canadian Airlines Intern.	1.058	0.976	1.084	0.976	1.069	0.913	1.08	1.145	0.944	1.199	0.938	1.278	1.01	1.045	0.967	1.044	0.983	1.063
Continental Airlines	0.972	0.868	1.12	1.043	0.987	1.057	1.086	1.177	0.922	0.958	0.965	0.993	1.007	1.033	0.975	0.887	0.955	0.929
Delta Air Lines	0.928	0.882	1.052	1.076	0.996	1.081	1.072	1.163	0.922	0.982	0.96	1.024	1.182	1.034	1.142	0.961	0.954	1.008
FINNAIR	0.914	0.97	0.942	1.088	1.051	1.036	1.086	1.028	1.056	1.088	0.96	1.133	1.177	1.057	1.114	1.1	0.995	1.105
IBERIA	0.928	0.978	0.949	0.94	1.086	0.865	1.033	1.038	0.995	1.077	0.948	1.136	1.077	1.163	0.926	1.021	0.915	1.117
IRAN AIR	0.706	0.706	1	1.27	1.27	1	1.142	1.142	1	0.801	0.801	1	1.149	1.149	1	0.897	0.897	1
JAPAN AIR SYSTEM	0.896	0.896	1	0.922	0.922	1	0.988	0.988	1	1.099	1.099	1	1.12	1.12	1	0.98	0.98	1
Japan Airlines	0.934	0.934	1	1.032	1.09	0.947	0.54	1.001	0.54	2.108	1.078	1.956	1.087	1.087	1	1.114	1.114	1
LOT	1.368	0.9	1.521	1.261	1.066	1.183	1.121	1.052	1.065	1.069	0.979	1.092	1.138	1.134	1.004	1.006	0.929	1.083
LUFTHANSA	0.992	0.992	1	1.08	1.138	0.949	1.171	1.111	1.054	1.02	1.02	1	1.044	1.044	1	0.966	0.966	1
Olympic Airways	0.978	0.941	1.039	1.007	1.117	0.902	1.013	1.029	0.985	1.071	0.96	1.116	1.011	1.139	0.888	1.053	0.916	1.15
Philippine Airlines	0.943	0.998	0.944	0.889	1.121	0.793	1.17	1.04	1.124	1.013	0.97	1.045	1.066	1.083	0.985	1.081	0.939	1.151
SAS	1.003	0.983	1.021	1.043	1.046	0.997	1.076	1.118	0.962	0.971	0.933	1.041	0.975	1.113	0.876	1.041	0.951	1.095
Singapore Airlines	1.018	1.018	1	1.133	1.133	1	1.069	1.069	1	1.043	1.043	1	1.076	1.076	1	1.072	1.072	1
THAI AIRWAYS	1.166	0.966	1.207	1.146	1.292	0.887	1.097	0.916	1.198	1.042	1.042	1	1.078	1.078	1	0.928	0.928	1
Turkish Airlines	1.104	0.966	1.143	1.009	1.093	0.924	1.174	1.038	1.132	1.067	0.985	1.083	1.06	1.097	0.966	1.061	0.937	1.133
USAIR	0.942	0.958	0.983	0.999	1.058	0.945	1.094	1.048	1.044	1.063	1.012	1.051	1.039	1.068	0.973	1.01	0.948	1.065

Productivity changes for 29 airlines in period 1991-1997. MTFP is Malmquist Total Factor Productivity Index, T_Ch is technological change and E_Ch is efficiency change.

Appendix IV

BRITISH MIDLAND AIRLINE Accounting Reports 1991-1992

Balance Sheet

ASSETS (thousands of U.S. Dollars)		1991	1992
1	**Current assets**	120621.40	125340.30
2	**Equipment purchase funds**	0.00	0.00
3	**Other special funds**	0.00	0.00
4	**Flight equipment before depreciation**	112502.80	112768.40
4.1	Less: Reserve for depreciation	(26930.30)	(30565.76)
4.2	Flight equipment after depreciation	85572.46	82202.60
5	**Ground property and equipment before depreciation**	58601.74	65888.44
5.1	Less: Reserve for depreciation	(15008.92)	(20627.23)
5.2	Ground property and equipment after depreciation	43592.82	45261.21
6	**Land**	0.00	0.00
7	**Investments in affiliated companies.**	592.20	586.56
8	**Deferred charges (total)**	0.00	0.00
8.1	Development and pre-operating costs	0.00	0.00
8.2	Other deferred charges	0.00	0.00
9	**Intangible assets**	0.00	0.00
10	**Other assets**	0.00	0.00
11	**TOTAL ASSETS**	**250378.90**	**253390.70**

LIABILITIES (thousands of U.S. Dollars)		1991	1992
12	**Current liabilities (other than reported in item 13)**	0.00	115081.60
13	**Unearned transportation revenues**	108626.20	0.00
14	**Deferred credits**	0.00	0.00
15	**Operating reserves**	0.00	0.00
16	**Self-insurance reserves**	0.00	0.00
17	**Other reserves**	456.89	132.28
18	**Advances from affiliated companies**	0.00	0.00
19	**Other liabilities**	6136.42	7068.37
20	**Long term debt**	109028.60	104022.10
21	**Capital stock**	8926.98	8841.98
22	**Capital surplus**	0.00	0.00
23	**Net balance of unappropriated retained earnings**	17203.76	18244.42
24	**TOTAL LIABILITIES**	**250378.90**	**253390.70**

Income Statement

REVENUES (thousands of U.S. Dollars)		1991	1992
1	**Scheduled services (total)**	413877.90	463746.40
1.1	Passenger	410150.70	459563.90
1.2	Excess baggage	0.00	0.00
1.3	Freight, express and diplomatic bags	2795.83	2678.70
1.4	Mail	931.36	1503.83
2	**Non-scheduled flights (total)**	56162.64	79456.02
2.1	Passenger and excess baggage	56162.64	79456.02
2.2	Freight (including express and diplomatic bags) and mail	0.00	0.00
3	**Incidental revenues (total)**	22219.04	27815.70
3.1	Air transportation activities (gross)	22219.04	27815.70
3.2	Other incidental revenues (net)	0.00	0.00
4	**TOTAL OPERATING REVENUES**	492259.50	571018.10

EXPENSES (thousands of U.S. Dollars)			
5	**Flight operations (total)**	121025.60	142618.80
5.1	Flight crew salaries and expenses	22602.12	27862.69
5.2	Aircraft fuel and oil	41459.48	46030.53
5.3	Flight equipment insurance and uninsured losses	1985.73	2401.96
5.4	Rental of flight equipment	52700.80	61336.91
5.5	Flight crew training (when not amortized)	1151.02	3000.71
5.6	Other flight expenses	1126.42	1985.97
6	**Maintenance and overhaul**	36533.83	47825.04
7	**Depreciation and amortization (total)**	15328.74	16747.55
7.1	Normal depreciation of flight equipment	10141.26	9774.92
7.2	Normal depreciation of ground property and equipment	5124.23	5790.80
7.3	Extra depreciation (in excess of cost)	0.00	0.00
7.4	Amortization of development and pre-operating costs	63.26	1181.83
7.5	Flight crew training (when amortized)	0.00	0.00
8	**User charges and station expenses (total)**	151031.10	180508.80
8.1	Landing and associated airport charges	92039.24	102911.60
8.2	Route facility charges	28513.61	36523.66
8.3	Station expenses	30478.25	41073.45
9	**Passenger services**	66704.55	82037.25

10	**Ticketing, sales and promotion**	54266.53	63300.25
11	**General and administrative**	27636.73	25378.93
12	**Other operating expenses**	5078.54	4567.20
13	**TOTAL OPERATING EXPENSES**	477605.60	562983.70
14	**OPERATING RESULT**	**14653.95**	**8034.37**

NON-OPERATING ITEMS (thousands of U.S. Dollars)

15	**Retirement of property and equipment**	1172.11	2913.68
16	**Interest**	(11225.50)	(9498.17)
17	**Payments from public funds not allocated elsewhere (total)**	0.00	0.00
17.1	Direct subsidies	0.00	0.00
17.2	Other payments	0.00	0.00
18	**Affiliated companies**	0.00	0.00
19	**Other non-operating items**	(93.14)	0
20	**NON - OPERATING ITEMS (balance)**	(10146.53)	(6584.49)

NET PROFIT OR LOSS (thousands of U.S. Dollars)

21	PROFIT OR LOSS BEFORE INCOME TAXES	4507.42	1449.88
22	**Income taxes**	(1412.85)	(565.68)
23	**PROFIT OR LOSS AFTER INCOME TAXES**	**3094.57**	**884.20**

Appendix V

Model SR1 EBIT

With annual change in EBIT as the dependant variable:

Annual Change	Independent Variable	Dependant Variable	Beta 1	Beta 2	R Square
91-92	MTFP index	Change, EBIT	2.705 (9.017)	-2.139 (9.093)	0.002 (5.269)
91-92	Efficiency Change	Change, EBIT	-0.561 (9.075)	1.102 (8.607)	0.001 (5.273)
91-92	Technological Change	Change, EBIT	9.715 (15.315)	-9.681 (16.226)	0.012 (5.242)
92-93	MTFP index	Change, EBIT	-1.147 (1.961)	0.402 (1.824)	0.002 (1.798)
92-93	Efficiency Change	Change, EBIT	-0.161 (2.568)	-0.564 (2.574)	0.002 (1.798)
92-93	Technological Change	Change, EBIT	-3.365 (3.615)	2.468 (3.360)	0.017 (1.784)
93-94	MTFP index	Change, EBIT	10.013 (12.817)	-10.722 (11.918)	0.024 (9.744)
93-94	Efficiency Change	Change, EBIT	4.241 (13.882)	-5.713 (13.903)	0.005 (9.837)
93-94	Technological Change	Change, EBIT	25.274 (26.424)	-24.801 (24.501)	0.030 (9.713)
94-95	MTFP index	Change, EBIT	1.517 (5.502)	-0.930 (5.100)	0.001 (5.963)
94-95	Efficiency Change	Change, EBIT	0.544 (6.522)	-0.012 (5.977)	0.000 (5.966)
94-95	Technological Change	Change, EBIT	5.765 (14.761)	-5.324 (14.982)	0.004 (5.954)
95-96	MTFP index	Change, EBIT	0.770 (2.999)	-0.893 (2.843)	0.003 (1.300)
95-96	Efficiency Change	Change, EBIT	2.918 (3.221)	-3.139 (3.268)	0.028 (1.281)
95-96	Technological Change	Change, EBIT	-3.990 (4.683)	3.570 (4.370)	0.020 (1.286)
96-97	MTFP index	Change, EBIT	18.3729 (41.970)	-17.649 (41.812)	0.006 (13.662)
96-97	Efficiency Change	Change, EBIT	60.925 (41.166)	-58.042 (39.601)	0.067 (13.237)

96-97	Technological Change	Change, EBIT	-66.774 (54.869)	69.801 (56.720)	0.048 (13.370)
97-98	MTFP index	Change, EBIT	2.386 (7.269)	-2.263 (7.540)	0.004 (7.215)
97-98	Efficiency Change	Change, EBIT	7.610 (14.411)	-7.537 (14.677)	0.010 (7.190)
97-98	Technological Change	Change, EBIT	1.409 (14.462)	-1.209 (14.941)	0.001 (7.227)
98-99	MTFP index	Change, EBIT	-0.750 (3.453)	1.344 (3.253)	0.008 (3.477)
98-99	Efficiency Change	Change, EBIT	-1.268 (3.365)	1.931 (3.319)	0.015 (3.464)
98-99	Technological Change	Change, EBIT	4.069 (9.013)	-3.253 (8.537)	0.007 (3.479)

Model SR1Expenditures

With annual change in Expenditures as the dependant variable:

Annual Change	**Independent Variable**	**Dependant Variable**	**Beta 1**	**Beta 2**	**R Square**
91-92	Efficiency Change	Change, Exp.	0.365 (0.298)	-0.240 (0.283)	0.024 (0.173)
91-92	Technological Change	Change, Exp.	0.181 (0.512)	-0.072 (0.542)	0.001 (0.175)
91-92	MTFP index	Change, Exp.	0.391 (0.295)	-0.282 (0.298)	0.030 (0.173)
92-93	Efficiency Change	Change, Exp.	-0.004 (0.198)	-0.014 (0.198)	0.001 (0.138)
92-93	Technological Change	Change, Exp.	0.261 (0.276)	-0.26 (0.256)	0.031 (0.136)
92-93	MTFP index	Change, Exp.	0.087 (0.150)	-0.099 (0.139)	0.016 (0.137)
93-94	Efficiency Change	Change, Exp.	0.245 (0.170)	-0.205 (0.170)	0.042 (0.120)
93-94	Technological Change	Change, Exp.	0.314 (0.331)	-0.253 (0.307)	0.020 (0.122)
93-94	MTFP index	Change, Exp.	0.275* (0.156)	-0.219 (0.146)	0.064 (0.119)

94-95	Efficiency Change	Change, Exp.	0.096 (0.12)	-0.04 (0.11)	0.003 (0.11)
94-95	Technological Change	Change, Exp.	0.231 (0.27)	-0.178 (0.274)	0.013 (0.109)
94-95	MTFP index	Change, Exp.	0.104 (-0.101)	-0.044 (0.094)	0.007 (0.109)
95-96	Efficiency Change	Change, Exp.	0.241 (0.203)	-0.173 (0.206)	0.022 (0.081)
95-96	Technological Change	Change, Exp.	0.098 (0.298)	-0.026 (0.278)	0.001 (0.081)
95-96	MTFP index	Change, Exp.	0.225 ((0.187)	-0.147 (0.177)	0.021 (0.081)
96-97	Efficiency Change	Change, Exp.	0.231 (0.265)	-0.190 (0.255)	0.018 (0.085)
96-97	Technological Change	Change, Exp.	0.771** (0.326)	-0.762** (0.337)	0.146** (0.079)
96-97	MTFP index	Change, Exp.	0.628** (0.241)	-0.593** (0.240)	0.169** (0.078)
97-98	Efficiency Change	Change, Exp.	1.021*** (0.3)	-1.038*** (0.306)	0.316*** (0.150)
97-98	Technological Change	Change, Exp.	0.782** (0.327)	-0.8** (0.338)	0.185** (0.163)
97-98	MTFP index	Change, Exp.	0.531*** (0.148)	-0.554*** (0.153)	0.344*** (0.147)
98-99	Efficiency Change	Change, Exp.	0.141* (0.082)	-0.074 (0.081)	0.038 (0.085)
98-99	Technological Change	Change, Exp.	-0.217 (0.221)	0.269 0.209	0.073 (0.084)
98-99	MTFP index	Change, Exp.	0.114 (0.086)	-0.045 (0.081)	0.015 (0.086)

Model SR1 CF

With annual change in Cash Flow as the dependant variable:

Annual Change	**Independent Variable**	**Dependant Variable**	**Beta 1**	**Beta 2**	**R Square**
92-93	Technological Change	Change, FCF	-26.112** (12.964)	22.982* (11.974)	0.113* (6.155)
92-93	MTFP index	Change, FCF	-15.836** (6.694)	13.605** (6.191)	0.143** (6.050)
92-93	Efficiency Change	Change, FCF	-13.017 (9.196)	11.827 (9.229)	0.054 (6.357)
93-94	Technological Change	Change, FCF	-1.290 (19.552)	-0.768 (18.140)	0.000 (7.178)
93-94	MTFP index	Change, FCF	-3.485 (9.441)	1.285 (8.785)	0.001 (7.176)
93-94	Efficiency Change	Change, FCF	-3.590 (10.126)	1.487 (10.142)	0.001 (7.176)
94-95	Technological Change	Change, FCF	-69.303** (29.316)	69.302** (29.756)	0.141** (11.827)
94-95	MTFP index	Change, FCF	-1.262 (11.775)	0.075 (10.915)	0.000 12.762
94-95	Efficiency Change	Change, FCF	11.49737 (13.771)	-11.761 (12.619)	0.026 (12.597)
95-96	Technological Change	Change, FCF	23.196 (46.115)	-24.515 (43.036)	0.010 (12.662)
95-96	MTFP index	Change, FCF	9.788 (29.333)	-12.200 (27.811)	0.006 (12.688)
95-96	Efficiency Change	Change, FCF	-0.784 (32.004)	-2.298 (32.471)	0.001 (12.725)
96-97	Technological Change	Change, FCF	-42.926 (81.139)	40.441 (83.876)	0.008 (19.770)
96-97	MTFP index	Change, FCF	-5.508 (60.969)	1.664 (60.739)	0.000 (19.846)
96-97	Efficiency Change	Change, FCF	17.335 (61.601)	-20.403 (59.259)	0.004 (19.808)
97-98	Technological Change	Change, FCF	5.068 (5.426)	-5.896 (5.605)	0.042 (2.712)
97-98	MTFP index	Change, FCF	0.813 (2.777)	-1.508 (2.880)	0.011 (2.756)

97-98	Efficiency Change	Change, FCF	-1.381 (5.551)	0.785 (5.654)	0.001 (2.770)
98-99	Technological Change	Change, FCF	53.945* (27.684)	-51.194* (26.221)	0.148* (10.687)
98-99	MTFP index	Change, FCF	-1.767 (11.487)	1.761 (10.823)	0.001 11.569
98-99	Efficiency Change	Change, FCF	-9.887 (11.033)	10.038 (10.883)	0.037 (11.358)

Appendix VI

Tests on Regression Assumptions

Testing Assumption R3 (Homoskedasticity)

There are two ways to detect heteroskedasticity. The first one is to analyse the residual plots. Another one is to utilize Goldfeld-Quandt test. The *Goldfeld-Quandt test* is used in the present study. According to Hill et al (2001), it involves the following steps:

1. Split the sample into two approximately equal sub-samples. If heteroskedasticity exists, some observations will have large variances and others will have small variances. Divide the sample such that the observations with potentially high variances are in one sub-sample and those with potentially low variances are in the other sub-sample.

2. Compute estimated error variances $\hat{\sigma}_1^2$ and $\hat{\sigma}_2^2$ for each of the sub-samples. Let $\hat{\sigma}_1^2$ be the estimate from the sub-sample with potentially large variances and let $\hat{\sigma}_2^2$ be the estimate from the sub-sample with potentially small variances. If the null hypothesis of equal variances is not true, we expect $\hat{\sigma}_1^2 / \hat{\sigma}_2^2$ to be large.

3. Compute $GQ = \hat{\sigma}_1^2 / \hat{\sigma}_2^2$ and reject the null hypothesis of equal variances if $GQ > F_C$, where F_C is a critical value from the F-distribution with (T_1-K) and (T_2-K) degrees of freedom. The values T_1 and T_2 are the numbers of observations in each of the sub-samples; if the sample is split exactly in half, $T_1 = T_2 = T/2$.

Testing Assumption R4 (Autocorrelation)

The Durbin-Watson test is used in order to investigate the *autocorrelation* in the model. Let us assume the errors of the linear regression model to be represented by the following:

$$e_t = \rho e_{t-1} + v_t,$$

where v_t are independent random errors, normally distributed $\sim N(0, \sigma_v^2)$. If $\rho=0$, then $e_{t-1} = v_t$ and there is no autocorrelation between errors in the model. Hence, the null hypothesis of no autocorrelation is H_0: $\rho=0$ against the alternative H_1: $\rho>0$. Durbin-Watson test is based on the statistic *d*, which is calculated by the following:

$$d = \frac{\sum_{t=2}^{T} (\hat{e}_t - \hat{e}_{t-1})^2}{\sum_{t=1}^{T} \hat{e}_t^2}$$

The *d* statistic is expressed as $d \approx 2(1-\hat{\rho})$. Thus, if $\rho=0$ then $d\approx2$, which shows absence of autocorrelation. On the other hand, if $\rho=1$ then $d\approx0$, and this indicates the autocorrelation between errors. This test is however not precise enough to determine where in the interval between 0 and 2 the d statistic should be to conclude about no autocorrelation. This problem can be solved using either the critical value of d distribution, or the *bounds test*. The Durbin-Watson bounds test offers next rule for decision-making:

- If $d < dL_c$, hence, reject H_0 and accept H_1
- If $d > dU_c$, do not reject H_0
- If $dL_c < d < dU_c$, the test is inconclusive

Values of dL_c and dU_c can be obtained from the statistical tables for the chosen level of significance[44].

[44] The description of the test is from Hill et al,(2001)

Testing Assumption R5 (Collinearity)

The *collinearity* of the multiple regression model is tested with the help of correlation analysis. If the correlation coefficient between two independent variables is larger than *0.8* or *0.9* in absolute value, then there is a strong linear relationship between the variables. Thus, this indicates collinearity between variables, and the assumption of regression does not hold.

Appendix VII

Correlation Matrices

1. Correlation Matrice of regression model with Expenditures

	Exp	TE	Tech. Change	Effic. Change
Exp.	1			
TE	0.043	1		
Tech. Change	0.019	0.067	1	
Effic. Change	-0.028	-0.392	-0.160	1

2. Correlation Matrice of regression model with EBIT

	EBIT	TE	Tech. Change	Effic. Change
EBIT	1			
TE	-0.051	1		
Tech. Change	0.005	0.067	1	
Effic. Change	-0.029	-0.392	-0.160	1

3. Correlation Matrice of regression model with CF

	CF	TE	Tech. Change	Effic. Change
CF	1			
TE	0.028	1		
Tech. Change	0.210	0.067	1	
Effic. Change	-0.027	-0.392	-0.160	1