Master's degree thesis

LOG950 Logistics

Application of Data Envelopment Analysis and Malmquist Productivity Index in the Norwegian passenger car market: Implications for efficiency, productivity and product variety

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DEDICATION

This work is dedicated to the memory of my loving father George Pereira and also to my dear husband Odd Bjørn Kvadsheim and my little angel Kayla – Nina Pereira Kvadsheim.

I dedicate this work to my family and many friends – Cedric Kasongo Wasamba.

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Molde, 29.05.2014

Nina Pereira Kvadsheim

Cedric Kasongo Wasamba

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ABC	Activity Based Costing
AE	Allocative Efficiency
AFC	Average Fixed Cost
ATC	Average Total Cost
AVC	Average Variable Cost
B2B	Business to Business
CES	Constant Elasticity of Substitution
COLS	Corrected Ordinary Lease Squares
CPI	Consumer Price Index
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DFM	Deterministic Frontier Model
DMU	Decision Making Unit
DRS	Decreasing Returns to Scale
EE	Economic Efficiency
FDH	Free Disposal Hull
FS	Frontier Shift
GDP	Gross Domestic Product
IRS	Increasing Returns to Scale
JIT	Just in Time
LDV	Limited Dependent Variable
MC	Marginal Cost
MR	Marginal Revenue
MPI	Malmquist Productivity Index
NIRS	Non-Increasing Returns to Scale
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturers
OFV	Opplysningsrådet for Veitrafikken AS
PPF	Production Possibility Frontier
QC	Quality Control
SE	Scale of Efficiency
SFA	Stochastic Frontier Analysis
SPSS	Statistical Package for Social Sciences
SSB	Statistisk Sentral Byrå
SW	Sum of Weights
TE	Technical Efficiency
TEC	Technical Efficiency Change
TFP	Total Factor Productivity
TPS	Toyota Production System
VRS	Variable Returns to Scale
WIP	Work in Process

ABSTRACT

Purpose – The purpose of this study is to make a contribution to the literature on efficiency and productivity of the Norwegian passenger car market. The study seeks to elucidate how the relative efficiency of Norwegian passenger car market can be assessed and how the changes in productivity of this market by time can be observed. The study will further expound on describing the impact of product variety on efficiency and productivity of Norwegian car market.

Design/methodology/approach – In measuring the relative efficiency and productivity of the Norwegian passenger car market for the years 2008 to 2012, this study integrated Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI). Truncated regression analysis was also performed in assessing the impact of product variety on efficiency and productivity of this aforesaid market.

Findings – The empirical findings show that on overall, the Norwegian passenger car market is significantly inefficient by 40% and 65% under variable return to scale and constant return to scale assumptions, respectively. However, using the Malmquist Productivity Index between the periods 2008 to 2012, it is observed that this market has progressed in productivity by 38%, where 62% of the car brands show an increase in their average annual productivity. Nonetheless, there seem to be conflicting results on the truncated regression analysis where product variety was regressed on the efficiency and productivity scores. The efficiency results indicate a positive impact of product variety on efficiency while a negative impact is seen on the productivity scores.

Limitation of the study – A major limitation of the study was to collect data for the exact selling prices of each selected brand. The other one is time dimension used for this study which covered only five years for the simple reason that data for some car brands were unavailable that could have covered ten years for a thorough analysis of the market even though the study makes interesting findings regarding efficiency and productivity.

Managerial implication – In such a highly centralised market, the ability to utilise the resources effectively in order to maximise the output may lead to efficiency and productivity gains. However, the key lies in identifying the sources of inefficiency which usually bears a great policy implication that enhances development of optimal set policies.

Key words – Efficiency, productivity, product variety, Norwegian passenger car market.

CHAPTER 1

INTRODUCTION

1.1. Introduction

The concepts of productivity and efficiency have been gaining increasing attention in different sectors. Much has been written on the subject of performance measurement; and regrettably there has been confusion in the use of the terms: efficiency and productivity. The reason is that these terms seem to be overlapping, but they have slightly different meanings. Efficiency is a measure of a firm's performance. It can also be defined as the firm's ability to attain an amount of quantity (output) with a minimum level of resources, and this can be achieved for instance when a firm employs the right people and machine to do the job right. On the flip side, Haksever (2000) refers the productivity of a unit inimitable as it is the ratio of its output to input that is used to produce that output. This ratio, as put by Barros and Mascarenhas (2005), yields a relative measurement of performance that may be applied to any factor of production. The ratio can be calculated for a single input and output or by combining multiple inputs and outputs.

Today, as ever, improving productivity can have connotations of economizing on the use of inputs, and yielding more output. In general, productivity growth is influenced by a range of factors, which according to most studies there is no simple way to boost it (Englander and Gurney, 1994). Many have claimed that the degree of competition in the market is the main determinant of the overall productivity, given that a lack of competition in the market reduces the pressure on firms to incorporate better technology, remove organizational slack and improve performance. In addition to this, the increased global competition with a stronger focus on price, diversified consumer aggregate patterns of behaviour, and accelerated modification and diversification of the product portfolio are pressing challenges for many firms today. As trade barriers fall because of the bilateral trade agreement, transaction costs decline, and new global competitors are entering previously more protected domestic markets. This intensified competitive pressure has forced many companies to enhance performance by innovating and adopting process, and product improvements. This transformation may lead to lower costs, higher productivity, which, in turn, can create sustainable competitive advantages for companies, as well as capturing a greater market share in a given market.

In recent years, product variety has gained popularity in many markets particularly car market. Numerous firms have witnessed a slew of new product introductions that is driven by increasingly distinct consumer tastes as well as by the stipulation to differentiate from competition on dimensions other than price. As stated by Terwiesch and Ulrich (2009), product variety promotes new product introduction, and has also become a top priority for many car markets. Though, the link between productivity, efficiency and product variety still remains a debatable issue in numerous studies as regards the costs and benefits gained from offering a high degree of product variety in automotive market. Some argue that there is less productivity and inefficiency in the overall market especially where product variety is high as it implies that the market is producing an amount of output that is not optimal. As a result of the poor performance attained by individual firms, the overall market performance is also affected. An efficient market is considered when a majority of the firms competing in a particular market make the best possible use of available inputs. On the contrary, an inefficient market requires firms to improve their output without altering the level of resources used in producing those services or that an equal performance could be realized while consuming fewer input, provided that more efficiency is guaranteed. According to Dhingra and Morrow (2012), when a market is uneven as regards productivity; the distribution of resources across firms also affects the allocation efficiency of markets. For this reason, it may be assumed that productivity, efficiency, and product variety are indispensable to each other. In other words, the effectiveness of product variety strongly depends on these two elements.

Given Norway's car dealers' ambition in becoming more profitable in selling different models of cars, the importance of an efficiently functioning car market may be greater than ever. Thus, understanding the Norwegian passenger car market mechanism is substantial as it plays a key role through its impact on the decision-making environment. Moreover, the extent and characteristics of competition in the market affect the choice behaviour among the actors (Yadev, 1995 and Baumol, 1961). The Norwegian car market structure can be characterised as Monopolistic competition. This implies that each firm (car dealer) makes independent decisions about price and output, based on its product, its market, and its cost of production. Similarly, the initial investment to enter or cost to exit the market for the new entrant is relatively low. Put simply, there is freedom to enter or leave the market as barrier to entry or exit is very low. A central feature of monopolistic competition is that firms differentiate their products. Differentiation takes place in many forms. For example, differentiation can be in the form of human capital, where the firm creates differences through the skill of its employees and the level of training received. Furthermore, a firm can differentiate its product based on physical alternation for instance design its product differently than competitors. By doing so, firms create the perception that there is no close substitute product available on the market that matches their product.

Based on the aforesaid market characteristics, this paper will therefore analyse whether the performance of the present Norwegian car market has indeed been enhanced and how the changes in this performance of this market can be observed. Further, this study tends to contribute to the efficiency and productivity literature from dealership perspective relative to manufacturing perspective as is the case with most studies (see for e.g. Karaduman, 2006; Chen, 2011; Elahi et al., 2013; Alex and Chich-Jen, 2013, among others).

1.2. Background of the Study

Consider the automotive market, which in the early days followed Henry Ford’s philosophy. This philosophy put more emphasis on capturing market share and high profits by manufacturing large volumes of standardized products. It seemed a perfect system, providing that there were customers waiting at the end of the line ready to purchase. Put differently, automakers decided which vehicle to supply in the market, and customer’s involvement was limited. However in today’s car market, customers have the freedom to select combinations of engines, horsepower, chassis, fuel types, and numerous other options. As a matter of fact, the number of new vehicles introduced by the automakers into the market, measured by number of models sold or produced, has significantly increased (Van Biesebroeck, 2007). Only in Europe for example, one of the world’s largest markets, the total number of car models between 1990 and 2003 increased from 187 to 315 models (Midler, 2005).

Over the past two decades, the growth of passenger vehicle market has shown signs of slowing down in several developed countries, and in some, growth has stopped or turned negative (Van Dender and Clever, 2013). In contrast, the Norwegian passenger car market has shown slight growth as compared to the rest of Europe. According to Egil Steinsland, communications manager in Norway Automotive Association, the Norwegian passenger vehicle market has been steadily increasing over the past few years, and expects the market growth to level off somewhat in the coming years (Norwaytoday, 2013). In fact, the

International Road Federation[1] reported that the Norwegian passenger car market per 1,000 inhabitants has been experiencing a growth trend in spite of the fact that this growth is at a slower pace. According to the statistical result depicted in Figure 1.1[2] below, the market has been flourishing at a fast rate during the period between 2003 and 2007, but slackened after 2007.

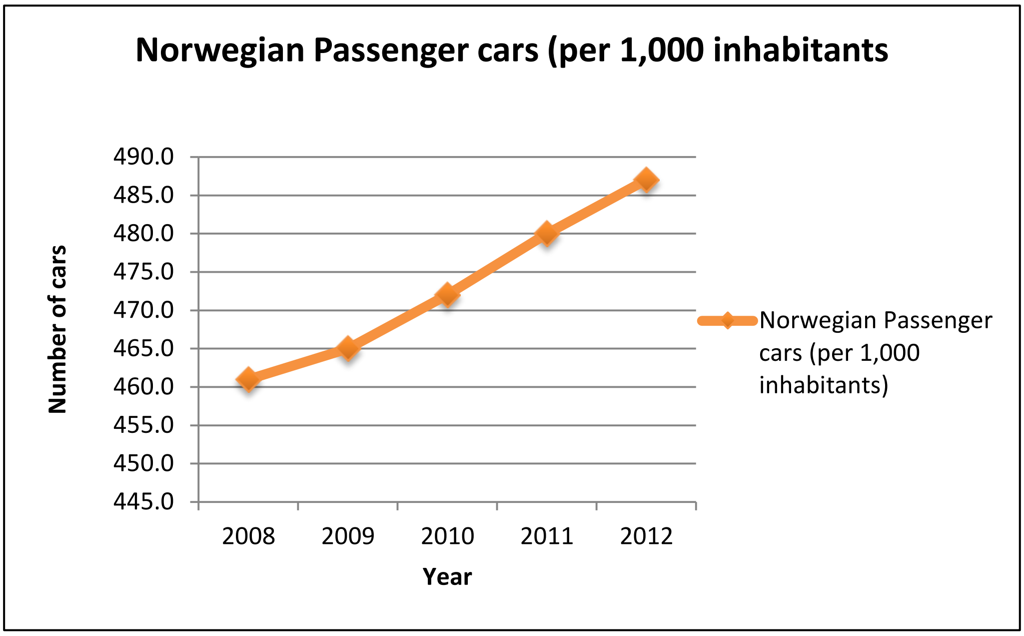

Figure 1.1: Norwegian passenger cars per 1,000 inhabitants. Source: own

Furthermore, when looking at the sales results of the Norwegian passenger car market of the last five years as depicted in Table 1.1, one can typify this market of being at its maturity stage. Generally, at maturity stage the market is characterised for being most profitable, and there is a high expectation of increase in sales at this stage, but it does so at a slower pace. Nevertheless, it should be noted that the data used in Table 1.1 originates from Opplysningsrådet for Veitrafikken AS, and that the calculation as seen in Table 1.1 was computed based on the study’s objective.

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[1] The International Road Federation is a non-governmental organization that promotes development and maintenance of roads.

[2] Data used in this graph was derived from International Road Federation, and out of that we plotted our own graph.

Month	Year								
	2008		2009	% Change	2010	% Change	2011	% Change	2012
January	9901	-45.9	5353	81.2	9697	7.0	10372	4.5	10838
February	10567	-40.5	6287	44.6	9094	15.9	10543	3.6	10925
March	9506	-20,0	7601	51.1	11486	12.3	12901	1.2	13051
April	11704	-35,9	7504	42.3	10677	6.1	11330	-4.0	10876
May	10217	-27,4	7421	33.4	9896	31.4	13005	-3.0	12612
June	9670	-21,6	7581	46.7	11119	-6.9	10354	6.8	11053
July	9605	-2,2	9394	22.5	11507	-2.8	11189	6.5	11920
August	7833	1.7	7967	30.7	10414	10.1	11464	2.8	11790
September	8453	12.7	9530	16.9	11137	5.4	11737	-5.1	11134
October	8390	21.4	10187	4.9	10683	8.1	11543	7.5	12413
November	6952	38.1	9600	24.0	11908	3.8	12357	-3.0	11986
December	7819	31.1	10250	-1.1	10136	14.0	11550	-18.9	9369
Total	110617		98675		127754		138 345		137 967
Annual % Change		-10.8		29.5		8.3		-0.3	

Table 1. 1: Passenger car sales in Norway's car passenger market. Source: own illustration

Reflecting these assumptions to the sale results found in Table 1.1 of the Norwegian passenger car market, it is apparent that there is indeed a growth in sales in this market, however, this growth has been at a slower pace. For example, between the periods of 2009 and 2010 there has been a significant growth of 29. 5 percent, while between 2011 and 2012 sales have dropped to negative 3 percent.

For the most part, Norwegian passenger car market has been attractive for many car companies for the past few years owing to the fact that number of car brands entering the market is constantly increasing. And yet, the market share is not equally shared among car manufacturers as some have held a dominant position in this market for many years. For example, it has been reported that in 2013 Volkswagen Group[3] has held the leading position in the Norwegian passenger car market for the past eight years (MøllerGruppen, 2013). A possible explanation for this dominant position is that the existence of joint ventures formed by big car manufacturers such as Volkswagen, Audi, and Skoda has allowed them to take advantage of the economy of scope by offering higher variety[4] to many segments in the

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[3] Volkswagen Group is an automotive alliance consists of Volkswagen, Audi, Skoda, and among others

[4] Volkswagen Group offered in 2013 35 car models in the Norwegian passenger car market

market. De facto, the driving forces behind this practice are observable at the car dealership level. Larger car dealers with a strong financial position are often franchised by multiple or single automaker[5], and open many workshops in all parts of the country in order to cater for various segments with different models of cars. For instance, Bertel O. Steen[6] with its subsidiaries owns numerous workshops in all parts of the country that specialise either in a single brand (e.g. Mercedes-Benz) or multiple car brands (Mercedes-Benz, Smart, among others). This being the case, the company has been able to hold the leading position as it has been reported that in 2003 they captured about 11.5 percent market share in the Norwegian passenger car market (Bos, 2014).

Because the aforementioned strategy is considered as one of the key elements to survive in the market, car manufacturers/dealers have also made great effort to increase their variety in terms of models so that they can maintain or increase their market share. In fact, the above statement becomes clear when we look at Figure 1.2 and 1.3 below on the number of passenger cars per 1,000 inhabitants per county in 2012 and new passenger car registration[7] in Norway, respectively.

Figure 1.2 shows the number of passenger cars owned by private people per 1,000 inhabitants per county[8]. From Figure 1.1 above, one clearly see that on average the number of vehicles among inhabitants in Norway were significantly high.

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[5] Franchised car dealers are recognized by the automaker and follow that company's operational policies

[6] One of the largest car dealerships in Norway distributing the group's car makes for instance Mercedes-Benz, Peugeot, Smart and Kia.

[7] New passenger car registration in this study refers to number of sales.

[8] Data used in Figure 1.2 was derived from Statistics Norway and based on this we plotted a graph.

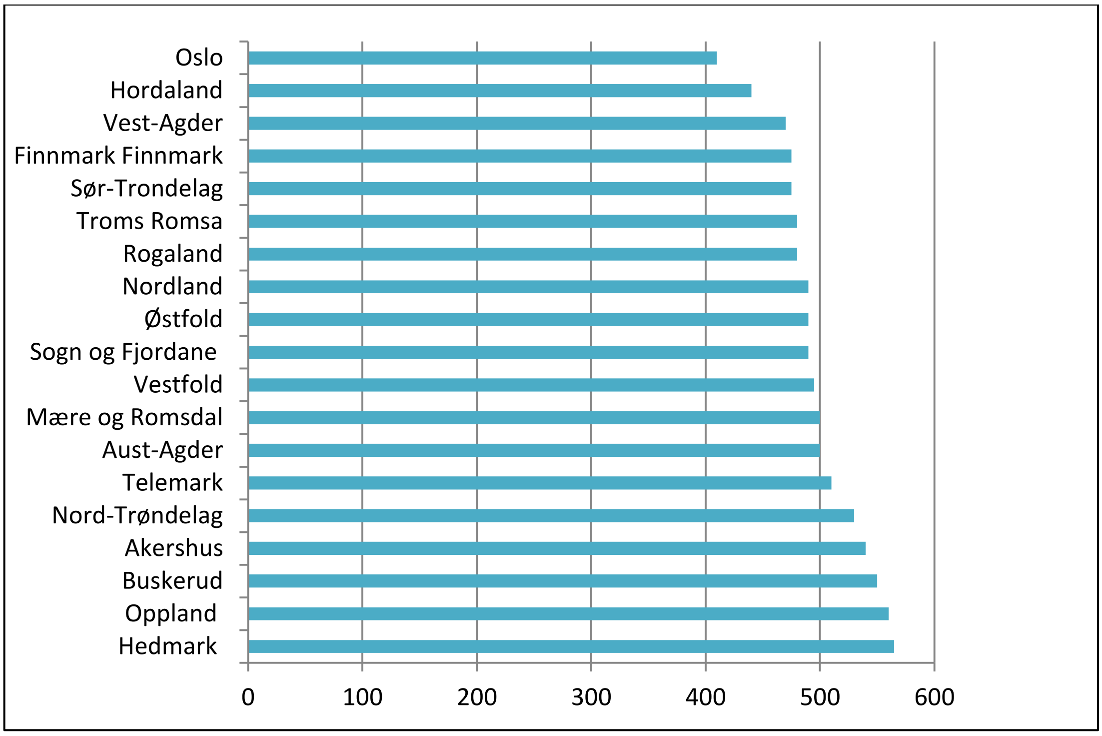

Figure 1. 2: Number of passenger cars per 1,000 inhabitants per county 31 December 2012. Source: Statistics Norway (2014)

Similarly, Figure 1.3 below also indicates that the number of new passenger car registration has been following an upward trend over the past four years and the data used in the graph were collected from the European Central Bank. Based on this we plot a graph to illustrate the trend clearly. Referring to the results found in Figure 1.3, we could hypothetically assume that higher variety is the core source of this high number.

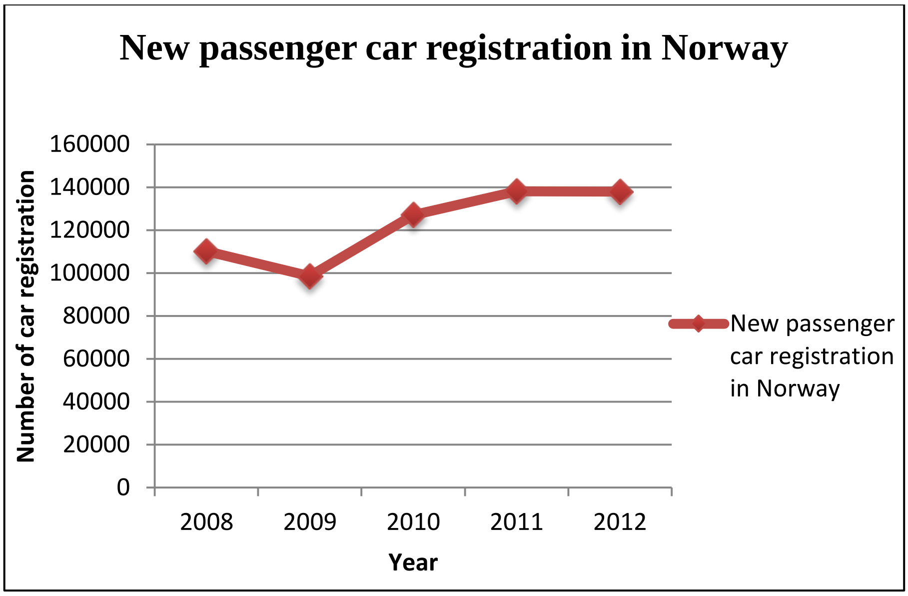

Figure 1. 3: New passenger car registration in Norway. Source: European Central Bank (2014)

These high sales in the Norwegian passenger car market are not just justified by the aforesaid reasons, there are also technological, political, and economic factors associated with them. The Norwegian government has put forward various types of incentives in order to stimulate car manufacturers for environmentally friendly technologies or practices in their vehicles, which in turn has also affected the Norwegian car market. These incentives have not only served for green technology but it has also re-boosted sales, which was shrinking. For example, in 2009 the Norwegian government established a committee named Transnova, and operated as a trial funding program supporting projects making a fast contribution to the adoption of new and greener technology (Odyssee-mure, 2012). As a result of this, great technology development has been done by the car manufacturers on Electric Vehicles (EVs), which has been acclaimed as the most exciting technical breakthrough in the Norwegian passenger car market and re-boosted sales. As of March 2014, a total of 25,710 electric passenger vehicles have been sold, and this has resulted in Norway being home to the largest per capita electric vehicle market in the world (TØI, 2013).

Other forms of incentives, such as exemption from vehicles taxes (registration tax, value added tax), all public parking fees, toll payments, and reductions in the annual road tax on electric vehicles, are also considered as one of the reasons for increasing sales. Indeed, these incentives have paid off for the Norwegian passenger car market as more models of electric vehicles from different car brands are expected to incline for the coming years.

The high standard of living, economic stability, and the low inflation rate in Norway have also played an important role in the Norwegian passenger car market. For example, over the last 32 years the GDP growth per capita in Norway has been positive, and relatively much higher as compared to other European countries (see Figure 1.4). Furthermore, low inflation means lower nominal and real (inflation-adjusted) interest rates. Low real interest rates reduce the cost of borrowing, which in turn stimulate households to buy durable goods such as cars (IMF, 2014). As a result, Norwegian consumers are able to choose among car brands that match their taste, and this has resulted to an increase in product variety in the market given that each segment has different preference.

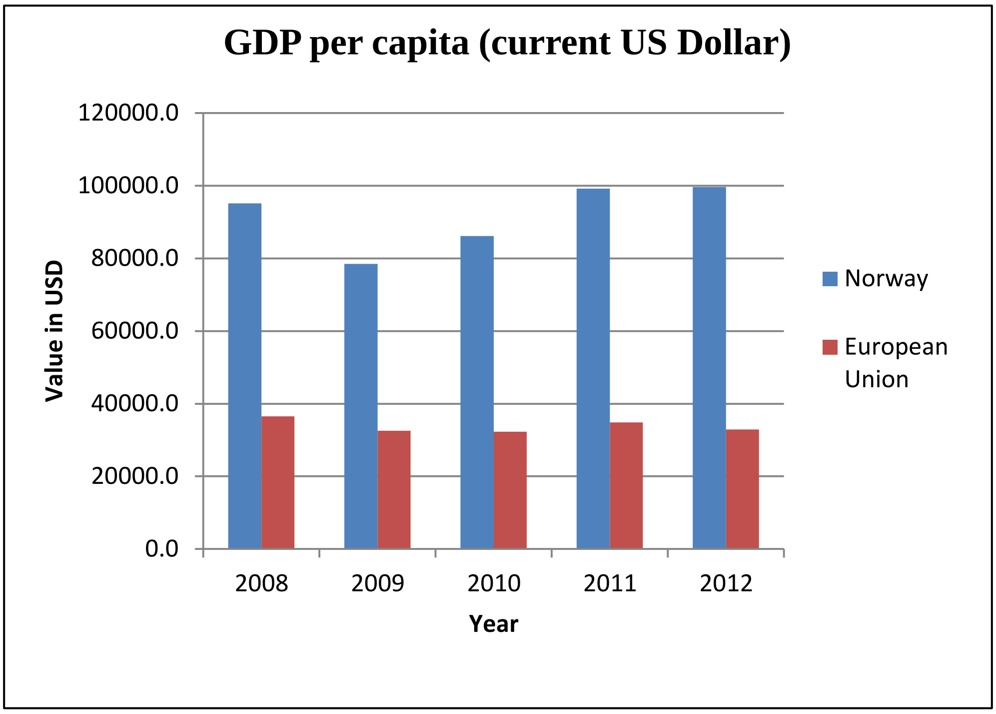

Figure 1. 4: GDP per capita $ in Norway and EU countries. Source: World Bank, International Comparison Program database (2014)

1.3. Research problem

This study is concerned with an in-depth evaluation of relative efficiency and productivity of car market sector, which is further explored by the impact of product variety. The context of this study is Norway, which according to our knowledge; no study has so far assessed the efficiency and productivity of its car market as well as integrating it with product variety in order to assess the impact between them. Efficiency and productivity of Norwegian car market is being investigated in this study for the simple reason that, although Norway is a country that has extremely rich natural resources such as oil and natural gas, and has experienced strong economic growth ever since the discovery of such resources (Bjørke, 2013), prospects for manufacturing its own cars still remains a mystery. Actually, Bjørke (2013) argued that the country might be heading for a situation where the manufacturing sector as a whole will decline due to the country’s dependence on resource exploitation. This therefore rationalises the car dealership perspective taken by this study as opposed to the manufacturing perspective.

However, the history of Norwegian car market may indicate that there is considerable potential to improve the performance of this sector. Thus, Norway is one of the very few western European countries where the passenger car market is still heavily protected by the government. The Norwegian tax system for cars is something that deserves some more comments and reflections. Cars in Norway have always been expensive compared to other European countries. For instance, cars in Norway usually cost twice of what they cost relative to other countries (Deutsche Welle, 2013). As reported by Hannisdahl et al. (2013), regular cars are taxed according to their weights, CO2 emissions and motor effect-as well as NOx emissions (effective from 1 January 2012). On top of this, cars are taxed with 25% VAT. Because of higher tax rates imposed on imported cars, many investors (dealers) are discouraged as they consider the Norwegian passenger car market being inefficient and unprofitable.

Thus, in view of the issues discussed, this present study is undertaken to seek answers to the following questions:

1. Has the Norwegian passenger car market been efficient between the years 2008 to 2012?
2. How Norwegian car market’s efficiency has evolved between 2008 and 2012?
3. What is the impact of product variety on efficiency and productivity of this aforesaid market?

1.4. Justification of the study

This study is envisioned to deepen our understanding on measurement of efficiency and productivity of Norwegian passenger car market. It is also intended to explicate the impact product variety has on the efficiency and productivity of this market. Principally, there have been a number of valuable studies linked to efficiency and productivity of automotive industry, for comprehensive analyses see Karaduman, 2006; Chen, 2011; Elahi et al., 2013; Alex and Chich-Jen, 2013, among others, all of which present efficiency and productivity from manufacturing perspective. Nonetheless, there is lack of empirical research from the car dealership perspective, taking into consideration such countries that do not manufacture cars like Norway, just to mention a few. As such, we only have a limited understanding if there is high efficiency and/or productivity gain in the car market particularly where merely importation of cars happens.

Similarly, most of the studies on product variety in automotive industry have mainly focused on the link between product variety and manufacturing complexity, automotive assembly operations, and in supply networks, none of which has been integrated with efficiency and productivity (see for e.g. Lancaster (1990); MacDuffie et al., (1996); Randall and Ulrich (2001); Pil and Holweg (2004). Hence, this study will make a substantial contribution in the literature as it allows gaining a better understanding on the importance of integrating efficiency, productivity and product variety. It also furnishes a baseline of comparison for future research on efficiency, productivity and product variety within the Norwegian passenger car market.

It is also worth-mentioning that as far as we know, this study is the first to integrate product variety and non-parametric approach 'Data Envelopment Analysis' (DEA) in light of car market. The car dealer may get big turnover but that doesn't imply it is efficient in utilising its resources. This is why DEA is used in this study to measure the relative efficiency of decision making units (DMUs) with respect to others. This way, efficient and inefficient DMUs (car brands) can be detected, hence helping decision makers to see how the inefficient ones may be improved. However, DEA does not allow measurement of the efficiency changes over time but only for a specific time (Karaduman, 2006). Hence, Malmquist Productivity Index (MPI) has been used to measure changes in efficiencies of the car market.

Hence, the results of this study may be useful for car managers, policy makers and academicians. Put simply, for car managers and policy makers, this study provides more insights on the fundamental factors that may explain the inefficiency of the car market as a whole. By doing this, distinct tactics, methods and strategies geared at reforming and refurbishing the car sector might be put in place. However, the key lies in the management being able to effectively implement such strategies. On the other hand, the policy makers will be aware of the factors that improve efficiency and productivity of the car market. This may be used as benchmarks for other car brands that are unable to utilise their resources and maximise their outputs.

Theoretically, the study owes its unique and significant attributes on many counts because it represents, as far as literature is concerned, a new approach of the efficiency and productivity within the car market. Thus, the integration of the key dimensions of product differentiation theory and production theory make it an ideal theoretical framework for the study of efficiency, productivity and product variety in a car market.

1.5. Scope of the study

This study covers car dealerships which sell cars of different brands across Norway. The study sample is limited to franchised dealers that only sell one brand of a car not as a group. Hence, only those brands that are not under a group were considered resulting into having twenty-one independent car brands representing Norway’s car market. Further, this study was delimited to only the car market sector for the simple reason that restricting sample to a single industry has an important advantage of tacitly controlling innumerable confounding factors that effect results derived from cross-sectional surveys (Ittner et al., 2003).

1.6. Structure and organization of the study

The study is organized into seven chapters. Chapter one covers the introduction and includes the background of the study, the research problem, the justification, the scope and the structure and organization of the study. Chapter two reviews the theoretical framework where two theories are presented. Chapter three is made up of the literature on the key concepts of product variety in the car market. In chapter four the research methodology employed in the study is outlined. The definitions and explanation of the variables is dealt with in Chapter five while Chapter six deals with the empirical findings and data analysis. Chapter seven is the concluding chapter consisting of a summary, discussion, implications, the limitations of the study and suggestions for further research.

1.7. Chapter Summary

The background to the study is provided in this chapter. The research gap, research problem, the justification, scope and an outline of the study has also been presented. In the subsequent chapter, the relevant literature on Product Differentiation Theory; market structure and profit maximization and, product differentiation in the neoclassical framework are outlined. Additionally, Production Theory has also been reviewed in this chapter.

CHAPTER 2

THEORETICAL PERSPECTIVES

2.1. Introduction

This chapter presents the main theoretical framework supporting this study. Product differentiation and production theories are the main theories used to establish the framework for this study. The following section therefore discusses the product differentiation and production theories and their relevance and application to the study at hand.

2.2. Product Differentiation Theory

Product differentiation[9] is a theory first introduced by Edward Chamberlin in 1933. It was proposed as a general theory, and alternatively to replace that of generalized pure competition market structure derived from the neoclassical economics (Hunt, 2011). Product differentiation emerges as the engine of economic progress especially when product differentiation is seen as a strategy to improve products rather than just to make them different Holcombe (2009). This could be interpreted that firms do not differentiate their products to make them different, or to offer customers variety but rather to improve their quality with the purpose of satisfying their customers. Besides, product differentiation also contributes to the launch of new products to the market[10].

2.2.1. Forms of Product Differentiation

In the literature on product differentiation, it is common to make an important distinction between models of vertical (quality) differentiation and models of horizontal (variety) differentiation.

In *vertical differentiation*, all consumers have the same preferences (when goods are priced at marginal cost), and thus accept the fact that some products are relatively better[11] than others.

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[9] In a broad sense, product differentiation refers to a certain degree of variations within a product class that consumers view as imperfect substitutes (Anderson, 2005).

[10] This implies expansion of product line, which is also referred to as product variety.

[11] The notion “better” refers to the quality of the product where consumers have different willingness to pay for quality.

In Economics this is equivalent to Cardinal utility, where satisfaction of wants and needs are achieved through the consumption of goods or services, and can be measured using an absolute scale (Camacho, 1980). Laurenhardt (1885) is one of the few researchers that have attempted to capture the essence of vertical differentiation through a simple, but very effective idea. The model assumes that two firms locate at different points along a street as described in the Hoteling, which is discussed more in depth later in the chapter, but have access to different transportation technologies when delivering their products to the market. If there is no difference in location and mill price by both firms, the firm with the lower transportation cost would be able to capture the whole market share. Put in a different way, two products which are functionally identical may be more or less difficult to carry. Thus, the product which is easier to transport may be viewed as a product of a higher quality. It is indisputable that the perceived difference in quality by different consumer will play an important role in the purchase decisions. Potential consumers can, nevertheless, develop a biased (good or bad) perception of the features of the good. One thing we can take away from vertical differentiation is that product variety emerges in the form of quality differences among products offered to customers.

Another form of product differentiation is *Horizontal differentiation*. It arises when produced goods are similar in quality, but different in their variety features. These features can be linked to differentiation in colours, shapes, styles, flavours, taste, among others. This can also be referred to ordinal utility, an Economics term that believes that satisfaction of wants and needs can be achieved through the consumption of goods and/or services. These are measured by a ranking of preferences (e.g. first, second, third, etc.) that are comparable on a relative basis (Pareto, 1906). The concept of horizontal differentiation is at the heart of Hotelling analysis (Hotelling, 1929). The assumptions of the model may be stated as follows:

- Consumers are uniformly distributed along a linear line. Hypothetically, there are consumers per unit of distance along the linear line.
- Marginal costs of production are constant, and are assumed to be zero. Firms might face fixed costs of being in production; it is assumed that they have the option to change their location in order to reduce cost.
- There are a fixed number of sellers (usually two sellers within the market). Each has a single location.
- A constant cost of transporting one unit of commodity one unit of distance is incurred. The additional transportation cost can be distributed in two ways, either buyer pay this

costs directly, and reckon this in their delivered price calculations, or sellers pass on the direct costs of transport, without discrimination.

- Demand for the product is completely inelastic at one unit per consumer. Consumers buy from the seller whose delivered price is the lowest, owing to the fact that the products are identical (e.g. quality or features).

According to the model, firms maximize their profits by moving towards the centre as much as possible. Thus, there is a tendency for firms to cluster, where buyers cannot make the difference between products sold in the market. Furthermore, the distance is a direct similarity for product differentiation. Figure 2.1 illustrates an example on how sharing the Hotelling market looks like taking the above assumptions into account. The example used in Figure 2.1 could be described as follows; if one vendor locates at x and the other at y, and $x < y$, those located between 0 and ½ $(x + y)$ will go to the left vendor, while the rest will go to the right. Furthermore, we can note that the vendor at location x will sell more by moving towards y, and vice versa. It is in vendors' best interest to locate in the middle so they can maximize profits. By relocating in the middle, one on the left will sell to everyone on the left of ½ $(x + y)$, whereas the one on the right will sell to the rest.

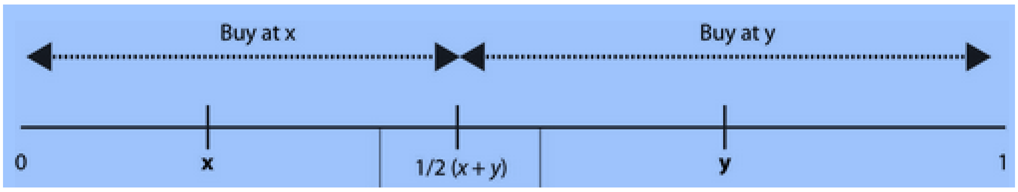

Figure 2. 1: Sharing the Hotelling Market. (McAfee and Lewis, 2009)

Based on the description of horizontal product differentiation provided above, one can see the link between product differentiation and product variety. Consequently, a product is differentiated based on the variety of characteristics.

Mixed differentiation is another form of product differentiation. Thus, certain multifaceted markets are characterized both by vertical and horizontal differentiation. For instance, differentiation in the car market is mixed as is seen in the amazingly rich combination of shapes, colours, trims, among others. In this case, the quality of the materials can often be seen as a vertical differentiation while shapes, trims, colours, are clearly horizontal (Piana, 2003).

2.2.2. Product Differentiation in the Neoclassical Framework

In neoclassical theory, product differentiation does not provide a homogeneous product that characterises purely competitive markets but rather offers consumers with a variety of different products within a particular industry (Holcombe, 2009). According to Holcombe (2009), product differentiation in the neoclassical framework, is depicted as creating downward-sloping demand curves for competitive firms. Thus, though product differentiation provides a benefit of greater product variety available to customers, it imposes a cost on the economy as firms do not produce at minimum average total cost (ATC). The cost-benefit analysis of product differentiation involves weighing the benefit of greater variety against the higher cost of production in competitive firms.

Hill et al., (2014) commented on this arguing that a lower cost structure, through production/importation of large volume of homogenous products (cars), is the best way to achieve high efficiency as far as the concept of economies of scale is concerned. The trade-off implicit in this idea is between unit costs of producing cars and product variety. For instance, producing numerous different models of car brands implies longer lead-times, which entails an inability to realise economies of scale, and thus higher costs. Thus, high level of product variety makes it even harder for the manufacturers to achieve efficiency and reduce their unit costs. Echoing that, Perloff (2004: 470) argues that differentiation is desirable in its own right despite the fact that it leads to higher prices, which harm consumers. That is, consumers are different and as such as they value having a choice which to some extent may lead them prefer a new brand to existing ones.

However, Pindyck and Rubinfeld (2005: 439), tend to differ with Hill et al., (2014) and Perloff (2004) proclaiming that,

> “Any inefficiency must be balanced against an important benefit that monopolistic competition provides: product diversity. Most consumers value the ability to choose among a wide variety of competing products and brands that differ in various ways. The gains from product diversity can be large and may easily outweigh the inefficiency costs resulting from downward-sloping demand curves”.

Varian (2003:454) agrees with the above statement stating that,

> “Firms may find it profitable to enter an industry and produce a similar but distinctive product. Economists refer to this phenomenon as product differentiation and that each firm attempts to differentiate its product from the other firms in the

> industry. The more successful it is at differentiating its product from other firms selling similar products, the more monopoly power it has".

Another important point that should not be overlooked when talking about product differentiation is the aspect of cost. However before getting into more details on the relationship between product variety and operating costs, let us first explain the concept of Average Total Cost (ATC). In economics total cost is considered as the overall opportunity cost incurred by a firm in production or operations as is the case with car dealers. Total Cost consists of variable cost, which depends on the quantity produced (i.e. labour cost), and fixed cost, which does not vary with the produced quantity i.e. machines, land or rent (Tucker, 2013). This can be written as follows:

$$\boldsymbol{Total\ cost\ =\ total\ fixed\ costs\ +\ total\ variable\ cost} \tag{2.1}$$

In order to calculate the average total cost, we must divide the total cost by output (quantity produced), and this can be written as follows:

$$Average\ total\ cost = \frac{\text{total variable cost+total fixed costs}}{\text{output or quantity produced}} \tag{2.2}$$

As one can see the total average cost can be defined as the cost per unit of output produced. The production function underlines that in any process where an output is produced, there should be a point where firm's average total cost reaches a minimum cost point (also known as the optimal), which depends on firm's maximum capacity. This is referred to as the law of diminishing marginal returns, an economic principle that states that as more and more of variable input is combined with a fixed input in the short-run, the marginal product of the variable input will eventually decline (Tucker, 2013). For the sake of illustration, let us look at the following numerical example, which supports the aforesaid statement. Assume that a firm has a fixed cost of NOK 48 with variable cost as depicted in Table 2.1 below:

Output Units (Q)	**Total Fixed Cost in NOK**	**Average Fixed Cost = FC/Q**	**Total Variable Cost in NOK**	**Average Variable Cost= VC/Q**	**Total cost in NOK**	**Average total cost in NOK**
0	48		0		48	
1	48	48	25	25	73	73
2	48	24	46	23	94	47
3	48	16	66	22	114	38
4	48	12	82	20,5	130	32,5
5	48	9,6	100	20	148	29,6
6	48	8	120	20	168	28
7	**48**	**6,8571429**	**141**	**20,14286**	**189**	**27**
8	48	6	168	21	216	27
9	48	5,3333333	198	22	246	27,33333
10	48	4,8	230	23	278	27,8
11	48	4,3636364	272	24,72727	320	29,09091
12	48	4	321	26,75	369	30,75

Table 2. 1: Variation of short-run cost with output (Perloff, 2006)

From Table 2.1 above, we see that both average variable and fixed cost decrease with additional production of output, then eventually increase with relatively large quantities of output. Graphically the average total cost is depicted by a U-shaped curve. As shown in the Table the optimal point where the average total cost reaches the minimum point is at 7 units.

The same concept could also be applied with product variety in a car market as depicted in Figure 2.2 below. However, it is important to mention that the graph depicted in Figure 2.2 was modified from the original idea of Holcombe (2009). In this graph, we compared product variety with the operating cost.

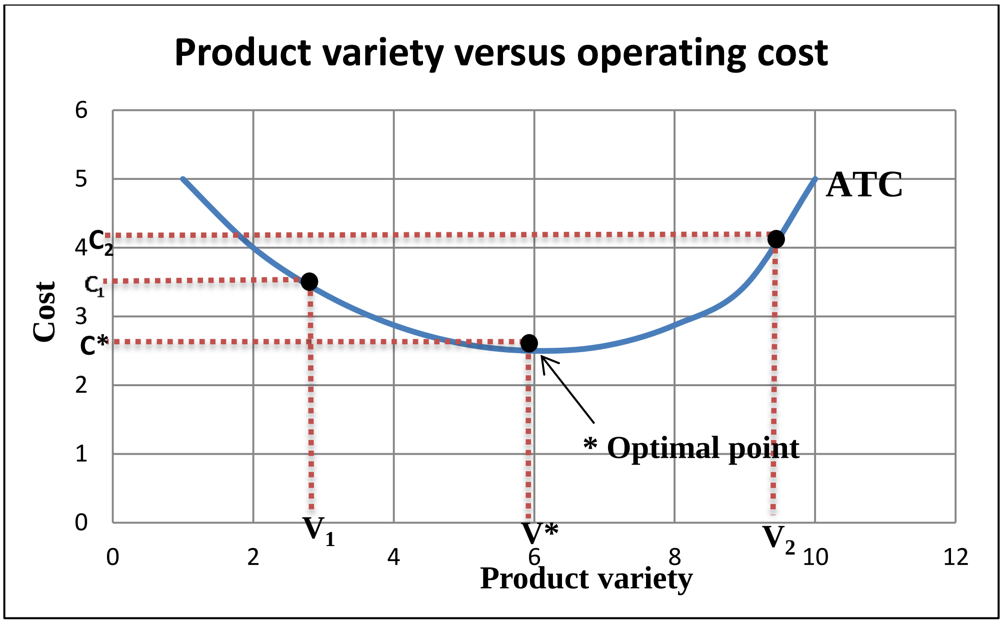

Figure 2. 2: Product variety versus operating cost. Own illustration

The logic behind this is that whenever a car dealer increases its product variety (importing various models of cars); they also incur additional fixed and variable costs. However, the fixed cost can decrease because the cost can be spread over an increasingly larger quantity of output. As shown in Figure 2.2, with low product variety at point V_1 a car dealer incurs operating cost at point C_1. Gradually, if the dealer increases more variety[12] by moving to the right-hand side along the X-axis we see that point V* is optimal given that the dealer incurs the lowest operating cost. However, any point beyond V* incurs the highest operating cost, for instance point V_2 incurs cost at point C_2, which is relatively high as compared to the other two. To put it briefly, the graph in Figure 2.2 tells us that increase in variety adds up extra costs, especially when variety exceeds the optimal point.

Furthermore, product differentiation does not provide a homogeneous product that characterises purely competitive markets but rather offers consumers with a variety of different products within a particular industry (Holcombe, 2009). Nevertheless, although neoclassical economics argues that markets with differentiated products do not produce at minimum average total cost, it nonetheless recognizes the advantages of product variety that product differentiation brings with it. In overall, the neoclassical theory asserts that product differentiation does not give firms any advantage just because they have made their products

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[12] Increase in product variety in this case refers to the ability of the car dealers in importing various models of car brands in order to capture different segments of the market that includes variety-seeking customers.

different. In fact, those firms that produce homogeneous products in competitive markets generate the same normal profits as compared to those firms that produce differentiated products. This may be understood that the competitive advantage to product differentiation comes from making a product that customers want more than the products of competitors through improvement of their products.

2.2.3. Market Structure and Profit Maximization in the Neoclassical Framework

The basic paradigm of neoclassical economics is that competitive firms can obtain a competitive advantage by pursuing the profit-maximizing strategy. This implies that firms are run by managers who maximize profits by finding the optimal combination of inputs and producing to the point where marginal cost and marginal revenue are equal. The firm's production is given as Q= f (K, L), where Q, K, L represent the total output, capital, and labour, respectively. It is up to the firm to choose the optimal capital and labour that maximize the company's profit (Pindyck and Rubinfeld, 2005). Similarly, the model assumes that a competitive firm cannot convey competitive advantage by differentiating one's product since the monetary rate of return from firms differentiating their products is insignificant (Holcombe, 2009). In other words, a firm that tries to differentiate its product, by offering higher product variety to customers, will place their company at a competitive disadvantage in the marketplace given that extra costs will add up, which results into the marginal cost (MC) exceeding the marginal revenue (MR).

However, Chamberlin (1933) took the competitive market structure with relative to product differentiation in completely different ways in methodology, aim, and content. His contribution to the study of product differentiation is credited by many scientists, and may be considered revolutionary (O'Brien, 1983). He attempted to better clarify his position in relation to the dominant theory of the firm and market structure. In a world of product differentiation, consumers benefit from increases in variety, but scale economies encourage limiting the number of varieties. A large number of outcomes are therefore possible when trading off between number of varieties and larger production facilities. According to Chamberlin (1933), perfect competition takes place on a scale of numbers of competitors and substitution of products (variety). Hence, any producer whose product is significantly different from the products of others has monopoly power in his own product to some degree, depending on the competition of substitutes (Silva, 2001). Browning and Zupan (2004: 314) note that product differentiation was a source of monopoly power for competitive firms, in their view consumers may perceive the product sold by a firm that differentiates its product to be superior to that offered by non-differentiated firm. Based on this perception, consumers are willing to pay more for the additional value created by the differentiated firm. With this in mind, firms could gain competitive advantage by implementing product differentiation by offering higher product variety as part of the competitive strategy.

2.3. Production Theory

As already discussed, it is the dealership perspective that is being looked into in this study and not manufacturing one. However, production theory has been used in this study as a framework for explaining how the different performances of car dealers can be explained and/or understood. Production is generally a process of transforming various material inputs and immaterial inputs (plans, know-how) into output(s). This does not imply manufacturing only but can also be applicable to car dealers, service providers, among others. Kotler et al., (2006) backs up this statement asserting that production means creating an output, which has value and contributes to maximise the utility of the individuals.

Theory of production has generally been used as a key tool of economic analysis in the neoclassical tradition. It explains the most fundamental principles by which firm decides the factors of production (input factors) such as fixed capital good, labour, raw materials, among others, that will be converted into output(s). An implicit formulation of production function[13] can be traced in Turgot's work (Turgot and Groenewegen, 1977). In the 1700s, he discusses how variations in factor proportion impact marginal productivities. Wicksteed (1894) is considered to be the first economist to algebraically formulate the interdependency between input and output as:

$$Q = f\,(X_1, X_2, \ldots, X_m) \qquad (2.3)$$

Where Q and X denote the total output and input, respectively. In this production function, it is expected that firms employ minimum input factors into the production process, and maximize the total output (Q). The output (Q) may consist of heterogeneous products, which

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[13] Production function can be defined as a relationship between the minimum inputs needed to produce the maximal technically feasible output. Though, in many theoretical and empirical studies the definition is slightly different, they define it as a technical relationship between output and inputs, and the postulation of maximizing the output and minimizing the inputs is often unstated (Shephard , 1970).

implies that firms offer wide range of variety to customers. To get back to the point, other people may argue that Johann von Thünen was the first to introduce theory in the 1840's (Humphrey, 1997). He was credited for implicitly formulate the exponential production function:

$$R = Y\ (p - c) - Y\ Fm \tag{2.4}$$

Where R denotes land rent, Y is the yield per unit of land, p is the market price per unit of commodity, c is the production expenses per unit of commodity, F is the freight rate (per agricultural unit, per mile), and m is the distance to the market. In the second stage of Thunen's work, he formulates the first algebraic production function as following:

$$Q = hq^{\mathrm{n}} \tag{2.5}$$

Q denotes output per worker (Quantity/Labour or Q/L), h is the parameter that represents fertility of soil and efficiency of labour, q is capital per worker (Capital/labour or C/L). The exponent n is another parameter that lies between zero and one. In order to find the total output per worker, all other inputs in the production process are fixed input, one must derive the equation in both sides, so that we get

$$Lp = hq^{n}L = hC^{N}L^{1-n} = P \tag{2.6}$$

By doing so, we characterize the productivity and efficiency of the firm's labour input. This can be traced in Cobb-Douglas production work. Lloyd did the extension of Thünen's work in 1969 where he applied the differential calculus to productivity theory, and used calculus to solve economic optimization problems and interpreted marginal productivities as partial derivative of the production function (Blaug, 1985). When using input in the production process, we might expect two types of outcomes in the output; namely increasing marginal returns[14] and diminishing marginal returns[15]. Figure 2.3 depicts different stages of the total product function. First, between 0-12 labour units, the output rises with additional labour at an increasing rate. The total product curve "output" gets steeper, and the curve is sloping upward. This range is called increasing marginal returns. From 12 and up, one can note that

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[14] Increasing marginal returns occur when an increase in the variable input, for instance in labour, result to upsurge of the total output at an increasing rate.

[15] The law of diminishing marginal returns states that ceteris paribus, as the amount of the input used in the production process increases, eventually a point is reached where the marginal product of an additional unit of that input decreases.

the total product increases as the quantity of labour rises, but at a decreasing rate. In other words, the curve becomes flatter as the quantity of labour rises.

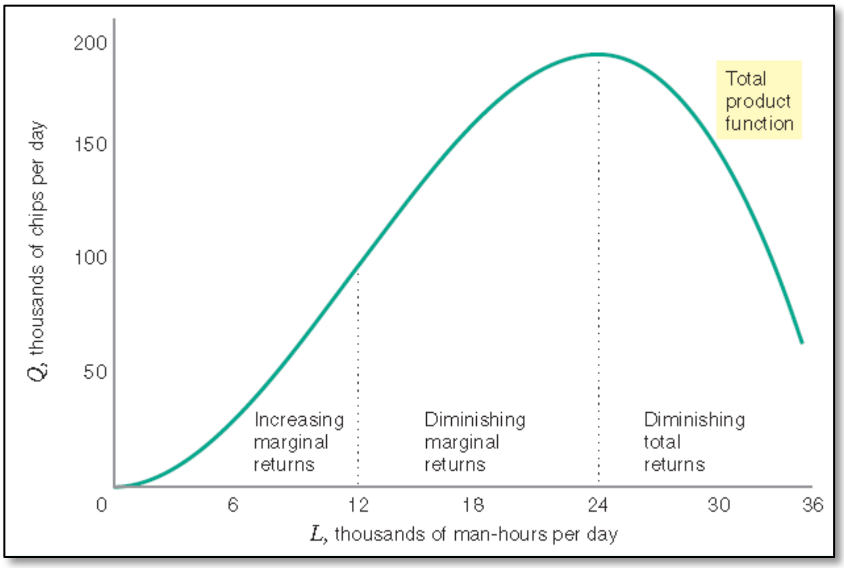

Figure 2. 3: Total Product Function (Besanko and Braeutigam, 2004)

It is important to note that marginal effect does not just limit with a single input as illustrated in Figure 2.3. The process of converting an input into output may also involve multiple inputs such as capital and labour. However, in order to gain a better insight, let us look at a three-dimensional graph shown in Figure 2.4 that illustrates the relationship between output and two inputs[16] employed in the production process by the firm.

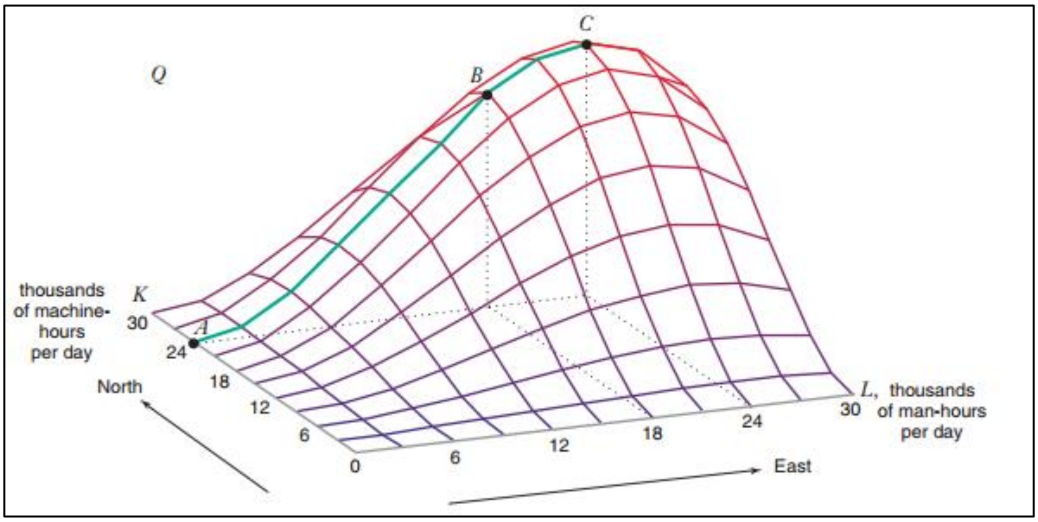

Figure 2. 4: Total Product Hill (Besanko and Braeutigam, 2004)

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[16] This is known as input-oriented measure and will therefore be discussed in detail in section 2.3.2.

As shown in the Figure above, the height of the hill at any point is equal to the quantity of output (Q) the firm produces from inputs (labour and capital) employed. There are two ways of reading the graph. First, we could increase the quantity of L by moving eastward whilst holding K at a fixed level to see the corresponding Q or vice versa. For example, points ABC in the graph shows that K is held at a fixed quantity (24) whilst changing the quantity of L. Second, we could also move the inputs (K and L) simultaneously to find out the corresponding Q. The marginal product of an input can also be expressed in mathematical terms. The marginal product of labour can be written as:

$$MP_L = \frac{change\ in\ quantity\ of\ output\ Q}{change\ in\ quantity\ of\ labour\ L} \|_{\text{K is fixed}} = \frac{\Delta Q}{\Delta L} \ \|_{\text{K is fixed}} \tag{2.7}$$

Likewise, the marginal product of capital can be written as

$$MP_k = \frac{change\ in\ quantity\ of\ output\ Q}{change\ in\ quantity\ of\ capital\ K} \ \|_{\text{ L is fixed}} \tag{2.8}$$

Furthermore, when inputs have positive marginal products, a firm's output (Q) must increase when the quantities of all inputs used in the production process are increased simultaneously. This implies that a firm's scale of operations[17] has increased. Another question that might be arisen as by how much output will increase when all inputs are increased by a given percentage amount. For instance, if a firm doubles its input both capital and labour, by how much will the output increases. Very often, we use the concept of returns to scale to measure the consequence of the quantity changes in the production. This is given by the equation:

$$Returns\ to\ scale = \frac{\%\,\Delta\ \ quantity\ of\ output\ (Q)}{\%\,\Delta\ \ quantity\ of input\ (K\ \&\ L)} \tag{2.9}$$

There exist three types of returns to scale; namely, increasing returns to scale (IRTS), constant returns to scale (CRTS), and decreasing returns to scale (DRTS). Early in the chapter, we have assumed that a firm employs two inputs, capital (K) and labour (L), to produce output (Q). Let us now assume that both K and L are expanded by the same proportionate amount λ, where lambda is greater than one. Let φ denotes the resulting proportionate increase of the output. If this is the case, a firm can expect one of the following outcomes:

- If $\varphi > \lambda$, it is increasing returns to scale. This means that a proportionate increase in input quantity is greater than proportionate increase in output. Increasing returns to

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[17] Scale of operations means the volume in which production is been made.

scale typically occurs in the homogeneous production because of the division of labour or capital in the production, which narrows specialization of tasks within a production process.

- If $\varphi = \lambda$, it is constant returns to scale. This implies that a proportionate increase in input have the same proportionate increase in output. This may be found in the homogenous production, even though, some people may disagree.
- If $\varphi < \lambda$, it is decreasing returns to scale. Meaning that a proportionate increase in input quantities results in a less than proportionate increase in output. This frequently occurs in the heterogeneous production, where firms manufacture wide range of variety. More insight on how decreasing returns to scale occurs is discussed in the subsequent section.

The new neoclassical economics of the production theory[18] was created by labour economist Paul H. Douglas and mathematician Charles W. Cobb in an effort to fit Douglas's empirical result for production, employment, and capital stock in the U.S. manufacturing into a simple function (Cobb and Douglas, 1928). Their work is credited by many economists because of its ease of use and its extreme flexibility. The functional form can be written as:

$$Q = AK^{\alpha}L^{1-\alpha} \tag{2.10}$$

Where Q is output, A is the level of technology (it is constant and must be A>0), K is capital, L is labour, α is a constant that lies between zero and one.

In the Cobb-Douglas production function, the elasticity of substitution of capital for labour is fixed to unity. Arrow et al., (1961) mathematically demonstrated why substituting any of the inputs (capital and labour) will not result to output increase or decrease. The reason given by the authors was that regardless of the size of output or inputs used in the production process, the number along and across the isoquant will stay fixed. This function is also known as the Constant Elasticity of Substitution (CES) production function. At first, it was believed that the CES production function had a limitation when defining the said elasticity with more than two inputs in the production process. McFadden (1962, 1963), for instance, proved that it is not feasible to obtain a functional form for a production function with CES if the number of inputs is greater than two. However, in the later stage many researchers proved this statement to be wrong. Uzawa (1962) and Sato (1967) made fundamental contribution to incorporate

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[18] The existence of new neoclassical economics of the production theory is dated back to Cobb-Douglas production function literature which provides a reasonable description of actual economies.

more than two inputs in the production process. To explain this concept a little more, they formulate following equation:

$$Q = f\ (x_a, x_{b,} x_c x_d) \tag{2.11}$$

In which Q is output and X_i is the input. When combining X_a and X_b in a manner of CES to obtain S_1 and likewise, combine X_c and X_d to obtain $S_{2.}$ When blending S_1 and S_2 to obtain Q. One may say that nesting inputs depend on the nature of inputs and production technology. Providing that the elasticity of substitution in production function is constant, firms could increase variety in its outputs by combining different inputs. Figure 2.5[19] below shows various combinations of inputs in exchange for achieving variety in output, and is depicted in a form of a tree diagram. As regards production function, it is assumed that the following input combinations x_a and x_b are indifferent from x_b and x_a when converting them into output. Also, firms produce a single output with fixed quantity. Thus, firm may use the following input combinations $x_a, x_{b,} x_c x_d$ in order to get Q_1; $x_a, x_{c,} x_b x_d$ to get Q_2 or $x_a, x_{d,} x_b x_c$ to get Q_3.

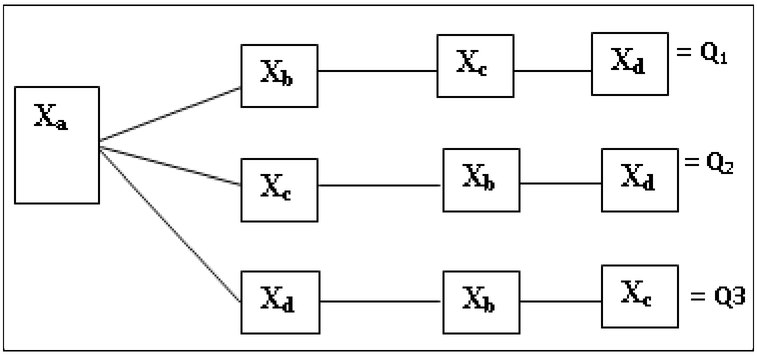

Figure 2. 5: Combinations of inputs and outputs. Own source

2.4. Efficiency Measurement Concepts

The prior section mainly emphasizes on the case where firms use single and/or multiple inputs and produces a single and/or multiple outputs in general. This section will, however, focus on

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[19] Figure 2.5 is derived from Sato's (1967) paper, but the model has been modified in order to illustrate possibilities of input and output combinations.

the concepts of efficiency measurement. Thus, the essence of these concepts is to generate a comprehensive understanding which can be reflected with the purpose of the study.

The terminology of efficiency[20], obtaining the most consumer satisfaction from available resources, can be traced back in the production system. Thus, the concept of efficiency can be amply understood through a production frontier. A production frontier is a graphical representation of a production function that shows how much output can be produced given the various combinations of factors of production[21]. Thus, a production function is extensively used to delineate the relationship that exists between inputs and outputs by illustrating graphically the maximum output obtainable from the given inputs consumed (Barros and Mascarenhas, 2005). Figure 2.6 below depicts a Production Possibility Frontier (PPF).

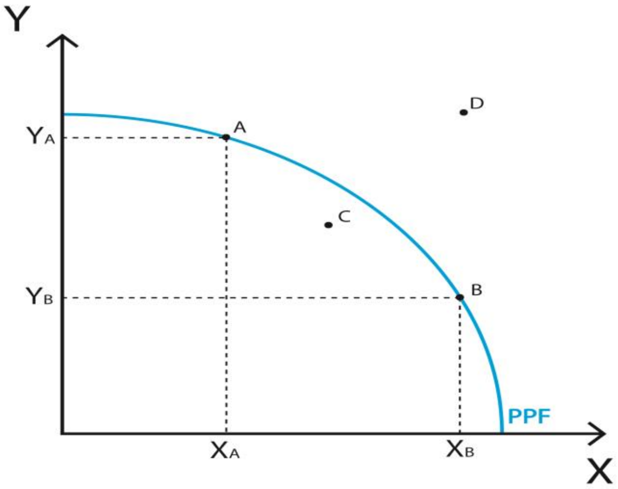

Figure 2. 6: A Production Possibility Frontier

The blue-coloured curve in this Figure above shows the PPF of output (Y) with various combinations of input (X). Thus, this simply implies that all the points on or below the PPF (A, B and C) are attainable whereas point D is unattainable as it is beyond the PPF. In as far as efficiency is concerned; production at point C is regarded as inefficient given that it is situated below the PPF. This may be due to inability of a firm operating at point C in utilising its resources optimally to produce given output. In other words, a firm with an output at point C is not producing as much output as it could with the same amount of input. In contrast, points A and B are efficient as they are located on the PPF and that means they are producing the maximum possible output with the given input.

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[20] The efficiency literature discussed in this section is based on car brands, which is the unit of analysis in this study, in Norwegian automotive market.

[21] Factors of production in this case refer to the inputs to the production process.

In short, not only does any point on the PPF show how efficient firms are but it is also a reference point for the inefficient firms. Therefore, a measurement to calculate efficiency is the distance between the observed production and the frontier production. However, Greene (1997) asserts that “producers are efficient if they have produced as much as possible with the inputs they have essentially employed and if they have produced that output at minimum cost”. Echoing in the same line, Worthington and Dollery (2000) in Porcelli (2009) argue that efficiency is only one part of the whole performance of the firm. They add on saying that the measurement of effectiveness and the degree to which a system achieves programmes and policy objectives as regards to outcomes, quality, accessibility and appropriateness, complete the performance of the firm. This is illustrated in Figure 2.7 where the distinction between efficiency and effectiveness is clearly portrayed.

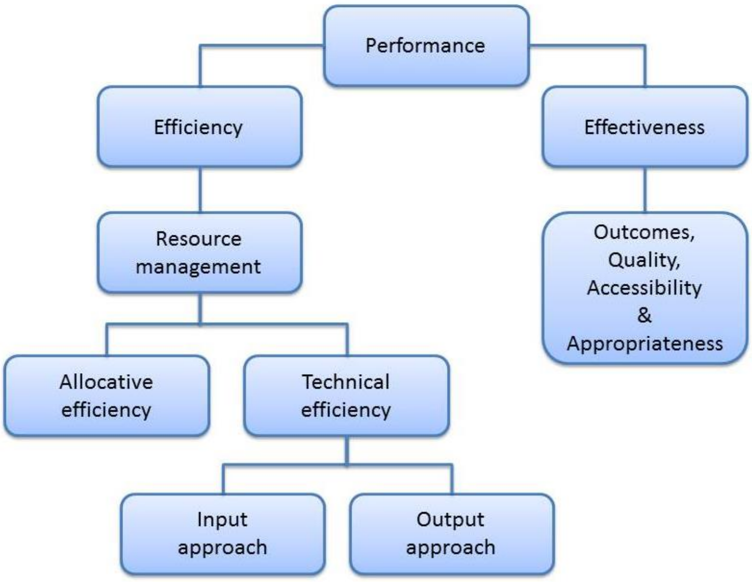

Figure 2. 7: Framework for performance assessment. Own illustration

As is reported in Figure 2.7 above, it is important to explicate both concepts of efficiency even though this study focuses only on measuring technical efficiency (TE). Thus, this is due to the fact that TE is the most widely used measure of performance in the literature and it doesn’t require cost/price data, which is usually difficult to obtain. Farrell (1957) began the modern efficiency measurement by drawing upon the work of Debreu (1951) and Koopmans (1951) in order to define a simple measure of firm efficiency which could account for multiple inputs. He substantiated that the efficiency of a firm can be classified into allocative and technical efficiencies, which are then combined to provide total economic efficiency (EE)[22].

1) ***Technical efficiency (TE)*** refers to the firm's ability to obtain maximum output given an optimal combination of inputs with reference to a production function. Porcelli (2009) defined TE "as the ratio between the observed output and the maximum output, under the assumption of fixed input, or, alternatively, as the ratio between the observed input and the minimum input under the assumption of fixed output". Following Koopmans (1951),

> "a producer is technically efficient if an increase in an output requires a reduction in at least one other output or an increase in at least one input, and if a reduction in any input requires an increase in at least one other input or a reduction in at least one output".

Inversely, Debreu (1951) and Farrell (1957) described the following technical efficiency measure, which is known as the Debreu-Farrell measure as:

> "one minus the maximum equi-proportionate reduction in all inputs that still allows the production of given outputs, a value of one indicates technical efficiency and a score less than unity indicates the severity of technical inefficiency".

2) ***Allocative (or price) efficiency (AE)*** denotes the firm's capability in utilising the inputs in optimum proportions as regards to their respective prices. Thus, following Odeck and Braathen (2012), AE refers to the ability of the decision-making unit through use of cost minimising input ratios in order to produce a given level of output. According to Porcelli (2009), allocative efficiency is "the ability to combine inputs and outputs in ideal proportions in the light of prevailing prices, and is measured in terms of behavioural goal of the production unit, for instance, observed versus optimum cost or observed profit against optimum profit". Thus, this measure quantifies how near a firm is to using the optimal combination of production units when the goal is maximum profit. Allocative efficiency exists when the resources are best allocated by a firm according to production necessities and market prices (Richetti and Reis, 2003).

Farrell (1957) also based his ideas on two main approaches that measure both allocative and technical efficiencies:

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[22] The term total economic efficiency (EE) will be used in this study instead of 'overall efficiency'. This terminology however is not been used in the recent efficiency literature as much as it used to be.

- *Input approach*: This is whereby the ability to minimise inputs while keeping outputs fixed is evaluated. Thus, in this way waste is avoided through producing as much output as input usage allows.
- *Output approach*. This is the opposite of input approach as outputs are maximised while keeping inputs fixed which then enables waste avoidance due to using as little input as output production allows.

2.4.1. Input-Oriented Efficiency Measure

Farrell (1957) demonstrated his ideas using an example where a firm uses two inputs to produce one output, under the supposition of constant returns to scale (CRTS)[23]. Figure 2.8 shows a two dimensional space of a production function for two inputs and a single output (Karaduman, 2006).

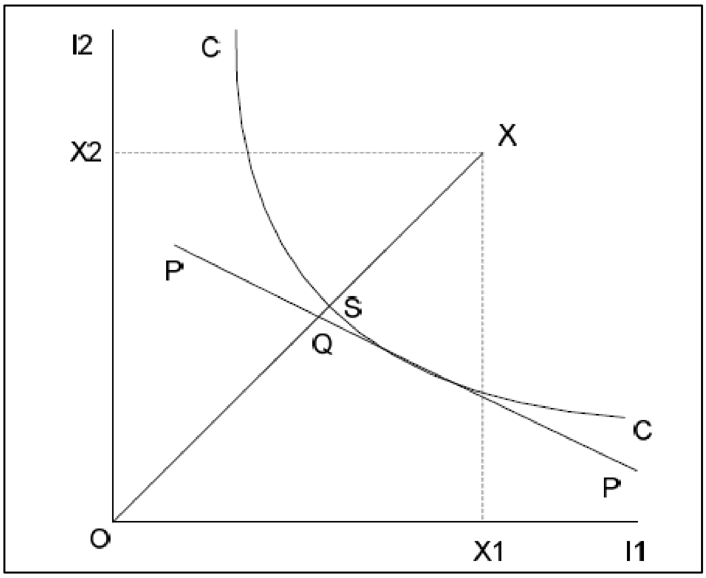

Figure 2. 8: Technical and Allocative Efficiency (Input-oriented) (Karaduman, 2006)

In Figure 2.8, the CC curve represents the knowledge of the unit isoquant of the 'fully efficient firm'[24] in the Norwegian car passenger market for example, which allows the measurement of TE. I1 and I2 denote two inputs used for producing a single output. One can note that a car brand operating at X uses X1 units of input I1 and X2 units of input I2 to produce one unit of output (total sales of car models imported). This therefore means that car

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[23] With the constant returns to scale assumption, technology is represented using a unit isoquant.

[24] The fully efficient firm's production function normally is predicted from the observations on a sample of firms in the concerned industry. However, DEA will be used in this study to estimate this frontier.

brand at point X is technically inefficient as it lies above CC and this inefficiency could be represented by the distance SX, which is the amount by which all inputs, without a reduction in output, could be proportionally reduced. In percentage terms, this is usually expressed by the ratio SX/OX, which signifies the percentage by which all inputs could be reduced. Hence, the technical efficiency of the car brand operating at X is defined to be the ratio:

$$TE_I = OS/OX$$

This ratio equals one minus SX/OX[25] (1-SX/OX). The degree of TE of a firm is indicated by the value between zero and one. A value of one indicates that the firm is fully technically efficient (Coelli, 1996). For instance, from Figure 2.8, the point S is technically efficient as it lies on the efficient isoquant (CC curve).

The line PP represents the input price ratio, which if known, may help calculate the allocative efficiency (AE) of a firm. Thus, AE of a car brand at point X is represented by the distance from PP line. Thus, the AE of this car brand operating at X is hence measured by the ratio:

$$AE_I = OQ/OS$$

This is because the distance QS represents the reduction in production costs that would occur if production were to occur at the allocatively (and technically) efficient point[26] instead of at the technically efficient point S but allocatively inefficient.

The total economic efficiency (EE_I) is the product of technical and allocative efficiency and is given as follows:

$$\text{Technical} \times \text{Allocative efficiency} = (OS/OX) \times (OQ/OS) = OQ/OX = EE_I$$

That is, $EE_I = OQ/OX$, where the distance QX can also be interpreted in terms of a cost reduction. Note that all the three measures are bounded by zero and one (Coelli, 1996).

These efficiency measures assume that the production function of the fully efficient firm is known (Coelli, 2008). In reality however, this is not the case, as the efficient isoquant must be

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[25] To show that it is an input-oriented efficiency measure, the subscript "I" is used on the TE measure. Output-oriented efficiency measure is indicated by the subscript "O", see below.

[26] Allocatively and technically efficient point in this case is where CC intersects PP

estimated from the sample data. Hence, the use of either a non-parametric piecewise linear convex isoquant should be constructed in a way that no observed point should be located to the left or underneath it (see Figure 2.9 below), or a parametric function like the Cobb-Douglas form, that is fitted to the data also in a way that no observed point should be located to the left or below it.

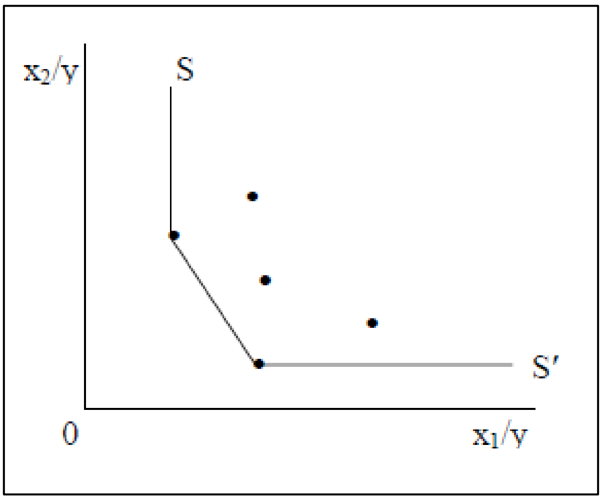

Figure 2. 9: Piecewise Linear Convex Isoquant (Coelli, 2008)

2.4.2. Output-Oriented Efficiency Measure

The input-oriented efficiency measure discussed above addresses the question: “How much can inputs be proportionally reduced while maintaining the same level of output?” The analogous question could be: “How much can outputs be proportionally increased while keeping the level of inputs constant?” This latter question is addressed by an output-oriented efficiency measure and as one can see from this aforesaid question, it is different from input-oriented measure. Thus, the difference can further be illustrated through an example where a firm produces one output by using one input. This is depicted in Figure 2.10a where f(x) represents a decreasing return to scale (DRTS) technology and an inefficient car brand operating at point P. According to Farrell (1957), input-oriented measure of TE in this example would be defined to be the ratio: AB/AP whereas that of output-oriented measure would be CP/CD. Following Fare and Lovell (1978), input- and output-oriented efficiency measures will provide unequal measures of TE when increasing returns to scale (IRTC) or decreasing returns to scale (DRTS) exist, but will be equal when constant return to scale (CRTS) is present. Figure 2.10b depicts the CRTS where a car brand at point P is technically and allocatively inefficient, given by the ratios AB/AP and CP/CD respectively.

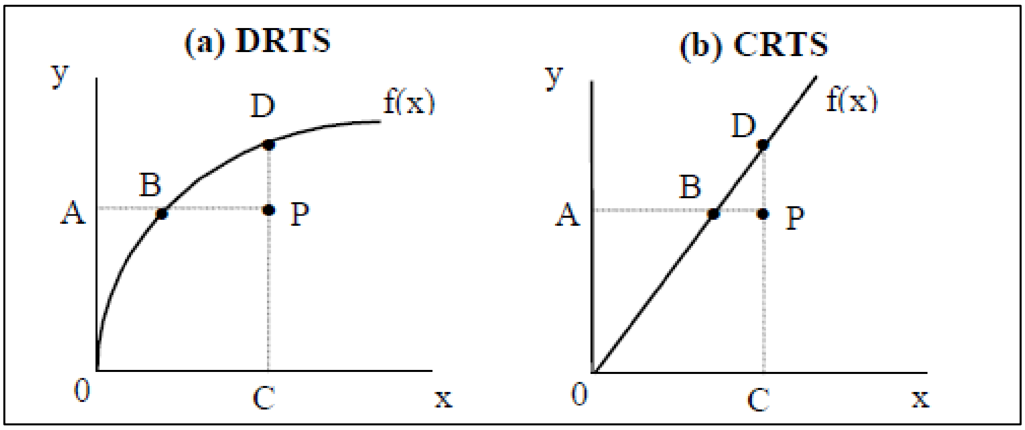

Figure 2. 10: Input and output oriented technical efficiency measures and returns to scale (Coelli, 1996)

Output-oriented measure can be more expounded by considering a case when a firm produces two outputs by using one input. See Figure 2.11.

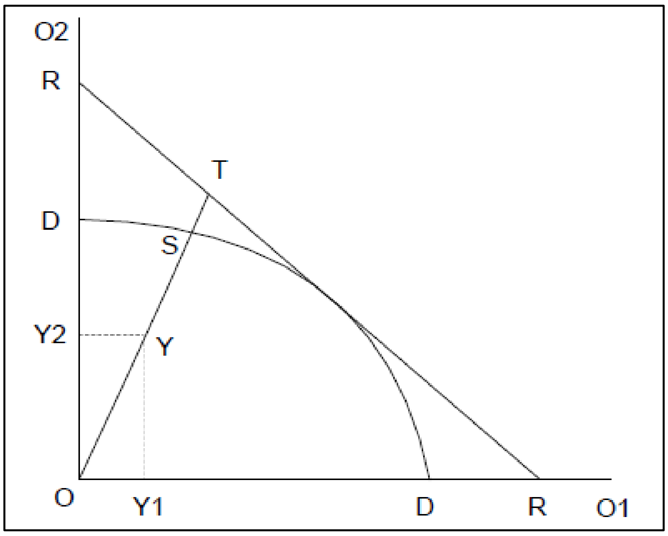

Figure 2. 11: Technical and Allocative Efficiency Measures (Output-oriented) (Karaduman, 2006)

In this Figure above, two outputs that are produced by using one input are represented by O1 and O2. DD is the isoquant or the unit production possibility curve[27] representing the upper bound of production possibilities. RR, as perceived by Varian (1987: 334), is the iso-revenue function representing the price information. Car brand at point Y lies beneath the isoquant and that implies it is inefficient. Car brand represented by point S lying in the production

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[27] The terms isoquant and the unit production possibility curve mean the production frontier in this study and as such, they will be used interchangeably.

possibility curve defines the efficient firm, which is producing outputs using the required inputs. The technical inefficiency of a car brand operating at Y is represented by the distance YS, which is the amount by which all outputs could be proportionally increased without the need of additional inputs. Hence, the output-oriented technical efficiency is:

$TE_O = OY/OS$,

S being the point of intersection in the production possibility curve, which is equal to one minus YS/OS. Even though car brand at point S is technically efficient, it is however simultaneously allocatively inefficient as it is off the iso-revenue line RR.

Besides, the AE is defined by the ratio $AE_O = OS/OT$. The distance ST represents the increase in production output that would occur if production were to occur at the allocatively and technically efficient point[28] instead of point S where it is technically efficient and yet concurrently allocatively inefficient. Thus, the total economic efficiency is measured by the ratio:

$EE_O = (OY/OT) = (OY/OS) \times (OS/OT) = TE_O \times AE_O$,

again with all the three measures bounded by zero and one.

2.5. Approaches for measurement of technical efficiency

Speaking about the technical efficiency, some groups of economists see the technical efficiency as the least important factor. For instance, Shephard (1970) asserts that the managerial and engineering problems of technical efficiency in the production function can be omitted owing to the fact that they have already been addressed and solved. On the other hand, other economists consider it wrong to assume that the technical efficiency has been achieved as the reality turns to be different. In short, in real life production, there is no known functional form for the production function due to the complex process that comprises many inputs and outputs. Thus, since the production frontier cannot be observed directly, many techniques have been developed in order to estimate technical efficiency.

Essentially there are two principal methodologies evidenced in the literature through which to measure frontier efficiency:

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[28] This is the point where the production possibility curve (DD) intersects the iso-revenue function (RR).

a) Parametric (Econometric) Approach – regarding Deterministic Frontier Analysis (DFA)[29] and Stochastic Frontier Analysis (SFA)[30] developed by Aigner et al., (1977) and Meeusen and van den Broeck (1977).
b) Non-parametric (Mathematical programming) Approach – regarding Data Envelopment Analysis (DEA), which was developed by Farrell (1957) and Charnes et al., (1978).

As put by Dong et al., (2013), the difference between these two aforementioned approaches lies in the fundamental assumptions applied in estimating the efficient frontiers. Thus, these techniques use different methods to envelop data and as such they make different accommodation for flexibility and for random noise in the structure of production technology.

2.6. Parametric Approaches for Measuring Efficiency

This approach is mostly used in economy and it assumes a specified functional form of production function which is either estimated statistically or is assumed to be known (Karaduman, 2006). With this parametric approach, any hypotheses can be tested statistically and as such, the relationship between inputs and outputs can be shown as functional forms. The parametric techniques can further be categorised as:

1) Deterministic Frontier Model (DFM)
2) Stochastic Frontier Model (SFM)

According to Zamorano (2004: 35), the parametric deterministic frontier models are also termed ‘full frontier’ models. These models envelop all the observations, identifying the distance between the observed production and the maximum production, defined by the frontier and the available technology, as technical inefficiency. In other words, these models assume that any deviation from frontier is due to inefficiency. Following Odeck and Braathen (2012), TE is measured by a procedure called Corrected Ordinary Lease Squares (COLS), where an average practice is first estimated. This frontier is corrected by shifting the intercept up until all corrected residuals are non-positive and at least one is zero. Hence, the ratio of observed output value to the fitted frontier output value equals technical output efficiency.

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[29] In this study, Deterministic Frontier Analysis (DFA) and Deterministic Frontier Model (DFM) mean the same and as such they will be used interchangeably.

[30] The same applies to Stochastic Frontier Analysis (SFA) and Stochastic Frontier Model (SFM) though they are not the focus of this study but will be discussed briefly as they are part of efficiency literature and hence cannot be left out.

This implies that any measurement error in the data is accredited to inefficiency and this is the main problem of these deterministic frontier models.

In contrast, the stochastic frontier model covers errors in the observations and in the measurement of outputs and it also accounts for any statistical noise. This model integrates a composite error term that sums a two-sided error term, which measures all effects outside the control of the firm, and a one-sided, non-negative error term that measures technical inefficiency (Kokkinou, 2009). The parametric stochastic frontier models, according to Odeck and Braathen (2012), have some shortfalls. Thus, they include the cost of making certain distributional assumptions for the one-sided error term related with the TE and imposing a certain functional form that could introduce a potential source of error. Nonetheless, the most commonly employed parametric technique is the Stochastic Frontier Analysis (SFA), which will be discussed in section 2.6.1 below in detail though it is not the focus of this study.

2.6.1. Stochastic Frontier Analysis (SFA)

Battese and Corra (1977), Meeusen and van den Broeck (1977) and Aigner, Lovell and Schmidt (1977) developed a Stochastic Frontier Model (SFM) simultaneously but independently. SFA does not only incorporate the efficiency term into the analysis, it also captures the effects of external factors that are beyond control of the analysed units (Zamorano, 2004). SFMs are made up of three components:

i. The deterministic production function
ii. The inefficiency error component
iii. The idiosyncratic error

The SFMs are often known as ‘composed error models’ since the error term comprises two components, namely: a one-sided component, which captures the effects of inefficiency as regards the stochastic frontier, and a symmetric component that allows the random variations and captures the effects of external factors that are beyond the producers’ control such as statistical noise, measurement error, among others.

The general version of the stochastic frontier production function model for cross-section data can be written in the following way:

$$\mathbf{Y_i = \mathit{f}\ (X_i; \boldsymbol{\beta}) + \varepsilon_i \quad i = 1, 2, \ldots, I} \tag{2.12}$$

Where:

- X_i is the input vector of producer i;
- Y_i represents the single output of the producer i;
- $f(X_i; \beta)$ is the deterministic component of the production function, where β is a vector of technology parameters to be estimated.
- ε_i is the composite error term, which can further be defined as

$$\boldsymbol{\varepsilon}\mathbf{i} = \boldsymbol{\nu}_{\boldsymbol{i}} - \mathbf{u}_{\boldsymbol{i}} \tag{2.13}$$

Where:

$\boldsymbol{\nu}_{\boldsymbol{i}}$ represents statistical noise (randomness) in the production process and is therefore assumed to have a symmetric or normal distribution with zero mean.

$\mathbf{u}_{\boldsymbol{i}}$ represents technical inefficiency and is assumed to be distributed independently of ν_i in order to satisfy the restriction $\mathbf{u}_{\boldsymbol{i}} \geq \mathbf{0}$

2.7. Non-Parametric Approaches for Measuring Efficiency

The non-parametric techniques do not assume any form of the production function. Instead, Norman and Stoker (1991) assert that it is from observed inputs and outputs that a best practice function is formed empirically. With this kind of approach, all deviations from the efficient frontier are assessed as inefficiencies. Nevertheless, the parametric statistical estimation approach accepts the fact that the deviation has noise and inefficiency components. Following Odeck and Braathen (2012), Data Envelopment Analysis (DEA) and its alternative variant, the Free Disposal Hull (FDH), are the two most widely used non-parametric approaches. However, since this study focuses on DEA only, FDH will not be discussed in this paper. The other reason for choosing DEA over FDH is due to the fact that by far DEA is the most widely used between these two aforesaid approaches in the technical efficiency literature regardless of the sector being analysed. Hence, for comprehensive treatments of the FDH's methodology, we refer readers to the literature, for example, Cooper et al., (1999).

2.7.1. Data Envelopment Analysis (DEA)

Charnes et al., (1978) were the first authors to coin the term DEA in the efficiency literature. DEA is a linear programming based non-parametric technique in measuring efficiency. It is because of this characteristic that DEA is called a non-parametric programming (Ganley and Cubbin, 1992). Relative to the frontier of best performance, DEA measures the efficiency of a

Decision Making Unit (DMU)[31] by its position. Since production function in many cases is unknown, therefore it can be concluded that DEA is a method that measures the relative efficiencies of DMUs. Thus, a subset of efficient 'best practice' DMUs (car brands) are identified by DEA and the remaining inefficient DMUs, their magnitude is derived by comparison to a frontier created from the 'best practices'. Additionally, a single summary measure of efficiency for each DMU is derived by DEA. For instance, efficient input and output targets and a reference set for the inefficient DMUs that tally with the respective subset of efficient DMUs are derived.

2.7.2. The Constant Returns to Scale Model (CRS) under Input-Oriented Model

Charnes, Cooper and Rhodes (1978) developed a model, which is the basis for the input-oriented CCR model[32]. Thus, this model had an input orientation and assumed Constant Returns to Scale (CRS)[33] in calculating resulting technical efficiency indices. However, the assumption of CRS is applicable when all DMUs are functioning at an optimal scale. External factors such as government control, imperfect completion, financial limitation, among others, may explain why a DMU may not actually perform at its optimal scale. Hence, distorted technical efficiency scores will be yielded if production is not at its optimal level under CRS assumption. The following is the input-oriented linear programming version of the model:

$$\text{Min } \delta_i^C - \varepsilon \sum_{r=1}^{t} S_r^+ - \varepsilon \sum_{k=1}^{m} S_k^- \tag{2.14}$$

subject to

$$x_{ki}\delta_i^C - \sum_{j=1}^{n} x_{kj}\varphi_j - s_k^- = 0, \quad k = 1, \dots, m,$$

---

[31] Charnes et al., (1978) first used the term 'Decision Making Unit' (DMU) in order to determine the units of which relative efficiency scores are calculated by DEA.

[32] The input-oriented CCR model's objective is to minimise inputs while using at least given outputs. This model, under Constant Returns to Scale (CRS), measures the total efficiency. Thus, with CRS concept, the CCR model is able to assess relative productive efficiencies of DMUs with multiple inputs and outputs (Lie and Lih, 2005).

[33] CRS will be used in this study to refer to constant returns to scale and not CRTS as portrayed in section 2.4.2 above. Most DEA papers however use the former while most economics papers use the latter.

$$\sum_{j=1}^{n} \gamma_{rj}\varphi_j - S_r^+ = \gamma_{ri}, \quad r = 1, \dots, t,$$

$$\varphi_j, S_k^-, S_r^+ \geq 0, \quad \forall j, r \; and \; k.$$

Where DMU$_i$ is the DMU (car brand) being evaluated in the set of j = 1,…, n DMUs.

X_{kj} denotes the observed level of the k^{th} input at DMU j.

Y_{rj} denotes the observed level of the r^{th} output at DMU j.

δ_i^C is a measure of the technical efficiency (TE) of DMU$_i$, with CRS assumption.

2.7.3. The Variable Returns to Scale Model (VRS)

Nevertheless, the consequent papers have considered other sets of assumptions, for instance, Banker, Charnes and Cooper (1984) suggested BCC models with Variable Returns to Scale (VRS) assumption. Thus, with VRS, it is possible to detect scale effects which may explain reasons for some of the inefficiency detected in model (2.12), which is not the case with CRS (Coelli, 2008). This explains the extension of model 2.12 to include VRS, where a convexity constraint is added to the original model (equation 2.12) requiring that the multipliers φ_j add up to 1. This constraint implies that each DMU is only compared to others of the same size. The resulting linear programming problem of VRS in input-oriented model is given as:

$$\text{Min } \delta_i^C - \varepsilon \sum_{r=1}^{t} S_r^+ - \varepsilon \sum_{k=1}^{m} S_k^- \tag{2.15}$$

subject to

$$x_{ki}\delta_i^C - \sum_{j=1}^{n} x_{kj}\varphi_j - s_k^- = 0, \quad k = 1, \dots, m,$$

$$\sum_{j=1}^{n} \gamma_{rj}\varphi_j - S_r^+ = \gamma_{ri}, \quad r = 1, \dots, t,$$

$$\varphi_j, S_k^-, S_r^+ \geq 0, \quad \forall j, r \; and \; k.$$

$$\sum_{j=1}^{n} \varphi_j = 1$$

Given a certain amount of inputs, it is possible to estimate technical inefficiency as being any proportional increase in output production. Thus, the use of input orientation and output orientation rely on the objective of the DMUs. Nonetheless, the input-oriented and the output-oriented models are very similar. For instance, see the output-oriented VRS model as given:

$$\text{Max } \delta_i^C - \varepsilon \textstyle\sum_{r=1}^{t} S_r^+ - \varepsilon \sum_{k=1}^{m} S_k^- \tag{2.16}$$

Subject to

$$x_{ki}\delta_i^C - \sum_{j=1}^{n} x_{kj}\varphi_j - s_k^- = 0, \quad k = 1, \dots, m,$$

$$\sum_{j=1}^{n} \gamma_{rj}\varphi_j - S_r^+ = \gamma_{ri}, \quad r = 1, \dots, t,$$

$$\varphi_j, S_k^-, S_r^+ \geq 0, \quad \forall j, r \text{ and } k.$$

$$\sum_{j=1}^{n} \varphi_j = 1$$

Where δ -1 is the proportional increase in outputs when the input is kept at a constant level, and$1 \leq \delta \leq \infty$. That is, $1/\delta$ defines the score of TE, which is between zero and one.

2.7.4. Estimation of Scale Efficiency (SE) and the Nature of Returns to Scale

As put by Coelli (2008), TE scores obtained from a CRS DEA have been disintegrated into two components in various studies:

a. One due to scale inefficiency.
b. The other due to 'pure' technical inefficiency.

A measure of scale efficiency (SE) can be obtained by technical efficiency that is derived from CCR and BCC formulations.

Thus,

$$SE_i = \frac{eCCR_i}{eBCC_i} \tag{2.17}$$

Where SE$_i$ denotes the scale efficiency of *i*th car brand; $eCCR_i$ and $eBCC_i$ are technical efficiency measures for car brand *i* resulting from applying CCR and BCC formulations respectively. $SE_i = 1$ implies scale efficiency and $SE_i < 1$ implies scale inefficiency, which is as a result of either increasing or decreasing returns to scale. This therefore can be determined through inspection of the sum of weights under the CCR formulation:

$$SW = \sum_{i=1}^{n} \varphi_i \qquad (2.18)$$

Following Odeck (2008), SW = 1 indicates optimal scale of CRS, SW > 1 indicates decreasing returns to scale (super-optimal scale) and SW > 1 indicates increasing returns to scale (sub-optimal scale).

The calculation of SE may be done by conducting both a CRS and a VRS DEA using the same data. If the results show a difference in the two TE scores for a specific DMU (car brand), then this simply shows that the DMU has scale inefficiency. Hence, the scale inefficiency can be calculated from the difference between the VRS TE score and the CRS TE score (Coelli, 2008). This will be well illustrated in Figure 2.12 below where one input is used to produce a single output and where the CRS and VRS DEA frontiers have been drawn.

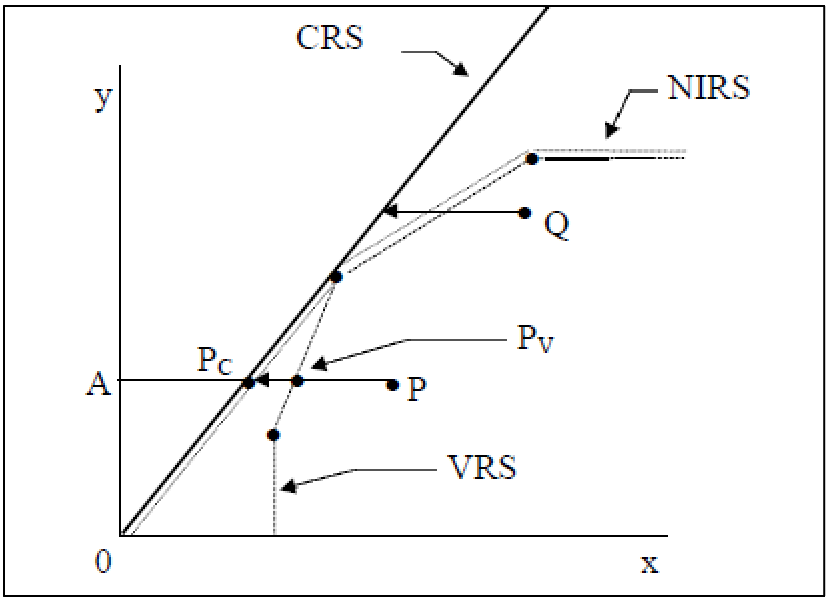

Figure 2. 12: Calculation of Scale of Economies in DEA (Coelli, 2008)

From this Figure, under CRS, the distance PP_C represents the input-oriented technical inefficiency of car brand *i* operating at point P, whereas under VRS, the technical inefficiency of car brand *i* operating at point P is the PP_V. Hence, the scale inefficiency is the difference between these two, $P_C P_V$. Take note that these can also be expressed in terms of ratios as follows:

$$TE_{I,CRS} = AP_C/AP$$

$$TE_{I,VRS} = AP_V/AP$$

$$SE_I = AP_C/AP_V$$

All these measures are bounded by zero and one.

Also, $TE_{I,CRS} = TE_{I,VRS} \times SE_I$, because $AP_C/AP = (AP_V/AP) \times (AP_C/AP_V)$

In this case therefore, the CRS technical efficiency measure is disintegrated into 'pure' technical efficiency and scale efficiency.

However, this measure of scale efficiency has a shortfall as its value does not indicate whether the DMU is operating in an area of increasing or the decreasing returns to scale. Fortunate enough, this may be resolved by running an addition DEA problem with non-increasing returns to scale (NIRS)[34], as shown in Figure 2.12 above. By evaluating whether NIRS TE score is equal to the VRS TE score, then the nature of the scale inefficiencies[35] for a particular DMU can be determined (Coelli, 2008). If they are unequal, as is illustrated by point P in Figure 2.12, then increasing returns to scale apply. On the other hand, if they are equal (as portrayed by point Q in Figure 2.12), then decreasing returns to scale exist for that DMU.

2.7.5. Slacks

A few difficulties in efficiency measurement can be caused by the piecewise linear form of the non-parametric frontier in DEA (Coelli, 2008). This problem comes in as a result of the sections of the piecewise linear frontier which run parallel to the axes (see Figure 2.9) which do not occur in most parametric functions (see Figure 2.8). Thus, this problem is well exemplified in Figure 2.13[36] below, where the DMUs (car brands) C and D (they use sets of

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[34] Non Increasing Returns to Scale (NIRS) won't be discussed in detail in this study as it is not relevant to this study

[35] These scale inefficiencies are due to increasing or decreasing returns to scale.

[36] Car brands represented by points A, B, C and D in Figure 2.13, relates to product variety as regards car market. Thus, all these car brands have different models that they offer to customers. Even though this is the case, these aforesaid brands being analysed are comparable in the sense that they use the same type of inputs to produce the same type of services.

inputs to produce outputs) are efficient and hence define the frontier whereas DMUs (car brands) A and B are inefficient. Therefore, the technical efficiency (TE) of car brands (DMUs) operating at points C and D, according to Farrell (1957), is defined as: OA′/OA and OB′/OB respectively.

Nonetheless, car brand *i* operating at point A′ raises some questions as to whether it is efficient since the amount of input X_2 used could be reduced by the amount CA′ and still produce the same output. This is therefore called *input slack*[37] in efficiency literature (Coelli, 2008). In Figure 2.13, CA′ of input X_2 is the input slack associated with car brand *i* at point A′. However, the identification of the 'closest' efficient point (e.g. car brand *i* at point C in this instance) and the consequent calculation of slacks is a complex task particularly when one is dealing with multiple inputs and outputs.

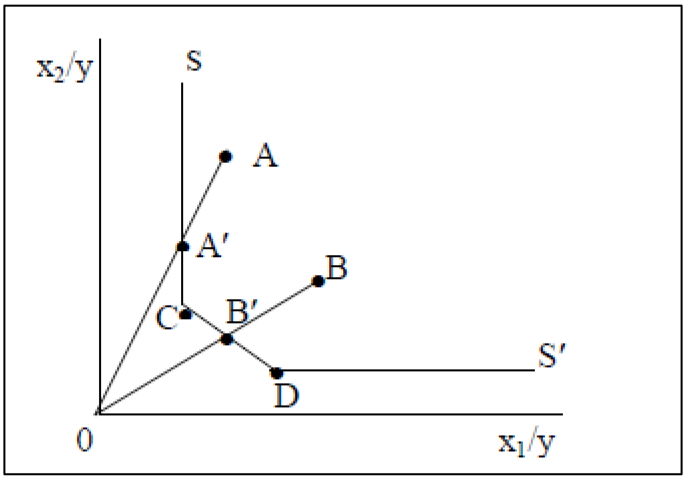

Figure 2. 13: Efficiency Measurement and Input Slacks (Coelli, 2008)

In contrast, output slack occurs in a case that involves more inputs and/or multiple outputs (refer Figure 2.14). Thus, DMUs (car brands) operating at points A and D lie below the efficient frontier and the sections of the curve, which are at right angles to the axes result in calculation of output slacks when a production point is projected onto those parts of the efficient frontier (curve) by an outward increase in outputs. For example referring to Figure 2.14, car brand i at point A is projected to point A′, which is on the frontier but not on the efficient frontier. This is because production of Y1 could be increased by the amount BA′ without using any more inputs. Hence, there is output slack in this case of BA′ in output Y1.

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[37] Input slack, in other books or articles, is also known as input excess.

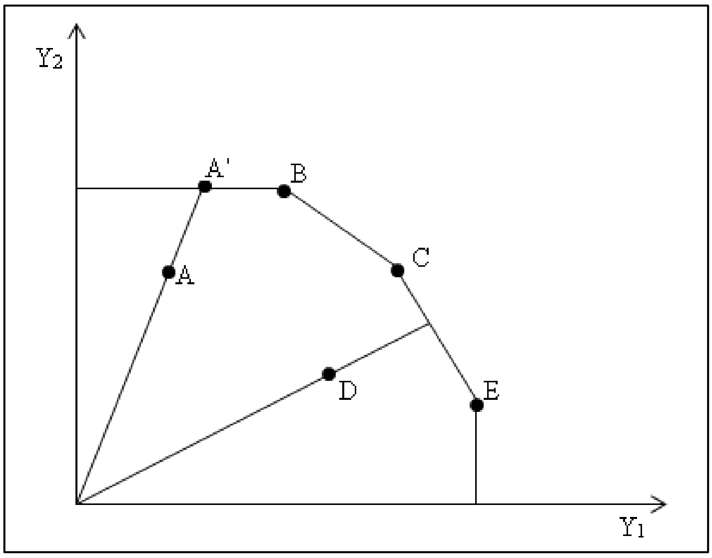

Figure 2. 14: Output-oriented DEA. Own illustration based on (Coelli and Netlibrary, 2005)

The conclusion can thus be drawn from this that both Farrell measure of TE and any non-zero input or output slacks should be reported in order to have a precise indication of TE of a DMU in a DEA analysis[38]. For more details on mathematical programming approach to efficiency analysis especially that of slacks, refer to Ali and Seiford (1993).

2.8. Chapter Summary

In this chapter, product differentiation theory and production theory, which are the key theories for this study, are presented. In product differentiation theory, different car brands are offered/sold by competing firms/dealers as a way of being unique and gaining competitive advantage in the market. Thus, by differentiating themselves, such firms/dealers are able to defend their price from levelling down to the bottom part of the price spectrum as well as preventing other firms/dealers from providing the same products to the same consumers. In theory of production, the most central principles by which firm decides the input factors that it will employ during the production process in order to get a certain quantity of firm's outputs is explained. The next chapter presents an overview of product variety in general and in Norwegian passenger car market.

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[38] This supports Koopman's (1951) definition of technical efficiency (TE) which was stricter as compared to Farrell's (1957) definition. Thus, Koopman argued that a firm is only technically efficient if it both operates on the frontier and made sure that all associated slacks are zero.

CHAPTER 3

PRODUCT VARIETY – AN OVERVIEW

3.1. Introduction

In the previous chapter, a review of the relevant literature on product differentiation and production theories was presented. This chapter discusses an overview of product variety in Norwegian passenger car market. Thus among others, definition, dimensions, sources of product variety, product offering, will be discussed.

3.2. Product variety

The practice of product variety, which is replacing the market of yesterday, has become a buzzword among researchers, and many companies across different industries. They have now pushed the task of accommodating product variety into their strategy. For example, the aeroplanes, medical device, retail, and automotive industry offer such a large range of combinations of product features that millions of variants of a single product are possible (McKay et al., 1996). Apparent reasons for increasing variety in today's businesses arise from factors such as internationalization of the market, the growing sophistication of customers, economic changes, evolving technology, and shorter product life cycles (see e.g. Clark and Fujimoto 1991; Ramdas 2003; Vaagen and Wallace 2008 and Gagnon, 2007). MacDuffie et al., (1996) propose to use a framework upon which product variety is divided into two factors; the external driven-forces "pull" and the internal driven-forces "push". "Pull" comes into view when customers reward companies that offer high variety while matching the price and quality of competitors with narrower product lines. On the other hand, "push" emerges when there is an incentive for companies to increase their variety as a result of new technologies and programmable automation. Before discussing different aspects of product variety into more details, let us first define product variety.

3.2.1. Definition of Product variety

Constructing a definition of product variety is not a straightforward matter, since definitions are often coloured by the detailed specification of variety, type of industry and various aspects that are taken into account (Southey and George, 1998). For these reasons product variety is defined in twofold: broadly and narrowly. In the broad sense, product variety is defined as the number of product groups corresponding to the number of brands or the number of models (Nguyen, 2010). In the literature on the consumer durable goods, product variety is defined as the number or series[39] of options of products offered by a firm to customers at a single point in time (Randall and Ulrich, 2001).

However, other authors[40] have proposed similar definition but in a narrower sense. Ramdas (2003), for instance, defines product variety as company’s commitment to achieve more economic benefit and enhance consumers’ value by offering a wider spectrum of choice, differentiating more features and functions (variants), and tailoring products for customization to customer preferences. Moreover, Vaagen and Wallace (2008) define the term product variety as the number of variants[41] within a specific product line. They also underline that the essence of product variety is to break down the overall product variety to the level where the market dynamics is comparable across business units. Consistent with the statement of the above authors, Erens and Wortmann (1995) affirm that the large set of options offered to consumers can take the form of either “add-on” gadgets sold with the main product or as compulsory choice in determining the nature of the main product to be delivered. This is a common practice in the car market, for example, VW dealers sell Jetta-models without Bluetooth option. So, they charge for add-on if customers want it in their vehicle.

Considering the aforementioned definitions and the purpose of the study on Norwegian passenger car market, product variety in this thesis is defined as number of options based on functions of a product offered by a car brand. The functions in this study are measured on the number of models, type of chassis, type of fuel, engine displacement, and horsepower.

3.2.2. The Dimensions of Product Variety

Having defined product variety in the previous section, we will now look at common dimensions of product variety in the interdisciplinary body of literature. Ramdas (2003) refers the dimension of variety as the differences in physical form and product function. Pil

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[39] Number or series of options could be based on product characteristics such as form, feature, style, technology, functionality and materials (Park, Velicheti, and Kim, 2005).

[40] For more details on definition of product variety, see ElMaraghy et al., (2012); Thonemann & Bradley (2002) and Chakravarty & Balakrishnan (2001).

[41] In the context of product variety, the term variant is defined as an instance of a class that exhibits differences within the product lines.

and Holweg (2004) extend the work of Ramdas (2003) by stating that dimensions help to understand the role of variety in the value chain. Figure 3.1 shows a proposed framework of dimensions of variety that aid to illustrate the essence of product variety (see MacDuffie et al., 1996; Holweg and Pil, 2004, and Randall and Ulrich, 2001).

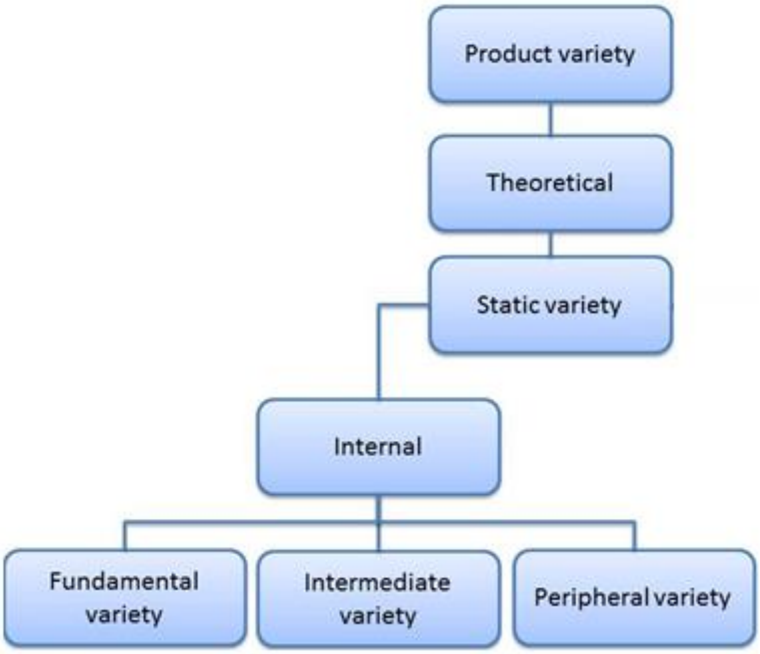

Figure 3.1: Framework of product variety dimension: Internal, external & dynamic variety (MacDuffie et al., 1996)

As shown in Figure 3.1 above[42], the theoretical dimension is characterized as the static variety. The static variety refers to stationary and wide variety of products that can be offered at an instant of time (Kohlberger et al., 2006). Static variety can be classified into two types, viz. internal and external variety. The external variety will be omitted as it is beyond the scope of this study. Though, we would like to emphasize that the practice of this variety is just as important as the other, and may be relevant for other study purposes.

3.2.2.1. Internal Variety

Internal variety refers to business practices that handle range of different variants. The internal variety consists of three subtypes; namely, fundamental, intermediate and peripheral variety. A well-established internal variety enables businesses to enhance their external variety, which is very often considered to favour the increasing of process complexity

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[42] It should be noted that the chart flow as shown in Figure 3.1 has been modified from the original idea derived from MacDuffie et al. (1996) for the simple reason that the study only focuses on one part of the product variety dimension.

(Scavarda et al., 2010). Typically, the practice of any of these aforementioned subgroups is often noticeable in the car market. Thus, any examples used in this section will therefore refer to the car market from the car dealer's perspective.

Fundamental, Intermediate, and Peripheral variety

Fundamental variety occurs when the distinct variety is given by different models in a range. For instance, these may be based on the number of models, type of chassis, type of fuel, engine displacement, and horsepower. Intermediate variety refers to components variation or combinations as regards the number of models, engine, chassis, among others. These elements may have negative impact on business practices of car dealers. The peripheral variety is the number of the add-ons to the products without a change in the fundamental variety, for example colour, headlights, window tinting, radio-stereo, among others. (MacDuffie et al., 1996). In other words, consumer choice is the one that determines the level of the supplementary elements (Kohlberger and Gerschberger, 2006). In this case, it may be said that the options for each product are weighted by their cost, and the total cost of options as a percentage of selling price is calculated. This assumes that the price of the option reflects the amount of labour required to install the option.

3.2.3. Sources of variety

The preceding sections have focused on the definition and dimensions of product variety. In this section therefore, we will be looking at the major sources that cause increasing variety, which are derived from the literature. A number of researchers have revealed that over the past few years, companies have experienced an explosion in product variety (see e.g. Schaars, 1998, and Prenkert et al., 2009). Cooper and Griffiths (1994) identified class/segment as one of the core sources that increases product variety in the car market. Nevertheless, it is noteworthy to mention that these sources can also be found in other markets.

Consumers seem to like having so many choices among products. It is therefore crucial that car dealers create separate offers for each class/segment in order to fulfil an increasing number of finely differentiated needs. To put it another way, a market with numerous segments may result to a higher variety. Let us take a car brand such as Nissan as an example. In Europe, Nissan offers several different car models for different segments such as sport, large family car, and others. Within each segment, we find different models such as the

100NX, 200SX, and 300ZX models, which target different market niche. This being the case, car manufacturers like Nissan end up having a higher variety in view of the fact that different class/segment of vehicle has different design requirement, and performance attributes.

Yet, Kohlberger et al., (2006) argue that the identified source comes from the internal parameters, and suggest several different external sources which according to them are sometimes overlooked. They identify rapidly evolving technologies and shorter product life cycles as external sources. Similarly, Berry and Cooper (1999), assert that these sources favour increasing variety.

3.2.4. Impact of variety on performance of companies

It is unarguably that variety has had an impact on company's performance even though the impact of variety has been controversial in the marketing and operations management literature (Wan et al., 2012). Furthermore, saturating the market with a large number of varieties is associated with the drop in sales, which in turn diminish the profits (See e.g. Schwartz, 2000, and Osnos, 1997). For instance, Proctor & Gamble Company reduced the number of versions of Head & Shoulders, one of its very popular shampoos, from a staggering 26 to 15, resulting in a ten percent increase in sales. MacDuffie et al., (1996) claim that product variety has two-fold impact on company's performance. Thus, on one hand, many view variety as a "necessary evil" for the reason that it promotes complications in the operations, exerts a steady downward pressure on profits and increases costs.

In terms of costs, Cooper and Kaplan (1999) present the activity-based costing (ABC) systems to measure variety-related overhead costs, and note that variety has an impact on the fixed costs (e.g. setting up a machine) and product-sustaining activities. Their explanation is that more product variety requires companies to reduce their output units; consequently, it evokes a higher unit cost as the fixed and product-sustaining activities costs are written off over fewer units. Forza and Salvador (2002) comply with the above statement affirming that, "Suppliers may experience diseconomies of scale due to component variety caused by high variety, with potential negative impact on component prices, and delivery times".

Furthermore, Miller and Vollman (1985) identify logistical, balancing, quality and change transactions to be affected by product variety. Similarly, Fisher et al., (1995) conduct a field research in the automotive industry, and conclude that product variety can impact number of transactions in each of the aforesaid groups. For instance, more parts and lower volume per part in light of high variety increase the coefficient of variation in demand for a particular part and increase the risk of stock-outs. Stock-outs incur additional costs such as labour needed to expedite parts, and quality problems caused by stock-outs. Productivity per worker is also affected in presence of high variety as the risk that a worker chooses the wrong part is significantly higher when customizing cars at the dealer's level, and this may result in lowering the man-hours per unit.

In contrast, the Toyota Production System (TPS), developed by Toyota Motor Corporation with the main purpose to eliminate the negative consequences of increased product variety on the company's performance, is a good example that car dealers can learn from, despite the fact that it is mostly used in manufacturing. Toyota has achieved cost reductions and improvement of productivity in the manufacturing phase by using various techniques of TPS (Monden, 1993). As far as cost reductions are concerned, the system focuses on completely eliminating waste. The four major sources of waste identified in Toyota plant were excessive production resources, overproduction, excessive inventory, and unnecessary capital investment. All four sources have negative impact on costs such as direct or indirect labour costs, administrative costs, overhead costs, and others. In order to address the aforesaid sources of waste, Toyota has established a method that controls the quantity of production; ensure the quality of products, and shows respect for humanity.

TPS is used to address the excessive production resources, for example when there is an excessive workforce that creates idle time[43], by re-allocating work operations. Consequently, labour costs are reduced and other related costs caused by other sources of waste are also reduced. Besides, Toyota uses other techniques such as Just-in-Time[44] (JIT) and Automation[45] to eliminate waste completely from the production.

Toyota employs a system named Kanban, which helps to support JIT. Kanban is a system that manages the JIT production method by harmoniously controlling the production quantities in every process, which make use of information system (Monden, 1993). For instance, within Toyota plants Kanban is attached with two card tags. One card is for withdrawal, it specifies the quantity which the succeeding process in the production line should withdraw, and the other card is for production ordering, it shows the quantity which the preceding process must produce. These cards circulate between Toyota and its many cooperative companies. By

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[43] Idle time refers to waiting time for a worker to perform subsequent task

[44] Just-in-Time means to produce the necessary units in the necessary quantities at the necessary time.

[45] Automation refers to autonomous defects control.

doing so, Toyota has the flexibility to adapt whenever there is a change in production quantities.

However, Kanban also makes use of the following sub-systems or methods to support Just-in-Time: smoothing of production, reduction of setup time, design of machine layout, standardization of jobs, and improvement of activities.

According to Monden, (1993), the smoothing of production in Toyota plants is used to minimize idle time in regard to manpower, equipment, and work-in-process (WIP). Smoothing of production is intended to prevent fluctuation in production. For instance, if the subsequent process withdraws parts in a fluctuating manner in regard to time or quantity as a response to increased product variety (e.g. when a new model is launched), then the preceding process should adjust accordingly in terms of inventory, equipment, and manpower. Thus, Toyota plant, specifically in the assembly line of finished cars, must be able to produce and accommodate each type of automobile according to its own time interval within which one unit of the car can be sold on average. This time span is also known as takt time. Production smoothing has played a key role in Toyota plants in light of product variety. First of all, the system has enabled Toyota plants to adapt rapidly to variation in daily demand by equally producing various kinds of car models every day at a constant and predictable rate. Secondly, it has allowed Toyota to hold an optimal balance during the production process and eliminate inventories of work-in-process.

Shortening Setup time under the normal circumstance is obtained through continuously using one type of die, thereby producing in large batches and reducing setup costs. However, this method is not feasible or effective in higher product variety environment. Toyota is one of the first that has been able to shorten setup time under higher variety through TPS. For instance, in Toyota plant the final process has averaged its production and tried to reduce the stocks between the punch-process and its subsequent body line; the pressing department, which is regarded as a preceding process, makes frequent and speedy setup. Consequently, the types of dies for the press corresponding to a great variety of products are altered, and are withdrawn often by the subsequent process. As a matter of fact, this sort of practice has been beneficial for Toyota given that they have been able to reduce the setup time of the pressing unit from three hours to three minutes during the period of 1945 to 1970.

Traditionally, the layout or design of machines such as lathe, milling machines and drilling machines in a plant are laid side by side, and one machine is handled by one worker.

However, Toyota has done it differently with the TPS as the layout is arranged in a way to smooth the production flow thereby assigning each worker to perform a multi-process handling[46]. In a multi-process handling line, work at each process can only proceed when the required task is completed within a specified takt time. Because of this, the introduction of each unit to the line is balanced by the completion of another unit of finished product, as planned in the operation of a takt time. Some of the benefits of this method for Toyota are that it can decrease the number of workers needed, increase productivity, and allow workers to engage in teamwork. It is also worthwhile to note that Toyota has heavily invested in skills development of workers so that they become multi-functional worker.

Improvement of activities is one of the fundamental principles of which TPS is based on. In Toyota plant, the quality control (QC) circle[47] is given the chance to suggest improvement of production processes, which may be a response of increased product variety. The improvements can be in terms of quality assurance by avoiding recurrence of defective works and machine, in quantity control by adopting a method that frequently reviews the standard operations routine to changes in takt time and in respect for humanity by allowing each worker to get involved in the production process.

As noted earlier, TPS supported by JIT and Automation. These supportive components are not mutually exclusive. This implies that one cannot be realized without the other. Since we have just discussed on how Toyota uses JIT, let’s now look at the second component of TPS, Automation. Automation is defined as developing a mechanism that prevents mass-production of defective work in machines or product lines, but the autonomous detects the abnormality in a process. For example, in Toyota plant almost all machines are autonomous so that mass-production of defects can be prevented and machine breakdowns are automatically checked. This is also known as mistake-proofing. With regard to product variety, Toyota has effectively used improvement activities method to increase its variety (in this context it refers to vehicle models), while holding the cost low.

3.2.5. Product variety and dealers in the car market

Dealers play a major role in the automotive industry supply chain. Thus, they are located far in the supply chain downstream, see Figure 3.2 below. As put by Verhoef et al. (2007), in

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[46] Multi-process handling refers to a worker that handles several machines simultaneously.

[47] The quality control circle refers to a small group of workers in Toyota plant

many markets, manufacturers use dealers as intermediaries in selling products. The same applies for the car market where once the production and assembly of automobiles is completed; the finished cars are then shipped to dealerships around the world to be sold to the customers.

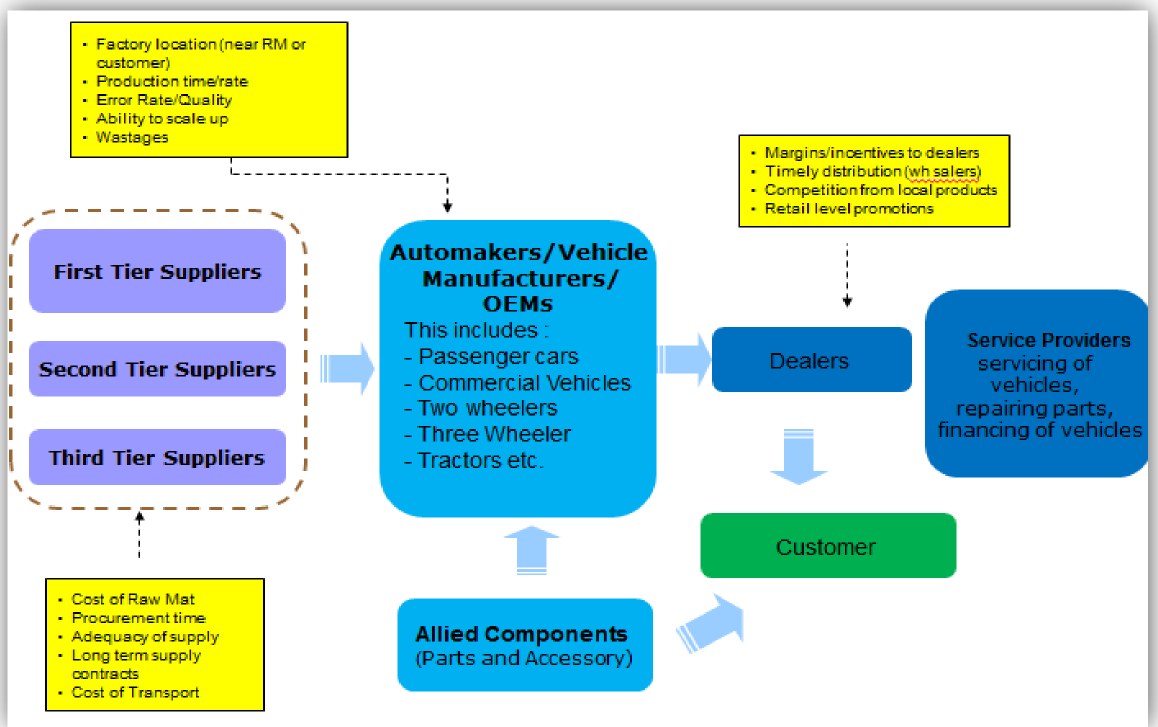

Figure 3. 2: Automotive Industry Supply Chain (Bodas, 2012)

Automotive industry is one of the industries with a complex supply chain due to its manufacturing of high complexity products in high volume. For example, “a typical automobile is made up of 20,000 detailed parts with approximately 1,000 key components coming together at assembly” (Thomas, 2010). Today automotive sector is not just about manufacturing vehicles, it also consists of multiple tier suppliers and business partners. As shown in Figure 3.2 above, first tier supplier is responsible for assembling parts into complete units like dashboards, brakes-axle-suspension, and sears. Second tier supplier is in charge for designing vehicle systems or bodies for first tier suppliers and Original Equipment Manufacturers (OEMs). Some of their services may comprise welding, bending, fabrication, among others. Third tier suppliers provide basic products like glass, steel, aluminium, and rubber to the second tier suppliers.

Whereas OEMs conduct market research first on consumers' wants and needs, and begin designing models which reflect to consumers' demands. In general, they have manufacturing units where engines are manufactured and some other parts from different tiers are assembled. The finished products (vehicles) are then shipped to different branches, and from there to the authorized dealers of the companies, which in turn sell the vehicles to the end customers. Allied components companies' provider sells additional products such as tyres, windshields, and GPS, among others, to OEMs, dealers and/or end customers. Additionally, there is also provision of vehicle services which include repairing parts, and financing of vehicles.

3.2.6. Managing product variety

There is a saying which goes like "we must learn to walk before we can run", and it means that we must first of all master the basic skill before we are able to learn more complex things. This can be worthwhile for companies that use product variety as part of their strategy. Toyota's case, described in prior section, is a good example to use in this situation. According to literature, managing variety has become one of the key determinant factors for the success of businesses amongst others owing to the fact that an optimal variety and effective management plan may have a leg up on the competition. In fact, just increasing variety without a proper management plan is the same as having water up to the throat. This can be interpreted as the chance for succeeding with variety strategy is significantly lower. Equally, Roy et al., (2011) quoted that management of complexity arising from high levels of product variety has become a critical problem in the automotive and many other industries because it is often associated with increasing cost.

In all the cases mentioned above, a clear understanding of managing product variety is the cornerstone for proposing effective alternatives. Managing product variety can be described as the need to find the best balance between additional costs and revenue or find a point where the difference between the revenue and costs curve is at its greatest. Managing product variety involves more than just determining the level of variety to offer to customers, it also deals with other decisions such as the number of product variant characteristics to provide, the frequency of product releases, product lifecycle to prevent the problems attached to obsolete products, the point where products differentiate, and many others. There is a significant amount of literature that concentrates on managing product variety, and this can be broken down into the following subgroups: product offering, option bundling and optimal level of product variety (see e.g. Pil and Holweg, 2004; Abdelkafi and Blecker, 2006; Scavarda et al., 2010; Salvador et al., 2002 and Appelqvist and Gubi, 2005).

3.2.6.1. Product offering

For example, Roy et al., (2011) have classified three key sets of decisions that should be taken into consideration when managing product variety. Thus, these include product offering, product design and process design. The authors claim that these key sets of decisions are interconnected, and should therefore be treated simultaneously. However, product design and process design will not be discussed in this study as they are irrelevant to the study's objective.

Product offering mainly focuses on the level of the variants in a product. Today, the number of variants in a vehicle from which customers could configure double or perhaps triple annually. Tanner and Alders (2003), for instance, reported that buyers of BMW 7 series were offered 10^{17} permutations[48] to configure their vehicle.

Prajogo and Olhager (2012) suggests applying lean manufacturing in the upstream operations as forecast is based on generic level, and maximizes efficiencies, while applying agile manufacturing in the downstream operations. Figure 3.3 below illustrates a framework on how the decoupling point divides these two components. When reflecting this concept in the automotive industry, lean manufacturing could be applied in the assembly line, the decoupling point in the semi-finished assembly line, and agile manufacturing at the dealers' level. The latter element is suitable to apply it at the dealers in view of the fact that they interact directly with the end customers. A competitive advantage could be gained as dealers can increase variety accordingly with the market needs without incurring higher costs or increasing complexity.

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[48] 10^{17} permutations refer to total number of variants in a car model offered to customers worldwide.

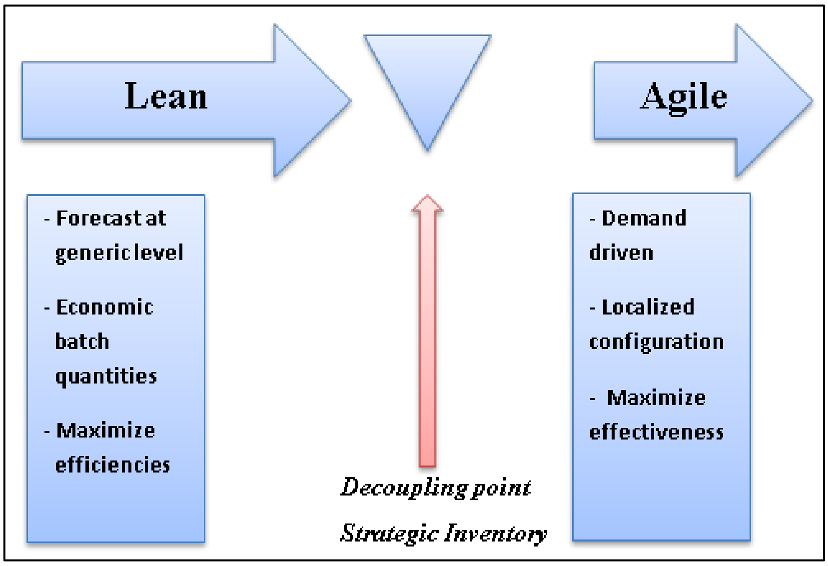

Figure 3. 3: The decoupling point. Source: Christopher and Towill (2001)

3.2.6.2 Option bundling

The practice of bundling or module options has been increased in the car market over the last few decades. The proponents have claimed that option bundling reduces forecast error, and thus the obsolescence risk of stock (Batchelor, 2000). Furthermore, it has been argued that offering options as coherent bundles has simplified the whole distribution system as compared to offering all possible permutations of options. Renault has proven that option bundling helps to reduce variety offering. For example, when comparing Renault Megane Classic with Ford Focus Saloon, we see a clear difference between these two models. Renault offers five power trains, 10 colours, and four trim levels. It tightly packs the options into 18 power-trains, trim combinations, resulting in a total choice of 870 variations out of a total 26,214,400 possible combinations. In contrast, Ford, which uses permutations of options, offers eight power trains, 12 colours, and two trim levels. This results in a total choice of 5,898,240 variations out of 75,497,472 variations (Pil and Holweg, 2004). We may say that option bundling help car dealers to mitigate the negative effect of variety.

3.2.6.3. Optimal level of product variety

As revealed by a number of authors, the complexity from increased product variants has a direct effect on the cost. For instance, Mather (1988) states that an increase in variety tends to raise the cost in an exponential manner, and flattening out the revenue. On the other hand, Roy et al., (2011) argue that a poor analysis carried by a firm can result to underestimation of costs and overestimation of revenue. Hence, they suggest that a company chooses an optimum level of product variants whereby the profit is maximized. In order to achieve this optimum level, it is important to make a distinction between complexity and variety. In the context of optimal level of product variants, variety is defined as customer expectation in the product offer whereas complexity is defined as "the effect on the internal operations, which is dependent on the capability of the organization to implement various complexity reduction methods". As one can note product variety is the driver of complexity, hence, we can assume that product variety equals to complexity. Based on the definitions provided above, we define optimal level of product variety in this thesis as car dealership's ability to meet customer expectations by offering them a wide range of variety (different models of cars) while applying internal flexibility.

Roy et al., (2011) have graphically showed how this optimum point can be obtained (see Figure 3.4). A slight modification was made in the graph in order to reflect it with the study objective, though the core idea remains unchanged.

When offering variety with unprofitable variants, we see in the graph that company's revenue and cost are at point R_1 and $C_{1,}$ respectively. Thus, profits are the difference between R1 and C1, which is represented in the graph as $P_{1.}$ However, removing these unprofitable variants from the product offer may result in an increase in revenue and cost reductions for the reason that there is less complexity. As shown in the graph, the new revenue and cost in the graph are at points R2 and C2, correspondingly. In short, the gain from reducing these complexities in terms of revenue, costs, and profit can be written as following

$$R' = R_2 - R_1 \tag{3.1}$$

Where R' denotes the revenue gained after reducing the complexity in manufacturing costs, R_2 is the new revenue after complexity reduction.

$$C' = C_1 - C_2 \tag{3.2}$$

C' denotes the gain from reducing cost. Where C_1 is the initial cost and C_2 represents the cost after complexity reduction.

$$P' = P_2 - P_1 \tag{3.3}$$

Where P' represents the gained profits, P_2 is the new profit after the complexity reduction, and P1 is the initial profits.

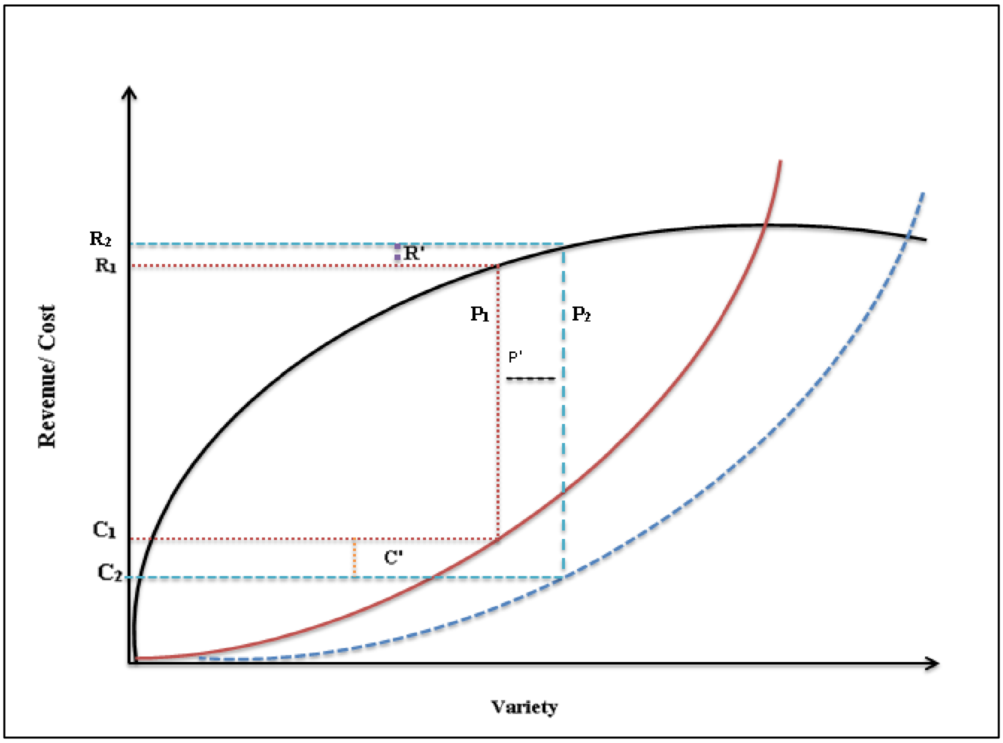

Figure 3. 4: Cost of Variety versus revenue from variety: Strategic options. Source: own illustration

3.3. Chapter Summary

The literature review on product variety above has covered numerous aspects of variety from basic to more complex concepts. As far as one can see, literature leaves some aspects of variety open to interpretation. For example, literature reveals that variety and company performance are unquestionably somewhat interconnected. Few researchers have been using the qualitative approach to prove the magnitude of product variety; unfortunately there has been controversy due to lack of empirical evidence and subjectivity. However, quantitative approach appears to be appropriate to answer some of the ongoing controversial debates in literature as the findings are empirically tested, and objective. In the consequent chapter, the research methodology of the study would be presented.

CHAPTER 4

RESEARCH METHODOLOGY

4.1. Introduction

This chapter presents a discussion of methodological issues relevant to this study. It provides an insight of the research philosophy, research design, data collection and data analysis. Moreover, it also discusses data collection strategies and finally but not least how these methodological issues were addressed in this study.

4.2. Research Philosophy

The quality of the outcome of the research might seriously be affected if the researchers do not put the philosophical nature of the research into consideration (Easterby-Smith et al., 2004). Thus, with the use of philosophical assumptions, the researchers will be able to choose the right research strategies and techniques, thereby helping the researchers identify and create the unknown research designs. Moreover, through understanding of the characteristics of diverse philosophical paradigms[49], the researchers may be able to foreknow the research design which may either work or not. While several authors (Hughes, 2001a; Mackenzie and Knipe, 2006; and Ates, 2008) have recognised quite a number of research paradigms, Kumar (2005) proposes the two main paradigms that form the underpinning of research in the social sciences. Thus, these include; the positivist approach and the interpretivist (naturalistic) approach. Echoing Easterby-Smith et al., (2004), these two[50] aforesaid paradigms are also known with other terms, thus for example the positivist is also referred to as quantitative, objective, traditionalist and experimentalist or scientific. On the other hand, interpretivist is also termed as qualitative, subjective, revolutionist, phenomenological, humanistic or social constructionism.

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[49] “A paradigm is a comprehensive belief system, world view, or framework that guides research and practice in a field” (Willis, 2007: 8). Putting differently, a paradigm represents a theoretical framework, within which research is conducted (Beech, 2005).

[50] In this study, only two comparable paradigms are considered. Actually, as Ates (2008) puts it, there are many paradigms in the literature namely; positivism, critical realism/relativism, interpretivism and action research.

Positivist paradigm, according to Easterby-Smith et al., (2004) and Scholarios (2005), proclaims that real events can be observed empirically and explicated with analytical/deductive analysis. Thus, the positivist paradigm lends itself to the use of quantitative methodology as it leads to a scientific and systematic approach to research. Usually, but not always, researchers that use a quantitative methodological approach concentrate on the confirmatory[51] stage of research in order to measure, quantify or find the extent of a phenomenon. Following Kumar (2005), the quantitative methodological approach is described as a structured approach whereby before data collection begins, all aspects of the research process are decided upon.

On the contrary, the interpretivist paradigm does not only take an 'open minded' approach but it also starts from data rather than a literature based theory or hypotheses to be tested out Additionally, as a way of overcoming generalisability critiques, interpretivist researchers study the phenomenon in depth and usually engage in extensive conversations, observations and secondary data analysis (Easterby-Smith et al., 2004: p40). Nevertheless, such researchers do not aim to generalise things but instead they appoint to a deeper understanding of meanings in data analysis. This paradigm, as argued by Beech (2005), deals with different contexts through sense making (subjective) rather than the objective real world.

Based on the discussed arguments of the scholars, this study follows the positivist paradigm as regards the philosophical direction. The work is based on two already established theories from the literature; product differentiation and production theories. Identified variables will be measured using a non-parametric approach Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI). Besides, this study is following a quantitative methodological approach where the research techniques that measure and quantify data are used as shown in stage-one analysis [52] followed by an application of truncated regression analysis in stage-two analysis[53].

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[51] The confirmatory stage refers to a point when a researcher starts with a theory about why a certain phenomenon is occurring and then formulates a prediction based on that theory (Johnson and Christensen, 2008).

[52] Here DEA method and Malmquist index is used in measuring the relative efficiency of Norwegian car passenger market and how the changes in productivity of this aforementioned market by time can be observed. There is no testing of hypotheses in this one-stage of DEA analysis as DEA does not allow testing of traditional hypotheses.

[53]This is the two-stage analysis of DEA where we are evaluating whether the differences in the efficiencies of Norwegian passenger car market can be explained by product variety (or not) and other factors. Truncated regression analysis will be done here. See detailed explanation of these stages in the following chapter.

4.3. Research Design

Research design is considered the backbone of good research owing the fact that it directs the study to develop techniques for data collection, defines the statistical analysis of the resultant data, and guides the interpretation of the results without any ambiguities (Knight et al., 2010). As stated by Knight et al. (2010), a poor designed research framework raises some confusions for readers to sketch out the variables in the margins of the paper as they try to understand how variables are related, or understand which variables were collected and when. Saunders et al., (2009) used an “onion” to illustrate the overall methodology, in which he considered the research problem to lie in the centre and thus several layers have to be “peeled away” before coming to this central position. These layers should be considered as the core aspects when determining the research methodology for a particular study. Consequently, research philosophy (as already discussed in section 4.2 above), approach, strategy, choice, time horizon, and techniques were the layers identified.

Although research might initially seem like a simple gathering of information, it is essential to understand different types of research design that may help identify the purpose of the study. In this thesis, a descriptive research case study will be applied for the following reasons:

- It is intended to describe the efficiency and productivity of the Norwegian passenger car market. In addition to this, it will also describe the impact of product variety on efficiency and productivity in the market by employing prior knowledge that has been acquired from literature of the automotive industry in general.
- It will assess whether there is an interconnection between variables (as discussed in the succeeding chapter) given that key variables[54] are already defined. Hanson et al., (2005) favour the idea of using descriptive research when key variables are pre-defined in the study owing the fact that descriptive research helps to understand why the world works the way it does through the process of proving a causal link between variables and eliminating other possibilities.

Since descriptive studies primarily concern with finding out “what is” happening, it is incontestable that this approach will be suitable for this study.

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[54] Key variables refer to a changing component for which the effects of the change will be measured.

Studying the car market with the purpose of assessing efficiency, observing by time the changes in productivity of this market and describing the impact of product variety on efficiency and productivity involve some amount of complexity, which may not be a straight forward matter. In order to reduce the level of complexity and gain a deep understanding of the phenomenon in the market, this study has therefore chosen to merely concentrate on a case study based on the Norwegian passenger car market.

4.4. Data collection

Data collection is a term used to delineate a process of organizing and collecting data systematically for a specific purpose from several sources that has been observed, recorded or organized. Thus, the choice of method is influenced by the data collection strategy, the type of variables to be measured, and the source (Lyberg and Kasprzyk, 1991). In general, data is divided into two categories; namely primary and secondary data. Primary data is defined as data that has not been previously available, and which have been obtained directly by the researcher by means of surveys, observation or experimentation in order to achieve the objective of a particular study. In contrast, secondary data are data that have already been collected for other purpose but have some relevance and utility for the research carried at present (Hox and Boeije, 2005). Besides the aforementioned types, data is also differentiated by its sources. The most common used data sources are internal and external sources[55] (Bryman and Bell, 2011). In this study, however, external secondary data will be used. Next, we will discuss the approaches used in this study to collect data.

4.4.1. Data Description

Collecting quantitative data about the Norwegian passenger car market was not a straightforward matter, and was difficult than anticipated. Car dealerships' data is the backbone of the analysis in this study given that not a single car is manufactured in Norway, and understanding the business practice of these car dealers with their subsidiaries was one of the main obstacles when collecting data. Given the high level of complexity and scope that exists in the Norwegian passenger car market, we could not unfortunately include all brands in our analysis. Thus, we restrain our sample size apropos car brands, and use mixture techniques in our data collection. Naturally, this will enable us to assess whether the sample

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[55] Internal sources include data that exists and is stored inside the organization , whereas external sources are data that exists outside the organization

drawn in our analysis is large enough to represent the population, and provide unbiased results.

In this study, all the data used are from 2008 to 2012. This five-year period was chosen as it is the period with complete and most reliable data for all the selected car brands. Thus, we could not include 2013 in our study for the simple reason that not all data were available for all the brands, hence dropped.

Due to the nature of the study (DEA analysis), data collection is processed in two stages, viz. stage-one and stage-two. In stage-one, we establish a prerequisite when collecting data about car dealerships. One of the main criteria used was to select dealers that were franchised by brands, and operate for a single brand. By doing so, double counting in the data is avoided and this will enable us to make a fair assessment between brands.

In pursuance of the criterion adopted, we selected 34 bestselling car brands in Norway based on the ranking released by Opplysningsrådet for Veitrafikken AS (OFV) according to quarter one of 2014. Following our brands selection, we consulted several sources to collect financial information about car dealers, and crosscheck the data. Based on our aforementioned criteria, only 21 brands qualified for our sample test, and the remaining brands were removed because of the following reasons:

- They did not meet our criteria of having one car dealership exclusively operating under their brand name (e.g. Renault, Mini, Smart, Dacia, among others). For the most part franchised car dealers operate under multiple car brands.

- Few car dealers (e.g. Tesla) did not have sufficient information for all years of observation (2008-2012) or in some cases financial reports were not made readily available to the general public.

- The financial reports for some brands, in particular Mazda and SsangYong contain significant costs fluctuation in several years of observation, which might negatively influence the results. For the fear of getting the wrong results, both brands were removed from our samples test.

This implies that our study consists of about 62% of the total bestselling brands in Norway. This number is more than sufficient to give conclusion or information on how these car brands perform in general. Nevertheless, since this number represents only part of the total bestselling brands, it is important to take caution regarding the conclusion drawn from this. We therefore advise extra care in interpreting these results.

After having decided which brands to include in our sample, our following step was to start collecting financial information about dealers of the selected brands. First, we adjusted the obtained financial data[56] about the dealers according to the consumer price index (CPI) as fluctuating prices distort the economy's price signals, and can result in the misinterpretation of results. However, it should be noted that for calculating the CPI we used the year 1998 as our base year.

Another challenge that arose for the data collection was to find the exact selling price for each model during the periods of observation since this information is used to compute the total sales. However due to time constraints and limited resources, it was difficult to obtain this kind of information. Instead, we estimated the selling price by calculating the median[57]. In order to find the median, we first identified all models of each brand (twenty-one brands in total) derived from the sample (see Appendix 3a). We then looked up the selling prices of each variant[58] that fell under a single model in a particular year[59] and have their median calculated. This median represented the selling price of each corresponding model. We then used the calculated median representing the models to calculate the median for a single brand (i.e. Audi). That calculated median therefore is a representative of a selling price of a single brand in a particular year. Finally, in order to find the total sales of car models, the total number of vehicles imported in a particular year was multiplied by the approximated selling price of the brand (median used to represent a brand). The same sequence was repeated for all years of observation. It is important however to note that number of variants of each model were different in some years and so were the prices. This variation implies product variety, thus, the recent the years, the more different and new models were imported.

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[56] Financial information in this study , which is used as inputs for our analysis, refers to as labour cost, capital cost, depreciation and other expenses

[57] Median was chosen over average in calculating selling prices of car brands due to the fact that it is the appropriate measure to describe the central tendency of data for this study. Bearing in mind that our data are not symmetric (since average is greater than the median implying that distribution of selling price is right skewed) , median becomes the correct measure which best summarises our data. Otherwise, average would have been an inappropriate measure in this case for the simple reason that it only represents symmetric distribution of data and is easily influenced by outlying measurements (Newbold and Carlson, 2013).

[58] Number of variants for each model was approximately between 10 and 194, see Appendix 3a.

[59] The years of observation for this study are 2008-2012. Hence, selling prices of variants were calculated annually, e.g. 2008 first and this process was repeated for all the five years.

Unlike stage-one, the process and criteria defined for the data collection in stage-two are different to some extent since the focus of our analysis at this point is to run a regression. Thus, product variety (measured by number of models, fuel, chassis, engine and horsepower types, see Appendices 3a-c) is regressed on the efficiency and productivity scores of the car market. In stage-two we collected additional data in order to proceed with our regression analysis.

4.4.2. Data Sources

The above information was collected from the following external sources;

Information Council for the Road Traffic (in Norwegian: Opplysningsrådet for Veitrafikken):

Information Council for the Road Traffic is an independent organisation established in 1948. The company's mission is to focus on the improvement and development of Norwegian road traffic. It consists of 70 members, which are representing different types of road users. These members are leaders in public transport, oil companies, banking, transport companies, and road safety. Information Council for the Road Traffic provides and sells information about the Norwegian passenger car market. For the purpose of the study, the following information was collected from this organisation;

- Dataset contains information about the monthly registration of new passenger cars in Norway in the period from 2008 to 2012 with the description of car brand, model, chassis, transmission type, cylinder type, horsepower, and fuel type.
- Monthly ranking of car brands based on their sales/market share.

BilNorge:

BilNorge is a subsidiary company owned by Bilforlaget AS, and is considered as Norway's largest specialty publisher of automotive information. It cooperates with the Norwegian car dealers for a great used car database and information council for Road traffic about an updated New Vehicle database. In addition to this, it publishes car news daily. The database contains the following information:

- List of all car dealers operating in Norway (franchised dealers operating with a single brand and multiple car brands).

- Imported car brand list.
- Price information for some car brands, though the selling price for some models were not readily available and was only based for the current year.

The Norwegian Tax Administration (in Norwegian: Skattetaten):

Norwegian Tax Administration is a government agency responsible for tax collection, registration of new vehicles. The agency is a division of the Norwegian Ministry of Finance. The organisation provides information related to tax for private and public companies. In this study, the following information was collected:

- A complete price list of all variants of car models imported in Norway between the years 2008 – 2012.

Proff:

Proff is a service provider for the Norwegian industry. The company's mission is to create a marketplace for buying and selling within Business to Business (B2B) in Norway. The company's database was used to collect the following data:

- Annual financial report of car dealers that are operating in Norway.

Purehelp:

Purehelp is a Norwegian business search engine that aims to create traffic in solution by offering various services to the public. The company's mission is to offer attractive and useful free service to Norwegian industry and the public sector electronically. The company's database in this study served to collect the following data:

- Annual financial report of car dealers that are operating in Norway; this information was in turn used to check whether the numbers match with the one obtained from Proff.

Statistics Norway (in Norwegian: Statistisk Sentral Byrå – SSB):

Statistics Norway was established as an independent entity back in 1876. The organisation is responsible for official statistics in Norway, and also carries out analysis activities. Its mission is to have primary responsibility for meeting the need for statistics on Norwegian society. In addition to this, the organisation is also involved in the international statistical cooperation. As far as the data collection is concerned, the following data were collected:

- Dataset containing information about the monthly registration of new passenger cars in Norway (2008 – 2012).
- Selling price for each car model.
- GDP per capita in Norway (2008 – 2012).
- Statistic of the Labour forces in Norway (2008 – 2012).
- Consumer Price Index (CPI) in Norway.

Official website of car brands:

Selected car brands have official websites that mainly focuses on the Norwegian customers. Their website mainly provides information such as car model that are currently offered, services, e-commerce, and among others. However, in this study the website was used for the following purpose:

- Find car dealers that are franchised with the car brands.
- Find information about the company (i.e. the year when the company was found).

Car Dealers official website

Many car dealers provide information on services, products, and among others. In this study car dealers' official websites were used to verify whether the selected car dealers are franchised for a particular car brand.

Organisation for Economic Co-operation and Development (OECD)

OECD is an international economic organisation of 34 countries founded in 1961. Its mission is to promote policies that will improve the economic and social well-being of people around the world. OECD releases reports about countries. As far as this study is concerned, information on GDP growth per capita in Norway was collected from the organisation's database.

Science Direct

Science Direct is scientific database, which is a subsidiary company of the Anglo-Dutch publisher Elsevier. It was found in 1997. In this study Science Direct was used to collect the following information:

- Academic journal articles.
- E-books.

Molde University College Library (Brage HiM):

In this study Molde University College Library database (Brage HiM) and other related documents were used to collect the following:

- Previous theses (both Master and PhD).
- Books.

4.5. Data analysis

In this section, we briefly describe the three analytical techniques used for the estimation of relative efficiency and the changes in productivity over periods of time of Norwegian passenger car market in light of product variety. Thus, this study has two stages as regards DEA analysis; the first-stage where the efficiencies of Norwegian passenger car market along with the Malmquist Productivity Index (MPI) are calculated using labour cost, capital cost, depreciation and other operating expenses as inputs, and total sales of car models imported (into Norway) as output. Put simply, this paper will measure only one form of technical efficiency, output-oriented efficiency for the simple reason that the main objective of Norwegian passenger car market is to maximise total sales of car models being sold while keeping the level of inputs constant.

The two-stage DEA analysis encompasses the efficiency and productivity scores, and the exogenous variables that may influence performance of the car market even though they cannot be controlled by the car dealers. These estimated efficiency and productivity scores are regressed on the exogenous variables using a truncated regression model. Determining how these variables impact on efficiency is essential for the car market to identify viable performance improvement strategies. The justification for using parametric technique (regression analysis) in this stage of DEA analysis owes its explanation on DEA's inability in summarising the impact of efficiency/productivity of exogenous factors in single coefficient (Odeck, 2009).

4.5.1. Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) has been applied in this study to estimate the output-oriented technical efficiency of individual car brands (as discussed in section 4.4) with different models in Norwegian passenger car market. DEA is based on Farrell's (1957) work, which was later extended by Charnes et al., (1981) and Färe et al., (1985). DEA, as described by (Ganley and Cubbin, 1992), is a non-parametric technique used for measuring relative efficiency of Decision making Units (DMUs), as already discussed in section 2.7.1 above.

The ratio form, as suggested by Peyrache and Coelli (2008), is the best way to introduce DEA. Thus, for instance, in order to obtain a measure of the ratio of all outputs over all inputs for each DMU, optimal weights have to be selected by specifying the mathematical problem (4.1), which is based on the concept of Total Factor Productivity (TFP)[60] as given below:

$$\text{Max} \qquad h = \frac{\sum_{r=1}^{s} u_{rk} Y_{rk}}{\sum_{i=1}^{m} v_{ik} \; X_{ik}} \tag{4.1}$$

Subject to

$$\frac{\sum_{r=1}^{s} u_{rk} Y_{rj}}{\sum_{i=1}^{\mathrm{m}} v_{ik} X_{ij}} \le 1; \quad \mathrm{j} = 1, \dots, n \tag{4.2}$$

$$u_{rk} \ \ge 0, v_{ik} \ge 0 \ \ r = 1, \dots, s; \qquad i = 1, \dots, \tag{4.3}$$

Where:

j represents the DMUs (car brands) and differs from 1 to n.

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[60] TFP is defined as the rate of transformation of total input into total output. However, in the production function context, TFP is termed as the increase in output that is not explained by increases in quantities of the input. Put differently, holding all inputs constant, it is the increase in output made possible by technological change (Kohli, 2004).

r is the output index and differs from 1 to s.

i is the input index and differ from 1 to m.

Y_{rj} denotes the r^{th} output value (total sales of car models imported) for the j^{th} DMU, whereas Y_{rk} is the value of r^{th} output for the DMU that is under evaluation.

X_{ij} represents the value of the i^{th} input for the j^{th} DMU, while X_{ik} represents the i^{th} input value for the DMU that is under evaluation.

U_{rk} is the weight of the r^{th} output for the DMU that is under evaluation.

V_{ik} is the weight of the i^{th} input for the DMU that is under evaluation.

The ratio of weighted sum of multiple outputs to weighted sum of multiple inputs is measured by the objective function (4.1). The first constraint (4.2) asserts that DMUs efficiencies should be less than or equal to one (100%) if the weights of a DMU are used for other DMUs. The second constraint (4.3) provides the positivity of weights (Karaduman, 2006).

Thus, DEA establishes the ‘best practice’ frontier from the given set of inputs and outputs. In this instance, the best practice frontier refers to those units that produce more output with the given level of inputs. Hence, these units act as the benchmark in estimating the performance of other units. As a result, units that are referred to as frontier or benchmark units will be 100 per cent efficient with the efficiency score of one. This implies they are the ‘best practice’ performers as compared to the other units in that group. All other units will have the efficiency score of less than one if they are not on the frontier as this indicates inefficiency. The efficiency of every non-frontier unit[61] is measured in relation to the most efficient unit. One minus the efficiency score of non-frontier units give the percentage by which these units need to increase their outputs in order to be on the best production possibility frontier (PPF).

This is well illustrated in Figure 4.1 below, where output orientation is represented and assumes one input and two outputs[62]. However, the graph was altered from the original idea of the authors, Odeck and Braathen (2012), because of the study objective.

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[61] Non-frontier unit refers to the unit, which is not situated on the production possibility frontier (PPF).

[62] This is illustration of DEA method

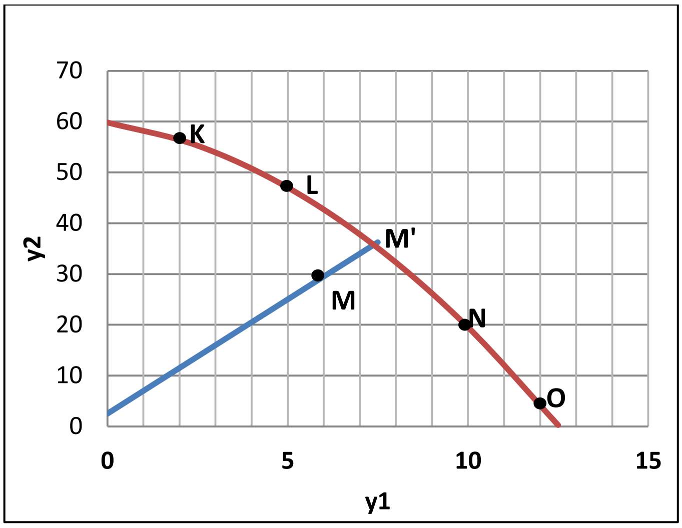

Figure 4. 1: Output Technical Efficiency (TE) measures. Source: own illustration

The segment line KO in Figure 4.1 represents an isoquant, where the best combination of the outputs (y1 and y2) is produced from a given level of input. Thus, points K through O denote individual car brands with different models (evidence of variety) and their particular level of output (total sales of models imported) using a combination of the required inputs (capital, labour, depreciation and other expenses). Henceforth, all the car brands operating at points K, L, M', N and O are technically efficient as opposed to car brand at point M as it is not located on the isoquant. This implies that car brand M produces excess output than needed. M's inefficiency is assessed by the ratio of best practice to observed inputs. Thus, the inefficiency of car brand operating at M is measured in terms of a hypothetical car brand at point M', which is the linear combination of the two best practice car brands L and N. Its degree of efficiency can be estimated as OM/OM' = 6/7.36 = 29.5/35.6 = 0.83. This means point M's output increasing potential is at 17%.

4.5.2. The Malmquist Productivity Index (MPI)

This study measures the output efficiency of Norwegian passenger car market with regards to product variety between the periods of time (2008 to 2012). In order to accurately estimate the changes in productivity of Norwegian car market between the periods of time, the Malmquist productivity index (Henceforth MPI) is used (See e.g. Johnes and Johnes, 2004; Coelli et al., 2005 and Agasisti et al., 2011). This method was first suggested by Malmquist (1953) as a quantity index to be used in analysing consumption of inputs. Färe et al., (1992) constructed an MPI directly from input and output data using DEA by combining their ideas on the measurement of efficiency from Farrell (1957) and the measurement of productivity from Caves et al., (1982). As Chen (2011) puts it, the DEA-based Malmquist productivity index has proven to be the most appropriate tool to use for measuring productivity change in various industries. For example, Färe et al., (1994b) studied productivity developments in Swedish hospitals, Grifell-Tatjé and Lovell (1996) studied the effect of deregulation on Spanish saving banks, Fulginiti and Perrin (1997) studied agricultural productivity changes in 18 developing countries, Löthgren and Tambour (1999) studied productivity change in the Swedish eye-care service provision, Odeck (2008) studied the efficiency and productivity of Norwegian road toll companies, among others.

As far as this study is concerned, the implication of productivity growth for an individual car brand *i*, based on time series, can be measured by the MPI as improved efficiency relative to the best performers[63]. Thus, MPI is expressed by the two adjacent DEA efficiency measures. In this study's setting, we will be estimating productivity of car brands from one time period to the other. For instance, for car brand i, based on the best performers, the Malmquist index between time periods *t* and *t +1* is measured as:

$$M_t^i = \frac{e_{t,t+1}^i}{e_{t,t}^i} \tag{4.4}$$

From the above equation (4.4), $e_{t,t}^i$ and $e_{t,t+1}^i$ denote input technical efficiency scores for car brand *i* that relate observations in periods *t* and *t+1* respectively, to a benchmark frontier, which in this case is period *t* technology. The input productivity change between periods *t* and *t+1* are measured by M_t^i. As $e_{t,t}^i$ and $e_{t,t+1}^i$ are efficiency scores which are usually between zero and one. Subsequently, these may induce three possibilities as regards productivity, which can be expressed as follows (Färe et al., 1992):

- $M_t^i < 1$ indicates a decline in productivity[64].
- $M_t^i = 1$ implies no change in productivity from time *t* to *t+1*.
- $M_t^i > 1$ indicates an increase or improvement in productivity[65].

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[63] Also known as the benchmark frontier

[64] Productivity loss

[65] Productivity gain

Similarly, a Malmquist index with a frontier benchmark based on period *t+1* can be expressed as:

$$M_{t+1}^{i} = \frac{e_{t+1,t+1}^{i}}{e_{t+1,t}^{i}} \tag{4.5}$$

The study of Odeck (2008), which is partially derived from Färe et al., (1985), suggested describing the input-output-oriented MPI as a geometric mean of equations (4.4) and (4.5) in order to circumvent arbitrariness in the selection of base period, as follows:

$$M^{i} = \left[\frac{e_{t,t+1}^{i}}{e_{t,t}^{i}} \frac{e_{t+1,t+1}^{i}}{e_{t+1,t}^{i}}\right]^{1/2} \tag{4.6}$$

The Malmquist index above (4.6), according to Färe et al., (1992), is decomposed into two mutually exclusive and exhaustive components that may help in explicating efficiency and inefficiency reasons. Thus, (4.6) is disintegrated into the product of an index measuring efficiency changes ("catching up") and the other one capturing the shift in the production frontier ("technical change"). This can be defined as:

$$M^{i} = \frac{e_{t+1,t+1}^{i}}{e_{t,t}^{i}} \left[\frac{e_{t,t+1}^{i}}{e_{t+1,t+1}^{i}} \frac{e_{t,t}^{i}}{e_{t+1,t}^{i}}\right]^{1/2} = TEC^{i} + FS^{i} \tag{4.7}$$

The efficiency change component *(TEC^{i})* is an index of relative technical efficiency change between periods for car brand *i*. It shows how much closer or farther away a car brand *i* gets to the frontier made up of 'best practice' of other car brands. That is, for this component to be greater than, equal to or less than unity, it depends on whether the evaluated car brand *i* is improving, stagnating or deteriorating[66]. On the flip side, the technical change component[67]*(FS^{i})* indicates the relative distance between the frontiers. In other words, this component measures the frontier shifts between two periods and indicates whether the best practice relative to which the evaluated car brand *i* is compared to, is whether improving, stagnating or declining. As Tortosa-Ausina et al., (2003) argue, the index will take a value greater than, equal to or less than unity whatever the case, as such technical change will be positive, zero or negative.

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[66] The estimated value of $M^{i} > 1$ indicates an improvement in productivity; $M^{i} < 1$ indicates a deterioration in productivity and $M^{i} = 1$ means stagnation in productivity.

[67] Also known as 'frontier productivity index' or 'frontier shift'.

Nevertheless, it is worth noting-taking that MPI inaccurately measures change in productivity particularly where CRS is not present (Grifell-Tatjé and Lovell, 1995). This owes its explanation to the imposition of VRS technology, which if it is different from the CRS technology, generates a systematic bias on the productivity measurement result. Following Grifell-Tatjé and Lovell (1995), various ways of modifying the bias have been suggested in order to attain a generalised MPI (GMPI) that suits the VRS technology. However, there is still an on-going debate on how MPI can be derived appropriately using VRS technology (see for example; Grosskopf, 2003 and Lovell, 2003). This study nonetheless measures the Malmquist index with an assumption of a CRS technology.

In sum, as regards this study, the efficiencies and changes in productivity of Norwegian passenger car market are calculated by a DEAFrontier, a Microsoft Excel Add-In for solving Data Envelopment Analysis (DEA) models, developed by Joe Zhu[68].

4.5.3. DEA Regression Analysis

Once the efficiencies and productivity of Norwegian passenger car market are assessed, the question arises as to what extent does product variety impact the efficiency. This is the two-stage DEA efficiency analysis where we are evaluating whether the differences in the efficiencies and productivity of Norwegian passenger car market can be explained by product variety (PRODVAR) and other exogenous variables such as; firm size measured by number of dealers (FIRMSIZ), age of car brands (AGE), GDP growth per capita (GDP) and market share (MRKTSHR). As such, our estimated regression models can be defined as:

i. $$\delta i = \propto_0 + \beta_1 \text{PRODVAR} + \beta_2 \text{FIRMSIZ} + \beta_3 \text{AGE} + \beta_4\, GDP + \varepsilon \qquad i = 1, \ldots, n \qquad (4.8)$$

In which δ^i denotes the efficiency of car brand i. $\propto_0$ is a constant term, PRODVAR is the product variety of car brand i, FIRMSIZ is the firm size, AGE denotes age of car brands and GDP stands for GDP growth per capita. All these variables are expected to have an impact on the efficiency.

ii. $$\theta i = \propto_0 + \beta_1 PRODVAR + \beta_2 \text{MRKTSHR} + \beta_3 \text{FIRMSIZ} + \beta_6\, GDP + \varepsilon \qquad i = 1, \ldots, n \qquad (4.9)$$

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[68] Joe Zhu is a Professor of Operations in the School of Business, Worcester Polytechnic Institute. He is the author and co-editor of several books on performance evaluation and benchmarking DEA.

Where θ^{i} represents productivity of car brand i, $\propto_0$ is a constant term, PRODVAR is the product variety, MRKTSHR denotes market share, FIRMSIZ is firm size (measured by number of dealers handling the vehicle), and GDP is GDP growth per capita of car brand *i*

However, due to the bounded nature of DEA scores, most empirical studies use tobit models. There has been nonetheless a controversy over applying this model in estimating productivity in the two-stage DEA efficiency analysis. Thus, Simar and Wilson (2007), argued why tobit model should be used in this setting when it is suitable for censored data[69]. Moreover, tobit regression analysis is also criticised for mis-specification. Nevertheless, the truncated regression analysis is followed in this study in estimating the above equations (4.8 and 4.9). Following Kennedy (2008), with truncated regression, values of the explanatory variables are known only when the dependent variable is observed. Thus, truncated regression fits best in this study due to the nature of our efficiency scores which are bounded to zero and one, hence all the observations that are outside this specified range are totally lost.

4.6. Chapter Summary

To show that this paper aims to demonstrate credibility, a research methodology, which is relevant to this study, has been presented. The research philosophy and the research design, data analysis as well as data collection methods and sources have also been discussed.

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[69] Unlike truncated regression, censored regression is when some observations on the dependent variable, corresponding to known values of the explanatory variables are not observable (Kennedy, 2008). Put simply, the tobit model is also known as a censored regression model and it is designed to estimate linear relationships between variables when there is censoring from below and above in the dependent variable. Censoring from below implies that the values that fall at or below some threshold are censored. On the other hand, censoring from above is when values fall at or above some threshold and all take on the value of that threshold in order to for the true value to be equal to the threshold or higher.

CHAPTER 5

DEFINITIONS AND SPECIFICATION OF VARIABLES

5.1. Introduction

This chapter discusses the definitions and specification of variables used in first-stage and second-stage DEA analyses. First-stage analysis consists of four inputs and one output, and second-stage includes the exogenous variables that are expected to have some impact on the efficiency and productivity of Norwegian passenger car market.

5.2. Measurement constructs

Following Odeck (2008), in order to be able to measure the technical efficiency of Norwegian passenger car market profoundly using the DEA technique described in section 4.6 above, the following requirements are considered, that:

- The data set includes clearly the identified production units (car brands).
- The identified output for each car brand indicates the services produced.
- The inputs for each brand indicate the resources that are used to produce those services.
- The individual car brands being evaluated are comparable in the sense that they utilise the same types of inputs to produce the same types of services. All the car dealerships of the selected car brands in this study are similar in the sense that they only deal with a single brand and not a mixture of brands as is mostly the case with most car dealerships in Norway.

The following section, which is divided into two stages (first and second stages), discusses the output, inputs and exogenous variables relevant for this study. Following Coelli et al., (2005), the first stage analysis is further subdivided into traditional inputs and outputs, while the second stage analysis is split into exogenous/environmental variables. These stages are depicted in Figure 5.1 which are derived from Coelli et al. (2005)’s idea.

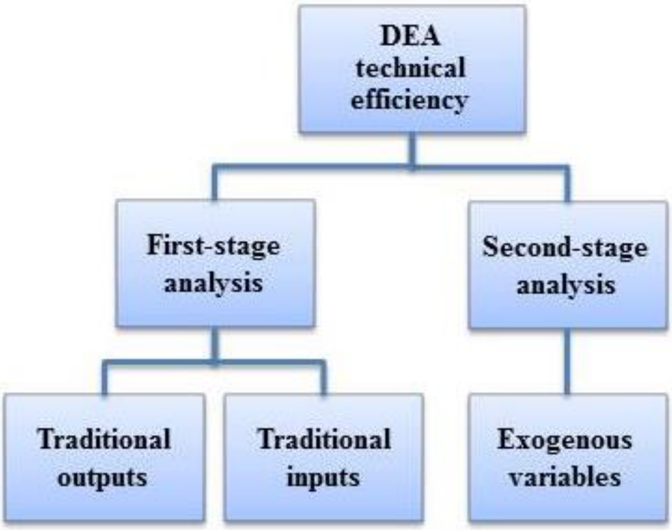

Figure 5. 1: Two DEA stages of technical efficiency analysis. Source: Own version

5.2.1. First stage analysis

The term traditional inputs include the factors of production, which are the resources used for producing services and the output obtained. In this study, we have four inputs and one output making a total of five items (See Appendices 1a-e for their descriptive statistics). This matches with the DMU's rule of thumb where the number of DMUs (car brands represented by n) is equal to or greater than max [$m \times s$, $3 \times (m + s)$]. Where, m and s denote inputs and output, respectively. Thus, we have 21 car brands as our DMUs and that means the DEA convention that the minimum number of DMUs should be greater than 3 times the number of inputs plus outputs $\{21 > 3\ (4 + 1\ )\}$has been maintained in this study. According to (Asmild et al., 2004), if this rule of thumb is not met, the DEA results will be biased and questionable. Put simply, the model may produce a large portion of the DMUs that will be identified as efficient and decrease discriminating power, hence giving misleading results.

- ***Input measurement characteristics***

The inputs selected in this study are based on the type of Norwegian passenger car market. Thus, Norway is one of the countries that do not manufacture cars as the nation's economy doesn't depend on it. The economy of Norway is a developed mixed economy where some strategic areas of the economy are owned by the state (Bjørke, 2013). Actually, the abundance of natural resources, including petroleum exploration and production, fisheries and hydroelectric power are the main drivers of its economy. It is of this reason that priority is given to oil-related industries and not to manufacturing industries[70] like that of passenger cars. It is therefore reasonable to believe that this may be a cause as to why cars are relatively costly in Norway as compared to other countries. For instance, these cars often cost twice of what they cost in other comparable countries (Deutsche Welle, 2013). As a result of this, many car dealers find it hard to keep the operating costs at a minimum while maximising profits since the import taxes are expensive. The inputs for this study therefore are based on this kind of car market (dealership perspective) and not on car manufacturing perspective, as is the case with most automotive studies. Hence, the following are the inputs; labour cost, capital cost, depreciation and other operating expenses.

Labour Cost: The term "labour is used in various senses worldwide. Economically, 'labour' is referred to as any work, which is undertaken for monetary consideration whether manual or mental. As put by Triplett (1983), labour cost means the cost that employers incur in hiring an incremental unit of labour. Thus, the term labour cost recognizes the complexity of labour hiring costs and stresses the point that all costs of employment are included (for example compensation, among others) not just direct wage payments.

However in this study, only direct wage payments are considered as labour cost due to unavailability of data on other costs of employment or forms of remunerations that represent a major portion of the total cost of a product or service. Thus, bearing in mind the fact that Norway doesn't manufacture cars, only total wages of sales people from different car brands' dealerships (only the 23 selected car brands) measure labour. Such amounts of wages were taken from different financial reports of the aforesaid car brands' official websites (as discussed in section 4.5), which in this case, represent different dealerships. Hence, labour cost is a relevant variable for this study as it is the key element of cost that covers one of the main portions of the total cost of a product (car). Moreover, this study aims to assess efficiency in Norwegian car market, therefore labour cost fits best as it is adversely affected due to inefficiency, idle time, among others, of the workers (sales people in this case).

Capital Cost: In the corporate world, the term 'capital' refers to money. Capital cost is defined as the firm's cost of using funds, provided by the creditors and shareholders, in financing a business. Thus, capital cost relies entirely on the method of financing used. For instance, if the business is only financed through equity, then it refers to the cost of equity;

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[70] It may be reasonable to suggest that Norway might be heading towards 'Dutch disease', implying a decline of a manufacturing sector as a result of reliance on resource exploitation such as oil (Bjørke, 2013).

and cost of debt if it is only financed through debt. Nonetheless, it is not unusual for many firms to use a combination of debt and equity to finance a business even though the capital sources may vary due to the firm's operating history, among others.

This study's measure of capital is total fixed assets, which imply expenses incurred by the aforesaid car dealerships on the purchase of property, plant and equipment used in the rendering of services[71]. Put differently, in order for these dealerships to bring a project to a commercially operable status, they need to have fixed assets whose costs usually occur solely at the launch of a project, hence making this capital cost variable suitable for our study.

Depreciation: Unlike labour and capital costs, depreciation is a non-cash expense that has an effect on the value of an asset over time. Thus, it reduces the value of assets over time (this affects the balance sheet of an entity or business) and it also allocates the cost of assets to periods in which the assets are used, which then affect the net income reported. Nevertheless, depreciation in this study is measured by the amount of depreciation indicated in the financial report of the selected car brands' dealerships. This is relevant to our car market study as is seen in the assets that decrease in value and are replaced by newer/latest car models. For example, a VW Golf 2012 model is less valuable due to the presence of a VW Golf 2014 model that is in the market, hence affecting the sales.

Other expenses: These are the other expenses incurred by different firms in running their business. These include insurance, office supplies, utilities, legal fees, among others. These are also vital for our study as they represent resources used in order for the car dealers to yield sales of car models imported.

➢ *Output measurement characteristic*

The production of an output can consist of a single product or multiple products. Nonetheless, it is easy to measure a single product as compared to many. Thus, problems may appear with multiple outputs production. Coelli et al., (2005) affirm that firms with multiple products should aggregate the products in the same unit before summarising them in units number of one product. In this study however, we have a single output, which is measured on the total sales of car models imported into Norway in a five-year period (2008 to 2012). Thus, these

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[71] This implies selling of different models of cars as this requires land, buildings, and machinery/equipment.

imported car models in question are only those models that are based on the selected car brands as discussed in section 4.5.

5.2.2. Second stage analysis

Unlike first stage analysis that results in efficiency scores for all the selected car brands, this stage is used to differentiate traditional inputs from other relevant variables that are expected to have an impact on the efficiency of the Norwegian car market. Such variables are referred to as ‘exogenous’ factors that influence the efficiency and are out of the car dealerships’ control. Put simply, second stage variables are measured by making a regression of coefficients that are adjusted to the efficiency scores that tally with the analysed factors (Coelli et al., 2005). Hence, the following are the aforesaid variables:

Product Variety: In this study, product variety is measured by number of car models, fuel type, chassis type, horsepower, and engine displacement. These variables are selected based on availability of data on Norwegian passenger car market. Product variety was selected as one of the exogenous variables as it has an impact on efficiency. Thus, it might be argued that those car brands with low variety in terms of the aforesaid measures will have an advantage in light of efficiency as compared to those with high product variety. It is claimed that high product variety as far as importation of cars is concerned, implies higher costs due to the market’s expensive import tax imposed on these cars. This therefore entails an inability to realise economies of scale.

Firm size: Firm size is measured by number of dealers in this study. Our interest lies in finding out total number of car dealers for each brand. Hence, we disregarded the characteristics attached to dealers as used in stage-one, implying that dealers are selected regardless of whether they are representing single or multiple brands. This variable has an impact on efficiency and one would expect the bigger firms to be efficient due to economies of scale.

Age of car brands: Age of car brand refers to how long the brand has been in the market. Company’s age was calculated by deducting the year of observation of this study from the year when the company was found. It is assumed that the older the company, the more efficient it is relative to the younger ones. Odeck (2008) supported this statement by arguing that there is a positive impact between age of companies and efficiency. This can be explained in terms of experience such companies have over time. With time, firms discover what they are good at and learn to do things better. They specialise and find ways of coordinating and speeding up their activities as well as holding their costs at a minimal level and improving quality, which eventually improves efficiency. However, some studies argue otherwise claiming that

GDP growth per capita: This is the percentage change in real GDP from one year to the next. In order to calculate this variable, we have used the moving base year technique where GDP is calculated with the previous year as a base year. For example, 2007 was used as a base year for 2008 GDP, and for 2009, 2008 was a base year. This procedure was repeated for all the other years. Below is the formula used;

$$GDP\ growth\ per\ capita\ = [GDP(2007) - GDP(2008)]/\ GDP\ (2007)\ \times 100$$

GDP has an impact on efficiency in the sense that it measures economic progress of a nation that indicates rate at which living standards are changing and this means high GDP per capita results into an increase in market value of the goods and services provided over time (Pye, 2012). This being the case, car dealers being goods/services providers, are better off as far as generating profit is concerned. This may enable them invest more in human capital, physical and, information and telecommunications technology, which can improve productivity. This increase in productivity may lead to lower cost of goods per unit, which in the long run may cause average cost of goods to drop hence gaining efficiency.

Market share: In this study, this is regarded as the percentage of total number of imported models of a Norwegian car market that is earned by a particular car brand dealer over a specified time period. This was calculated by taking total number of models imported for a single brand in a particular year and dividing it by the total number of imported models of the whole car market over the same period. This indicates how big or small the car brand dealership is relative to the market and other brands. Hence, may have an impact on productivity as an increase in market share implies greater achievement of operations scale and improvement of profit.

5.3. Chapter Summary

This chapter has discussed all the exogenous variables that are expected to have an impact on efficiency and productivity of Norwegian passenger car market. A detailed explanation of each variable has been given as well as their impact on efficiency and productivity has been discussed.

CHAPTER 6

DATA ANALYSIS AND EMPIRICAL FINDINGS

6.1. Introduction

This chapter presents the results of our research questions. It proceeds as follows: Section 6.2 gives an initial assessment of the data used as a way of ensuring that the output relates to the inputs. Section 6.3 answers the first research question “Has the Norwegian passenger car market been efficient within the period of 2008 to 2012?” by presenting the results derived from Data Envelopment Analysis (DEA). Section 6.4 answers the question about "How the Norwegian car market’s efficiency has changed between 2008 and 2012” by presenting the results of Malmquist Productivity Index (MPI) analyses which separates the difference in efficiency between two periods into a technical efficiency change and frontier shift. Finally, in Section 6.5 a regression analysis is performed to address the third question which is “What is the impact of product variety on the efficiency and productivity of the aforesaid car market?”

6.2. Initial Data Assessment

In order to ensure that total sales (output) relate to the inputs (labour, capital, depreciation and other expenses), the initial analysis was performed using scatterplots and correlation analysis in Excel and SPSS, respectively. The scatter plots that relate each individual input to output is shown in Figure 6.1a-6.1d.

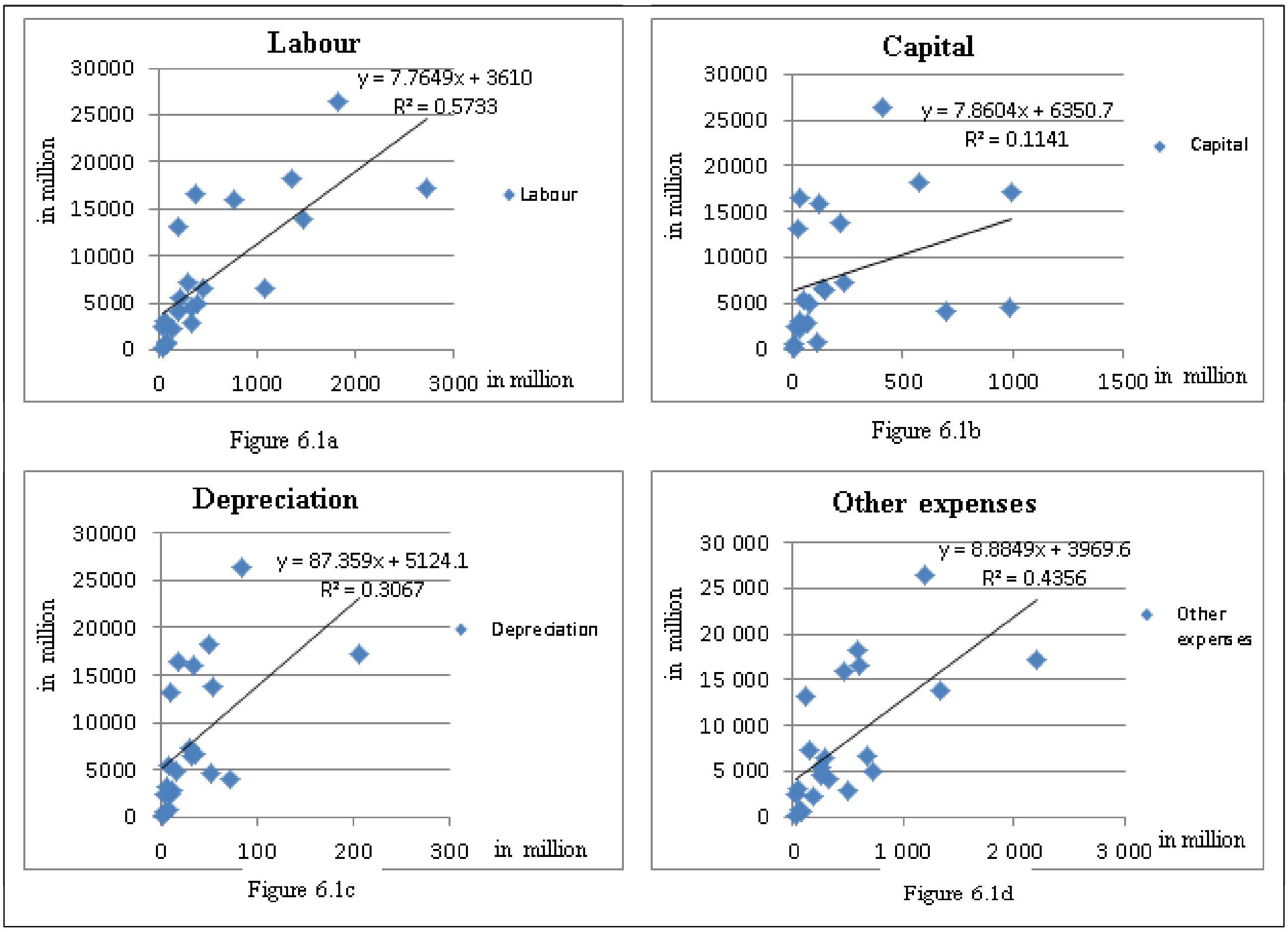


Figure 6.1a

Figure 6.1b

Figure 6.1c

Figure 6.1d

Figure 6. 1a -d: Scatterplot showing the linear relationship between output and four regressors

The scatterplot in Figure 6.1a–6.1d indicates that all the aforesaid regressors are positively associated with total sales of models imported (output). This is seen in the way the points are spread out in the scatterplots. Thus, the points do not fall inside a circle or horizontal ellipse and also the regression line through them is neither horizontal nor vertical indicating a positive relationship between the variables. This can also be explained in terms of a coefficient of determination (R^2) that statistically measures how close the data are to the fitted regression line. For instance, the regression models with labour, capital, depreciation and other expenses account for 57%, 11%, 31% and 44%, respectively, of the variance. The more variance is accounted for by the regression model, the closer the data points will be to the fitted regression line.

However, labour cost and other expenses prove to have a strong positive correlation as opposed to the rest that have a weak positive correlation. This entails that the average value of capital cost and depreciation change only slightly relative to changes in total sales of models imported and the opposite is true for labour cost and other expenses.

Further analysis of data assessment is illustrated in Table 6.1 where correlation coefficients of variables in the data set are presented. The results show that labour and other expenses are significantly correlated with total sales at the 0.01 level of significance. Depreciation is also significant but at the 0.05 level of significance. In contrast, capital is insignificantly correlated with total sales. The correlation between the input variables are in the interval 0.482; 0.938. The highest correlation is between labour and other expenses meaning that other expenses are labour related. This could be a reason for dropping other expenses in the analysis, however we did not do so for the reason that it do not perfectly correlate to labour. We thus continued our analysis where all the initial variables were included.

Correlations

		Totalsales	Labour	Capital	Depreciation	Otherexpenses
Totalsales	Pearson Correlation	1	.761**	.299	.547*	.701**
	Sig. (2-tailed)		.000	.187	.010	.000
	N	21	21	21	21	21
Labour	Pearson Correlation	.761**	1	.482*	.845**	.938**
	Sig. (2-tailed)	.000		.027	.000	.000
	N	21	21	21	21	21
Capital	Pearson Correlation	.299	.482*	1	.768**	.430
	Sig. (2-tailed)	.187	.027		.000	.051
	N	21	21	21	21	21
Depreciation	Pearson Correlation	.547*	.845**	.768**	1	.823**
	Sig. (2-tailed)	.010	.000	.000		.000
	N	21	21	21	21	21
Otherexpenses	Pearson Correlation	.701**	.938**	.430	.823**	1
	Sig. (2-tailed)	.000	.000	.051	.000	
	N	21	21	21	21	21

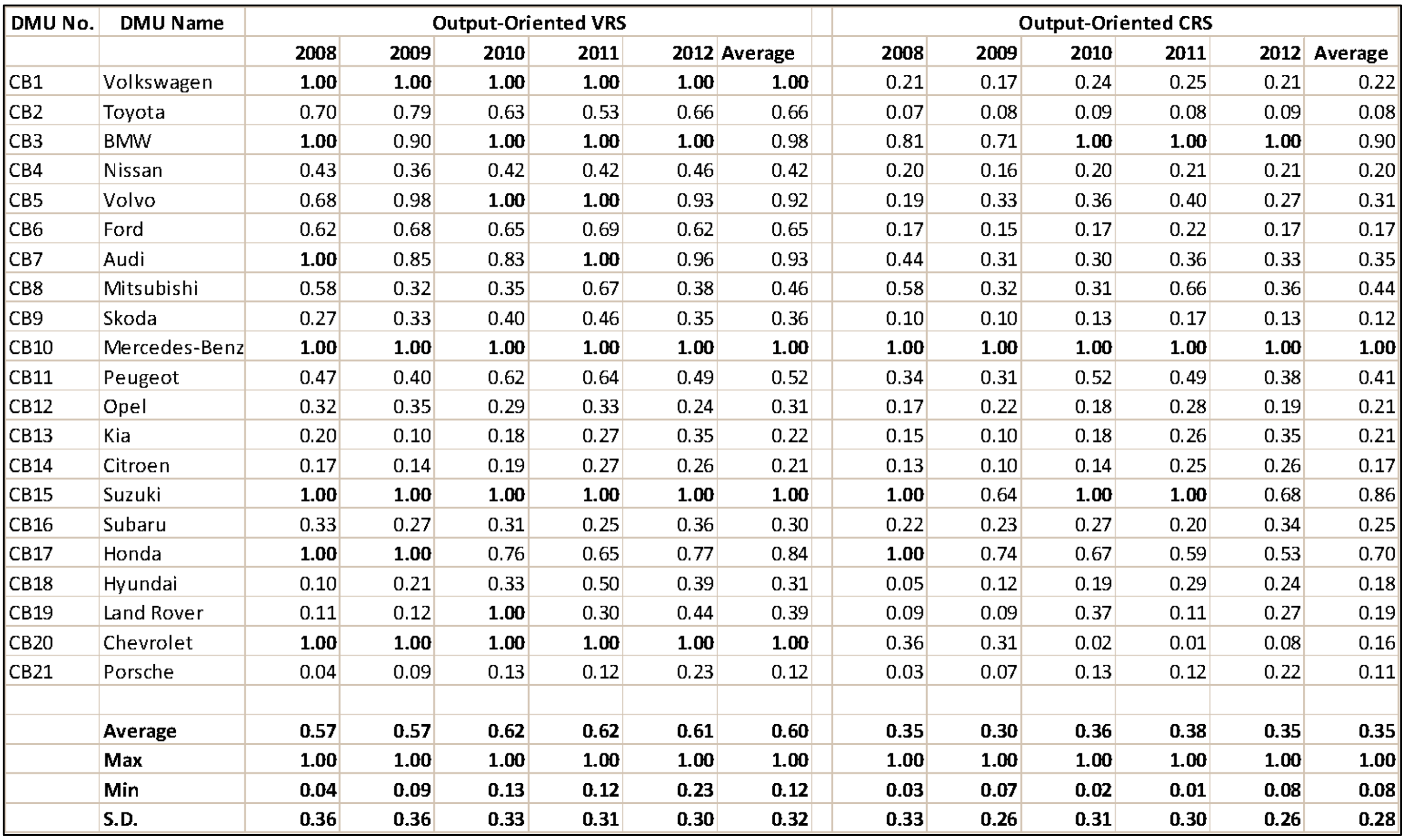
**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 6. 1: Correlation analysis of variables in the data set

6.3. The efficiency of Norwegian passenger car market from 2008 to 2012

To examine this question we used DEA to measure the relative efficiencies as explained in the data section previously. Table 6.2 reports the results for the first-stage output increasing DEA efficiency scores for all the car brands; under the assumption of both variable return to scale (VRS) and constant return to scale (CRS). The results are reported on an annual basis with observation and a summary statistic representing averages, standard deviation and, maximum and minimum values for all the years of observation (2008-2012). This approach of analysing performance of Norwegian car market year by year is applied in this study simply because we are interested in knowing how the change in the performance of such a market has been from one year to the next based on the prevalent frontier for each year.



DMU No.	**DMU Name**	**Output-Oriented VRS**						**Output-Oriented CRS**					
		2008	**2009**	**2010**	**2011**	**2012**	**Average**	**2008**	**2009**	**2010**	**2011**	**2012**	**Average**
CB1	Volkswagen	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	0.21	0.17	0.24	0.25	0.21	0.22
CB2	Toyota	0.70	0.79	0.63	0.53	0.66	0.66	0.07	0.08	0.09	0.08	0.09	0.08
CB3	BMW	**1.00**	0.90	**1.00**	**1.00**	**1.00**	0.98	0.81	0.71	**1.00**	**1.00**	**1.00**	0.90
CB4	Nissan	0.43	0.36	0.42	0.42	0.46	0.42	0.20	0.16	0.20	0.21	0.21	0.20
CB5	Volvo	0.68	0.98	**1.00**	**1.00**	0.93	0.92	0.19	0.33	0.36	0.40	0.27	0.31
CB6	Ford	0.62	0.68	0.65	0.69	0.62	0.65	0.17	0.15	0.17	0.22	0.17	0.17
CB7	Audi	**1.00**	0.85	0.83	**1.00**	0.96	0.93	0.44	0.31	0.30	0.36	0.33	0.35
CB8	Mitsubishi	0.58	0.32	0.35	0.67	0.38	0.46	0.58	0.32	0.31	0.66	0.36	0.44
CB9	Skoda	0.27	0.33	0.40	0.46	0.35	0.36	0.10	0.10	0.13	0.17	0.13	0.12
CB10	Mercedes-Benz	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
CB11	Peugeot	0.47	0.40	0.62	0.64	0.49	0.52	0.34	0.31	0.52	0.49	0.38	0.41
CB12	Opel	0.32	0.35	0.29	0.33	0.24	0.31	0.17	0.22	0.18	0.28	0.19	0.21
CB13	Kia	0.20	0.10	0.18	0.27	0.35	0.22	0.15	0.10	0.18	0.26	0.35	0.21
CB14	Citroen	0.17	0.14	0.19	0.27	0.26	0.21	0.13	0.10	0.14	0.25	0.26	0.17
CB15	Suzuki	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	0.64	**1.00**	**1.00**	0.68	0.86
CB16	Subaru	0.33	0.27	0.31	0.25	0.36	0.30	0.22	0.23	0.27	0.20	0.34	0.25
CB17	Honda	**1.00**	**1.00**	0.76	0.65	0.77	0.84	**1.00**	0.74	0.67	0.59	0.53	0.70
CB18	Hyundai	0.10	0.21	0.33	0.50	0.39	0.31	0.05	0.12	0.19	0.29	0.24	0.18
CB19	Land Rover	0.11	0.12	**1.00**	0.30	0.44	0.39	0.09	0.09	0.37	0.11	0.27	0.19
CB20	Chevrolet	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	0.36	0.31	0.02	0.01	0.08	0.16
CB21	Porsche	0.04	0.09	0.13	0.12	0.23	0.12	0.03	0.07	0.13	0.12	0.22	0.11
	Average	**0.57**	**0.57**	**0.62**	**0.62**	**0.61**	**0.60**	**0.35**	**0.30**	**0.36**	**0.38**	**0.35**	**0.35**
	Max	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
	Min	**0.04**	**0.09**	**0.13**	**0.12**	**0.23**	**0.12**	**0.03**	**0.07**	**0.02**	**0.01**	**0.08**	**0.08**
	S.D.	**0.36**	**0.36**	**0.33**	**0.31**	**0.30**	**0.32**	**0.33**	**0.26**	**0.31**	**0.30**	**0.26**	**0.28**

Table 6. 2: Efficiency results for Norwegian passenger car market

Under the assumption of VRS, Table 6.2 shows that the average efficiency score across sample years is about 0.60. This result reveals that there is indeed a presence of inefficiency in the car market. This implies that on average car brands can improve their efficiency or reduce their inefficiencies proportionately, by augmenting their outputs by approximately 40% without altering the inputs levels. Not only do the results tell us about the level of efficiency, but they also give a strong indication of room for efficiency improvement in this market. However for individual years, we observe fluctuations in average scores. For instance, the average scores in 2008 and 2009 are relatively steady. In other words, there is no significant increase in scores in these periods. Nonetheless, after 2009 there has been a stable rise up to 2011, followed by 8.8% fall in 2012.

By looking at standard deviation score of 30 – 36% from Table 6.2, one can observe that there is a great variation in the performance of brands in the Norwegian car market. There are some brands that operate either on or close to the frontier, but still, about 81% of the brands exhibit inefficiencies.

Further analysis on the individual car brands as shown in Table 6.2 reveals some interesting patterns that can be observed in this market. First of all, the descriptive statistics shown at the lower part of the table indicates that there has been extreme variation among brands given that the best performance car brands score 100% in efficiency, whereas poorest performance is approximately 12%. For example, the result in Table 6.2 under VRS assumption reveals that across all years of observation there are only four brands; CB1 (Volkswagen), CB10 (Mercedes-Benz), CB15 (Suzuki) and CB20 (Chevrolet) that achieve best performance (efficiency score of 1), and this roughly represents 19% of the samples being studied. See Figure 6.2 for graphical illustration of car brands based on average efficiency scores.

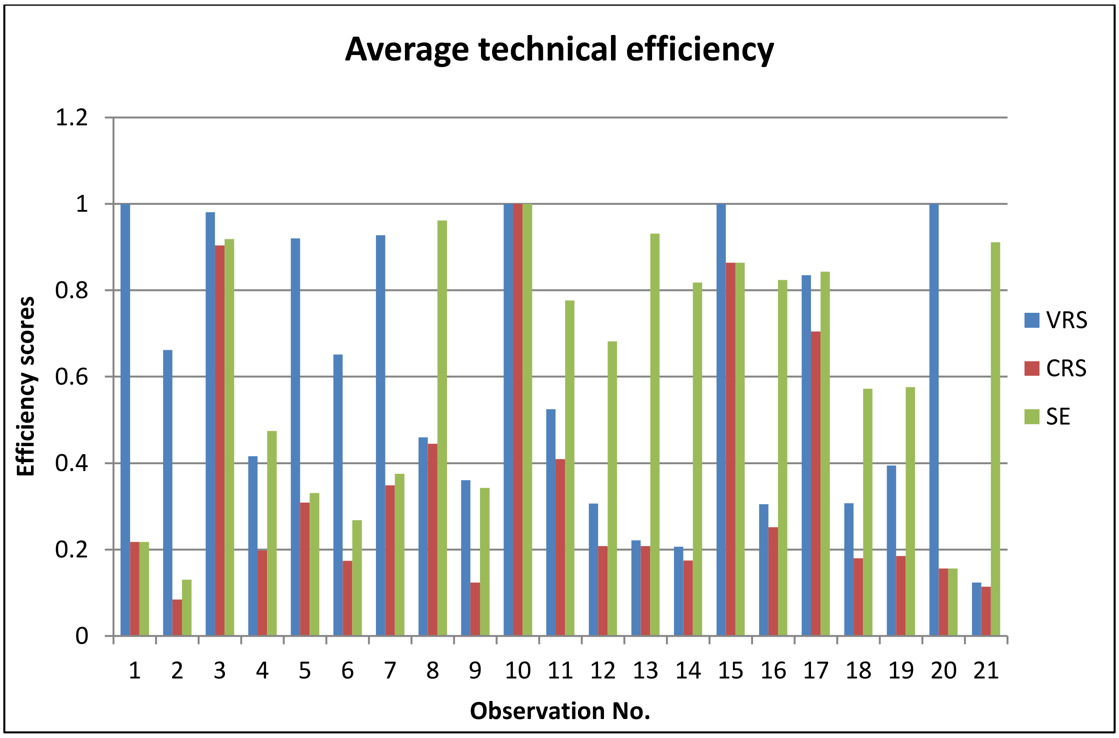


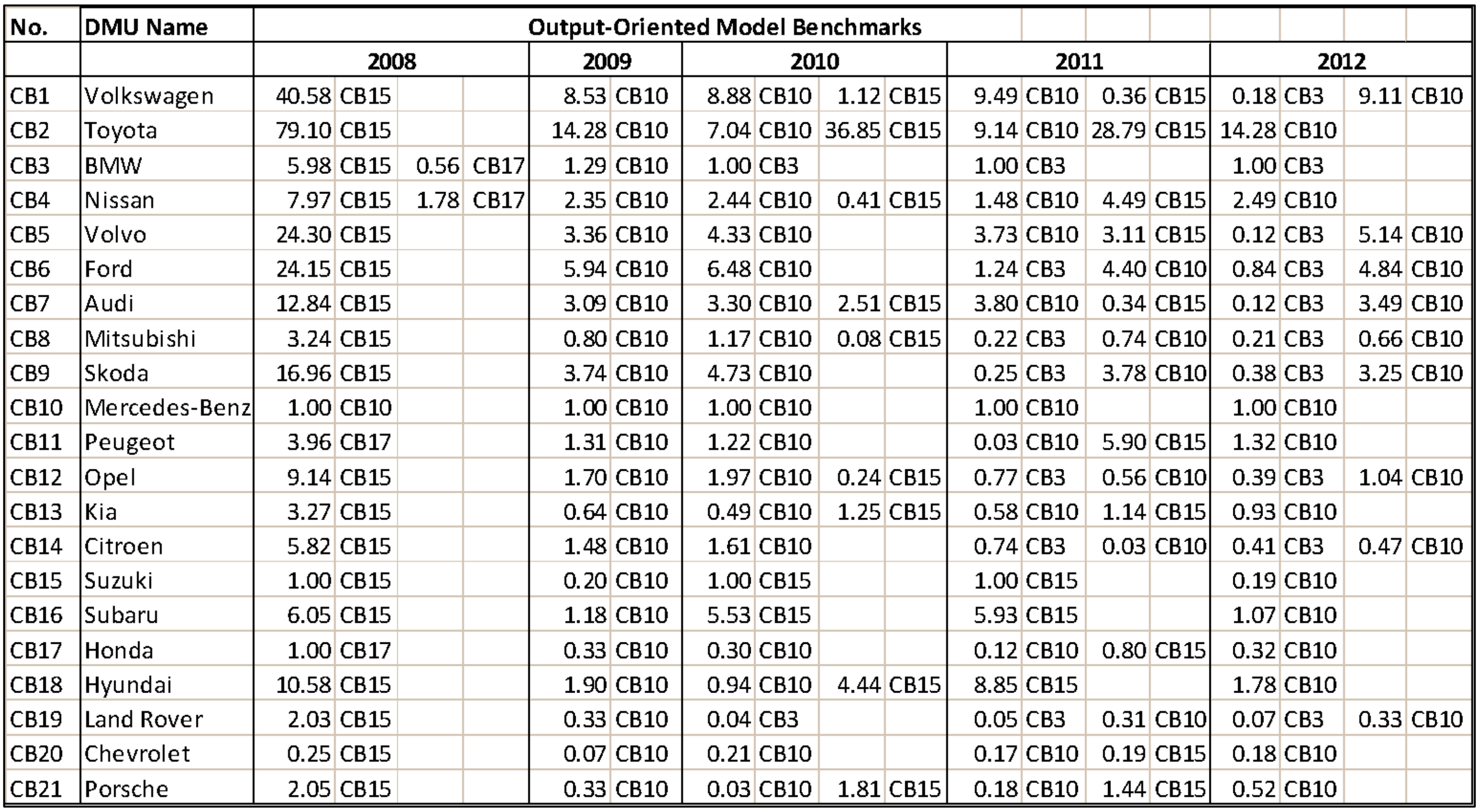
Figure 6. 2: Average results of technical efficiency of car brands for the period 2008-2012

Conversely, it is observed that there is little variation in efficiency scores for individual car brands across the sample years. This applies to those brands that are 100% efficient in one or more years but not in all the years of observation even though their efficiency performances seem not far from those with the best performance. Such brands include CB3 (BMW), which has been 100% efficient in all the sample years except for 2009, even though the variation is very little. Thus, BMW is 10% inefficient in 2009 indicating the need to increase its output by 10%. The same is said for CB5 (Volvo), CB7 (Audi) and CB17 (Honda) as they are all 100% efficient twice within the five years of observation with little variation in efficiency scores; 2010 and 2011 for Volvo, 2008 and 2011 for Audi and 2008 and 2009 for Honda.

Moreover, CB19 (Land Rover) experiences extreme unbalance in their efficiency performances with great variations. In 2010, Land Rover is seen to be most efficient in 2010 and has been since showing a worst condition as it has the lowest potential for improvement. This is indicated by its inefficient level of almost 89% and 88% as evidenced in the years 2008-2009 and 2011-2012 respectively. Put differently, Land Rover scores 11% efficiency in 2008 and 12% in 2009, then improved to 100% efficiency in 2010, followed by a decline to 30% and 44% efficiency in 2011 and 2012 correspondingly. Such performance scores indicate irregularities in efficiency of the car market, and that a considerable level of improvement in efficiency is needed.

Unlike aforementioned car brands, some brands, such as CB21 (Porsche) is considered as the black sheep in the market with regards to efficiency performance. One of the reasons is that across all years its efficiencies has not exceeded 15% based on average. The rest of the car brands have experienced ups-downs momentum but the differences between the score across sample years are insignificant. However, one should bear in mind that brands that are efficient with a performance score of 1.00 are relatively efficient and not strictly efficient. This implies that no other brand is clearly operating more efficiently than these car brands, but it is possible that all units, including these relatively efficient brands, can be operated more efficiently.

The right-hand side of Table 6.2 presents efficiency scores under the assumption of CRS. The average efficiency score across all the years of observation is 0.35. This entails that the average potential for increasing output among the dealers in Norwegian car market is about 65%. Despite being the same sector, CRS average inefficiency scores are higher as compared to VRS scores. As is the case with VRS, CRS average efficiency scores for individual years indicate fluctuations in a similar pattern. Thus, 2009 is observed to have a lower efficiency score relative to that in 2008, followed by an increase of about 20% and 5.5% with respective to 2010 and 2011. However, another drop is observed in 2012 showing a 7.9% decline in efficiency scores. In terms of standard deviation, this sector under CRS assumption shows that there is great variation in efficiency scores between the car dealerships (standard deviation of 26-31%). Hence, showing an extreme situation where some dealerships are 100% efficient whereas others are as low as 8%, meaning they are not efficient at all. This higher mean and lower standard deviation scores in CRS results confirm the poor performance of the sector on selling numerous different models of cars (high product variety). Thus, larger car brands are just as inefficient as small ones in converting inputs to output. Comparing CRS efficiency scores of individual dealerships to that of VRS, it is observed that CRS reveals that only one dealership (Mercedes-Benz) is the most efficient in all the years of observation. The remaining car brands are most efficient but not in all the sample years of observation. For example, BMW is efficient in 2010-2012, same with Suzuki and Honda which are most efficient in 2008, 2010-2011; and 2008 respectively. The other brands that are 100% efficient in all the years under VRS assumption (CB1, CB15 and CB20) are either not 100% anymore or are only 100% in certain years of the observation with CRS. Hence, making Mercedes-Benz a benchmark for measuring efficiency for most of the other car brands. See Table 6.3 for more details on benchmarks.



No.	DMU Name	Output-Oriented Model Benchmarks																	
		2008				2009		2010				2011				2012			
CB1	Volkswagen	40.58	CB15			8.53	CB10	8.88	CB10	1.12	CB15	9.49	CB10	0.36	CB15	0.18	CB3	9.11	CB10
CB2	Toyota	79.10	CB15			14.28	CB10	7.04	CB10	36.85	CB15	9.14	CB10	28.79	CB15	14.28	CB10		
CB3	BMW	5.98	CB15	0.56	CB17	1.29	CB10	1.00	CB3			1.00	CB3			1.00	CB3		
CB4	Nissan	7.97	CB15	1.78	CB17	2.35	CB10	2.44	CB10	0.41	CB15	1.48	CB10	4.49	CB15	2.49	CB10		
CB5	Volvo	24.30	CB15			3.36	CB10	4.33	CB10			3.73	CB10	3.11	CB15	0.12	CB3	5.14	CB10
CB6	Ford	24.15	CB15			5.94	CB10	6.48	CB10			1.24	CB3	4.40	CB10	0.84	CB3	4.84	CB10
CB7	Audi	12.84	CB15			3.09	CB10	3.30	CB10	2.51	CB15	3.80	CB10	0.34	CB15	0.12	CB3	3.49	CB10
CB8	Mitsubishi	3.24	CB15			0.80	CB10	1.17	CB10	0.08	CB15	0.22	CB3	0.74	CB10	0.21	CB3	0.66	CB10
CB9	Skoda	16.96	CB15			3.74	CB10	4.73	CB10			0.25	CB3	3.78	CB10	0.38	CB3	3.25	CB10
CB10	Mercedes-Benz	1.00	CB10			1.00	CB10	1.00	CB10			1.00	CB10			1.00	CB10		
CB11	Peugeot	3.96	CB17			1.31	CB10	1.22	CB10			0.03	CB10	5.90	CB15	1.32	CB10		
CB12	Opel	9.14	CB15			1.70	CB10	1.97	CB10	0.24	CB15	0.77	CB3	0.56	CB10	0.39	CB3	1.04	CB10
CB13	Kia	3.27	CB15			0.64	CB10	0.49	CB10	1.25	CB15	0.58	CB10	1.14	CB15	0.93	CB10		
CB14	Citroen	5.82	CB15			1.48	CB10	1.61	CB10			0.74	CB3	0.03	CB10	0.41	CB3	0.47	CB10
CB15	Suzuki	1.00	CB15			0.20	CB10	1.00	CB15			1.00	CB15			0.19	CB10		
CB16	Subaru	6.05	CB15			1.18	CB10	5.53	CB15			5.93	CB15			1.07	CB10		
CB17	Honda	1.00	CB17			0.33	CB10	0.30	CB10			0.12	CB10	0.80	CB15	0.32	CB10		
CB18	Hyundai	10.58	CB15			1.90	CB10	0.94	CB10	4.44	CB15	8.85	CB15			1.78	CB10		
CB19	Land Rover	2.03	CB15			0.33	CB10	0.04	CB3			0.05	CB3	0.31	CB10	0.07	CB3	0.33	CB10
CB20	Chevrolet	0.25	CB15			0.07	CB10	0.21	CB10			0.17	CB10	0.19	CB15	0.18	CB10		
CB21	Porsche	2.05	CB15			0.33	CB10	0.03	CB10	1.81	CB15	0.18	CB10	1.44	CB15	0.52	CB10		

Table 6. 3: Output-oriented Model Benchmarks

As observed in Table 6.3, those car brands that are efficient consider themselves as their own ‘benchmark’. Therefore in this case, benchmark for CB3 is CB3 in 2010-2012; CB10 is CB10 in all the sample years and CB15 is CB15 in 2008, 2010-2011. On the flip side, the benchmarks for the inefficient car brands are one or many of the efficient car brands. For instance, CB3 is benchmark for CB19 in 2010 and CB10 is benchmark for CB4 and CB11 in 2012. Benchmarks for CB4 and CB11 in 2011 are two car brands namely CB10 and CB15. This implies that CB4 and CB11 must use a combination of CB10 and CB15 in order for them to gain efficiency. However the question arises as to how much of CB10 and CB15 should be combined for these brands (CB4 and CB11) to become efficient. These values are presented in the table below. For example, CB4 will attempt to become like CB15 more than CB10, as observed from respective values of CB15 and CB10 (CB15 = 4.49 and CB10 = 1.48). A similar situation in a different magnitude exists for CB11 in 2011.

In addition, we can observe anomalies in efficiency among brands when analysing the results from one year to the next. For example, CB17 (Honda) shows average efficiency score of 100% in 2008, and after 2008, the efficiency declines to about 53%. In sum, CRS assumption indicates that all the car brands, except for Mercedes-Benz and those brands that are efficient in some years of observation, are on average 67% inefficient, entailing the need for them to increase their output by 67% if they are to improve their performance.

Another issue to address now is the comparison of the efficiency scores obtained by VRS against CRS. By conjecture, the CRS scores are expected to be lower than VRS scores since it is too restrictive in the sense that it requires that an increase in input usage should lead to a proportional increase in output which may not necessarily be true in a market like the car market. The VRS assumption is therefore expected to give us more correct picture in the sense that it allows for variability in returns from increases in inputs. A comparison of efficiency scores under the two sets of assumptions is illustrated in Figure 6.3.

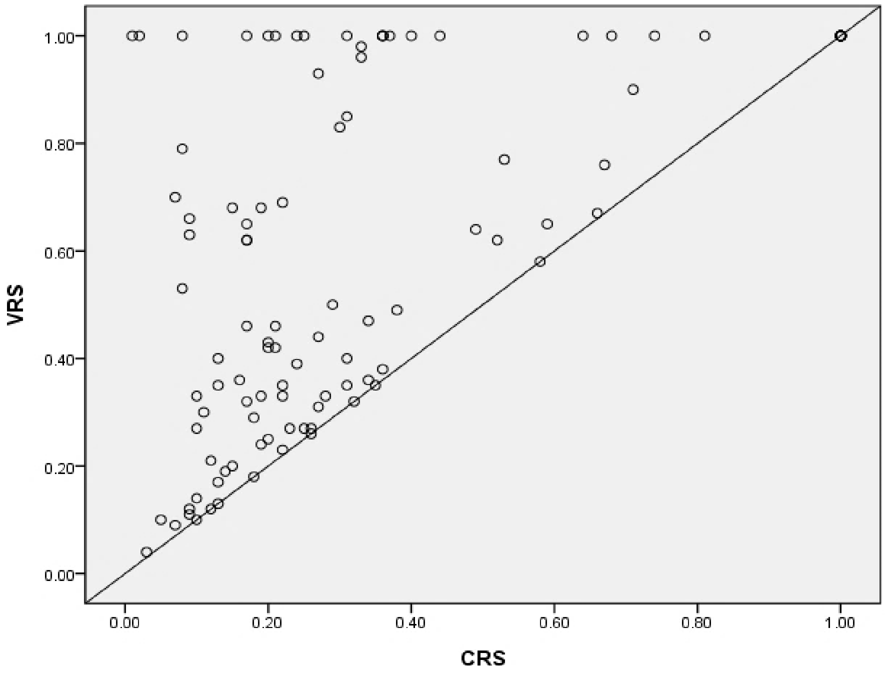


Figure 6. 3: Comparing VRS versus CRS assumptions

The results from Figure 6.3 below show that all the observations are above the line, apart from the very few that lie on the line, confirming the assumption that VRS scores are higher than CRS scores. Hence, the probability that at least one car brand can be 100% is quite large with VRS relative to CRS. This is evident in the number of car brands that are 100% efficient under VRS assumption as compared to those under CRS. For instance, with VRS there are four brands that are fully efficient whereas CRS has only one. The inference made from this therefore is that the lower efficiency is estimated in CRS, whereas the same car brands in VRS are more efficient implying a small increase output potential than in CRS.

The comparison of VRS and CRS is further illustrated in Figure 6.4a and b below where the relationship between size and efficiency is shown. Thus, the question to be addressed here is "Do large brands tend to be more efficient than smaller ones with VRS and/or CRS?"

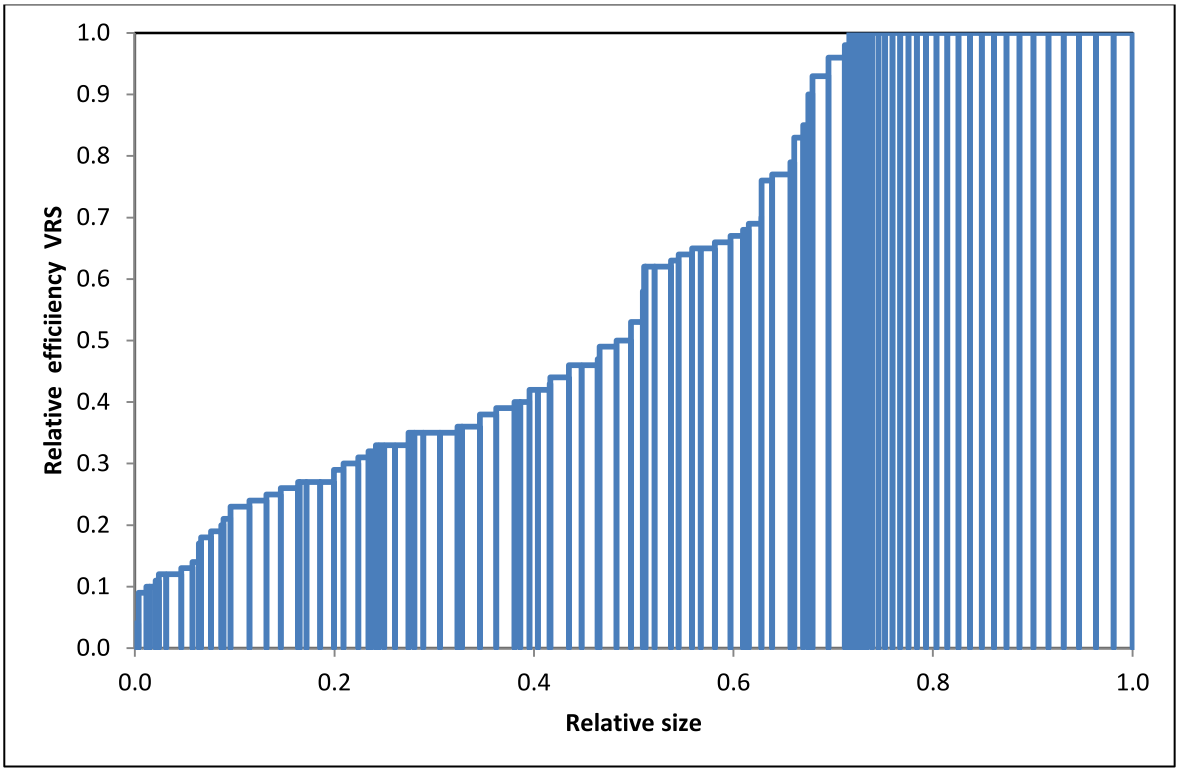


Figure 6. 4 a: The distribution of VRS scores relative to size measured by output

The distribution of efficiency scores under VRS and CRS assumptions across car brands for the period 2008 to 2012 are illustrated in Figure 6.4a and b, respectively. A unit (car brand) is represented by each histogram in both diagrams. The width of each histogram denotes the size of each car brand (measured by output) being studied over the five years, where the wider the histogram, the larger the brand. Thus, it is observed that the fully efficient car brands with VRS represent about 27% regardless of size implying that both large and small brands are seen to be 100% efficient. The same conclusion can be drawn for CRS where more efficient brands are both large and small ones even though the percentage with CRS is lower representing about 11% only.

Moreover, it can also be noted that the efficiency values for VRS assumption reduce swiftly from 1 to 0.6 then continue decreasing even more rapidly up to the car brand with the lowest efficiency level of about 0.1. In comparison, efficiency scores of CRS (see Figure 6.4b) fall rapidly to about 0.5, then start falling at a steady pace to about 0.1, followed by a rapid fall ending at the most least car brand measuring 0.0. This simply indicates that both large and small brands are more or less equally distributed at both ends of the scale regardless of whether VRS or CRS is applied. We can therefore attempt to conclude that large brands as measured by output are seen to be equally more efficient as smaller ones.

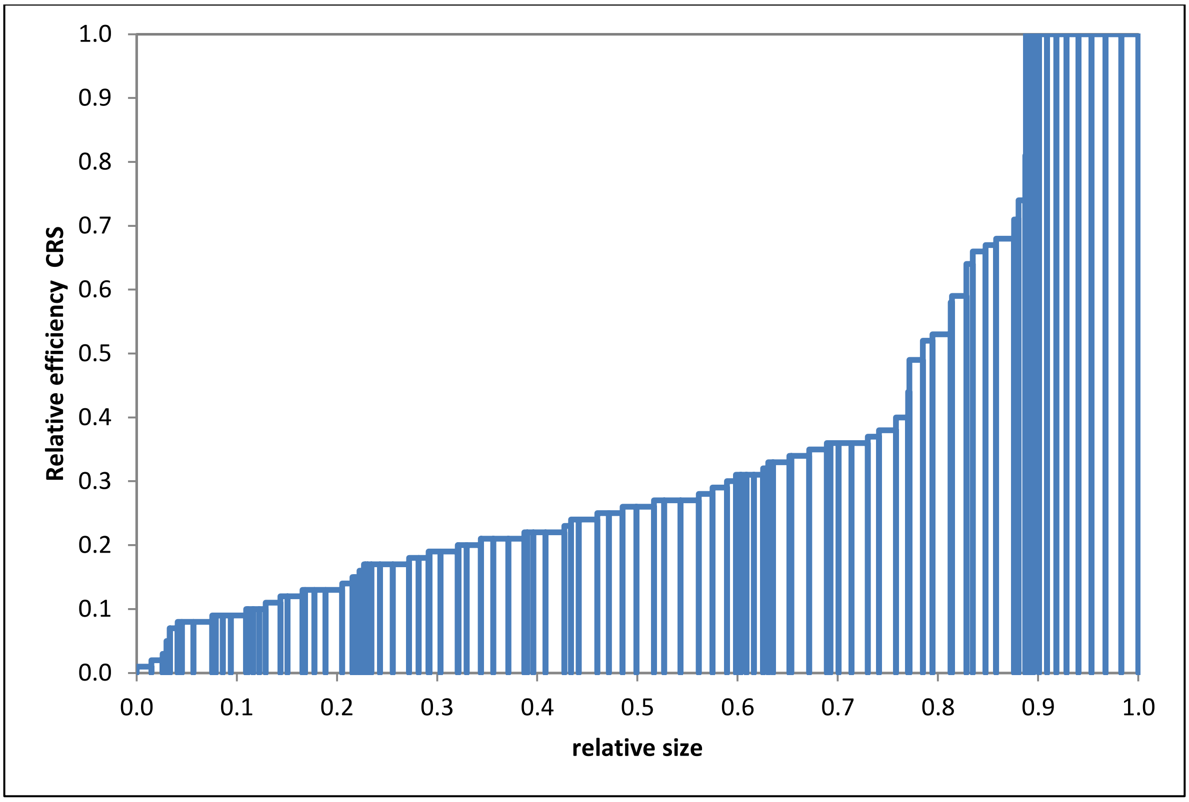


Figure 6. 4 b: The distribution of CRS scores relative to size measured by output

6.3.1. Slacks

Table 6.4 depicts the average slack results of both VRS and CRS. As mentioned earlier, the results of VRS and CRS in Table 6.2 show car brands that are inefficient and the potential for improvement in output in order to obtain efficiency performance. However, just increasing output does not guarantee that inefficient car brands will improve their efficiency performance. As far as the average VRS slack result is concerned, one can observe that none of the efficient brands (i.e. CB1, CB10, CB15 and CB20) have any slacks. Slacks exist only for those brands identified as inefficient. Slacks represent only the leftover portions of inefficiencies; after proportional augmentation of lacking outputs, if a car brand is unable to reach efficiency frontier (to its potential improvement target), slacks adjustment will be needed to push that car brand to the frontier (target).

DMU Name	Average VRS Input Slacks				Output slacks average	Average CRS Input Slacks				Output slacks average
	Labourc	Capitalc	Depreciation	Otherexp		Labourc	Capitalc	Depreciation	Otherexp	
CB1	0	0	0	0	0	30462674	32315069	0	18891471	0
CB2	179081350	116027799	24469981	204722113	0	0	86759371	6096473	82518257	0
CB3	4780028	0	211017	12775814	0	8981114	0	1023734	12482517	0
CB4	1396918	10814317	1807987	2552311	0	4000986	13112649	1125829	1115471	0
CB5	52093026	47912582	892411	895472	0	105625936	88521634	1221108	5123842	0
CB6	79300475	0	1079658	97841798	0	60499670	11664715	0	71295574	0
CB7	15479251	0	717398	1363730	0	23915307	3903780	28132	8176546	0
CB8	4132204	5331729	13177	16598386	0	5440757	5215144	0	17381203	0
CB9	61768838	357883	702917	9141436	0	64111731	5955417	0	20429052	0
CB10	0	0	0	0	0	0	0	0	0	0
CB11	9466330	37655936	2833906	0	0	13625088	34892199	2492723	0	0
CB12	1895193	6290519	188754	47523859	0	6828453	6351375	0	72188085	0
CB13	0	2966691	329260	19325416	0	0	2664752	127574	18589971	0
CB14	13106722	7057837	0	41318275	0	14426820	7419463	0	37561614	0
CB15	0	0	0	0	0	0	894157	137412	594422	0
CB16	0	134422494	12433764	30205518	0	0	128537465	10866254	34248368	0
CB17	1372293	2814111	21775	0	0	744257	4610398	239168	141450	0
CB18	0	184534861	6336452	5555907	0	0	180235975	5170160	6168189	0
CB19	1222148	365892	83432	2941057	0	2746250	782868	207116	2788283	0
CB20	0	0	0	0	0	2563822	362142	15767	1348915	0
CB21	0	18168747	366677	2569459	0	0	18649971	301440	2316710	0

Table 6. 4: Average slacks results of both VRS and CRS assumptions (unit of cost = NOK)

For example, there is no need for CB3[72] to augment its output at all, but could reduce its following average inputs: labour cost, depreciation, and other expenses, with exception of capital cost, by approximately NOK 4 780 028, NOK 211 017 and NOK 12 775 814 respectively. This implies that CB3 has potential of achieving efficiency if it reduces its aforementioned inputs costs since the slack on outputs is zero. A similar situation applies to CB5 where all its inputs (labour cost, capital, depreciation and other expenses) must be reduced by approximately NOK 52 093 026, NOK 47 912 582, NOK 892 411, and NOK 895 472 respectively. It is interesting to note that CB1, CB15 and CB20 despite being 100% efficient under VRS, are required to reduce almost all of their inputs cost in order for them to be efficient under CRS optimality.

The CRS slacks result shows similar patterns as observed in the VRS slacks. Here, we notice that CB10 is the only car brand that does not have to reduce any of its input slacks given that

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[72] This car brand has an efficiency score that is close to the best performance efficiency score

it is efficient, whereas the remaining brands have remarkable amount of reduction in their inputs.

6.3.2. Efficient Targets for Inputs and Outputs

		Efficient Input Target				**Efficient Output Target total**
DMU No.	***DMU Name***	***Labourc (NOK)***	***Capitalc (NOK)***	***Depreciation (NOK)***	***Otherexpenses (NOK)***	
1	CB1	333664051	50538741	16943765	219139370	24317443563
2	CB2	543208076	112122238	35317273	360234697	40944324574
3	CB3	68498873	7299117	2719792	107645044	3662419743
4	CB4	89050548	16768354	5213161	56482121	6573888290
5	CB5	165948460	26546902	8828351	110585273	12217785207
6	CB6	232003508	31728587	10900355	196398664	15959678715
7	CB7	128210600	20040152	6628776	85709507	9223297493
8	CB8	37582886	4985347	1704534	34190837	2505713711
9	CB9	151131317	21727868	7332671	112129256	10724190066
10	CB10	38549996	5327622	1811020	23762361	2618579002
11	CB11	48055235	12755746	3443184	29446787	3593858041
12	CB12	71464194	9440649	3269122	72474950	4777674514
13	CB13	28327787	5272593	1698050	18435693	2085236146
14	CB14	53946840	6549747	2327142	60915726	3468159988
15	CB15	7284298	1984742	600579	4938167	559780922
16	CB16	42368674	11494640	3485059	28700357	3262005352
17	CB17	11751098	2877751	768190	7201097	874516966
18	CB18	69013938	16376293	5114547	45678123	5292228815
19	CB19	12572544	1806471	621634	11539299	866207473
20	CB20	5566463	862082	285923	3511128	387879354
21	CB21	15765064	3813895	1168780	10601198	1186516286

Table 6. 5: Efficient Input and Output Targets for Norwegian passenger car market

Table 6.5 summarises the findings even further by examining the efficient target input and output levels for each car brand. These targets are derived by adding the original outputs to the respective slack values and then subtract them from the original inputs. More specifically, input target values are calculated by subtracting the input slacks from the inputs. Conversely, to calculate output targets, the optimal efficiency scores are multiplied by the output and then add the slack values to that value. From Table 6.5, it can be observed that the target values for efficient car brand (CB10) are corresponding to the values of its original inputs and output. In contrast, the target values for the rest of the inefficient car brands differ substantially from their inputs and outputs. This implies that they can improve their efficiencies with the help of such target values even though they may be unpractical.

6.3.3. Scale of Efficiency (SE)

This section addresses the scale of efficiency measure (SE_i), which indicates the degree to which the car dealers are optimising the size of their operations. Thus, SE measure is used to indicate the amount by which efficiency can be increased by moving to the CRS efficiency frontier. This measure is obtained by computing the ratio (CRS/VRS), and the results are set out in Table 6.6 below. The average scale of efficiency of the twenty-one car brands is 62%, implying that the average size of brands is less than 50% from the optimal size, and further increase optimal scale of 38%[73] would be feasible assuming there is no other constraining factors provided they adjust their car workshops operation to an optimal scale. The average level of overall standard deviation, minimum and maximum is estimated at 0.29, 0.13, and 1.00 respectively. Given that the standard deviation is smaller than the average, there is an apparent indication of moderate variability among car brands.

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[73] This also implies that the sector has about 38% potential for efficiency gains in light of scale.

DMU No.	**DMU Name**	**SE**						**Scale of operation-sum of weights (SW)**					**Returns to scale**
		2008	**2009**	**2010**	**2011**	**2012**	**Average**	**2008**	**2009**	**2010**	**2011**	**2012**	
CB1	Volkswagen	0.21	0.17	0.24	0.25	0.21	0.22	40.58	8.53	10.00	9.85	9.29	Decreasing
CB2	Toyota	0.11	0.10	0.15	0.15	0.14	0.13	79.10	14.28	43.90	37.93	14.28	Decreasing
CB3	BMW	0.81	0.78	**1.00**	**1.00**	**1.00**	0.92	6.54	1.29	1.00	1.00	1.00	Constant
CB4	Nissan	0.47	0.46	0.48	0.50	0.46	0.47	9.75	2.35	2.85	5.97	2.49	Decreasing
CB5	Volvo	0.28	0.33	0.36	0.40	0.28	0.33	24.30	3.36	4.33	6.84	5.26	Decreasing
CB6	Ford	0.27	0.22	0.26	0.31	0.27	0.27	24.15	5.94	6.48	5.64	5.68	Decreasing
CB7	Audi	0.44	0.37	0.37	0.36	0.35	0.38	12.84	3.09	5.81	4.14	3.61	Decreasing
CB8	Mitsubishi	0.99	0.99	0.88	0.99	0.96	0.96	3.24	0.80	1.26	0.96	0.87	Increasing
CB9	Skoda	0.35	0.32	0.31	0.37	0.36	0.34	16.96	3.74	4.73	4.03	3.63	Decreasing
CB10	Mercedes-Benz	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	1.00	1.00	1.00	1.00	1.00	Constant
CB11	Peugeot	0.71	0.78	0.85	0.77	0.78	0.78	3.96	1.31	1.22	5.93	1.32	Decreasing
CB12	Opel	0.53	0.62	0.62	0.84	0.80	0.68	9.14	1.70	2.20	1.32	1.42	Decreasing
CB13	Kia	0.76	0.95	0.98	0.97	0.99	0.93	3.27	0.64	1.75	1.72	0.93	Decreasing
CB14	Citroen	0.75	0.70	0.73	0.95	0.97	0.82	5.82	1.48	1.61	0.77	0.88	Decreasing
CB15	Suzuki	**1.00**	0.64	**1.00**	**1.00**	0.68	0.86	1.00	0.20	1.00	1.00	0.19	Constant
CB16	Subaru	0.66	0.85	0.85	0.81	0.95	0.82	6.05	1.18	5.53	5.92	1.07	Decreasing
CB17	Honda	**1.00**	0.74	0.89	0.91	0.69	0.84	1.00	0.33	0.30	0.92	0.32	Increasing
CB18	Hyundai	0.52	0.55	0.59	0.58	0.61	0.57	10.58	1.90	5.38	8.85	1.78	Decreasing
CB19	Land Rover	0.82	0.72	0.37	0.37	0.61	0.58	2.03	0.33	0.04	0.36	0.39	Increasing
CB20	Chevrolet	0.36	0.31	0.02	0.01	0.08	0.16	0.25	0.07	0.21	0.36	0.18	Increasing
CB21	Porsche	0.89	0.82	0.95	0.96	0.93	0.91	2.05	0.33	1.84	1.62	0.52	Decreasing
	Average	**0.61**	**0.59**	**0.61**	**0.64**	**0.63**	**0.62**	**12.55**	**2.56**	**4.88**	**5.05**	**2.67**	
	Max	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**79.10**	**14.28**	**43.90**	**37.93**	**14.28**	
	Min	**0.11**	**0.10**	**0.02**	**0.01**	**0.08**	**0.13**	**0.25**	**0.07**	**0.04**	**0.36**	**0.18**	
	S.D.	**0.29**	**0.28**	**0.32**	**0.33**	**0.32**	**0.29**	**18.27**	**3.39**	**9.31**	**8.09**	**3.50**	

Table 6. 6: Scale of Efficiency (SE) and Scale of operation

The results presented in Table 6.6 therefore show that CB10 (Mercedes-Benz) is the only brand that is using its scale efficiently over all years of observation, and this result correspond with the one found in CRS from Table 6.2. Further, we can note that brands such as BMW, Suzuki and Honda show presence of scale efficiency but with anomalies in their scores over the years. Even though BMW shows instability in terms of optimising the size of its operation, the variation in its scale efficiency scores is little; the same applies for Suzuki and Honda.

More specifically, about 57% of the car brands can improve their performance with respect to scale by less than 50% but more than 3%. On the other hand, potential for improvement for the rest of the car brands (representing 39%) lies between 51-87%. However, Toyota is considered to be the one with poorest performance (87% scale inefficient) relative to the following reference brands: Mercedes-Benz in 2008-2012; Suzuki in 2008, 2010-2011 and Mazda in 2012.

From the SE results therefore, we can observe some remarkable trends occurring in the passenger car market. One observation is that over the two years (2010 and 2011) there has been slight improvement or steady rise in scale efficiency among brands, despite the fact that these improvements fall under the inefficiency range. Out of the twenty-one selected car brands, only one brand (CB10) is operating under scale efficiency in all the years of observation and the remaining brands are either not efficient in the use of scale or are scale efficient in the selected sample years. A distribution of scale efficiency is plotted in Figure 6.5.

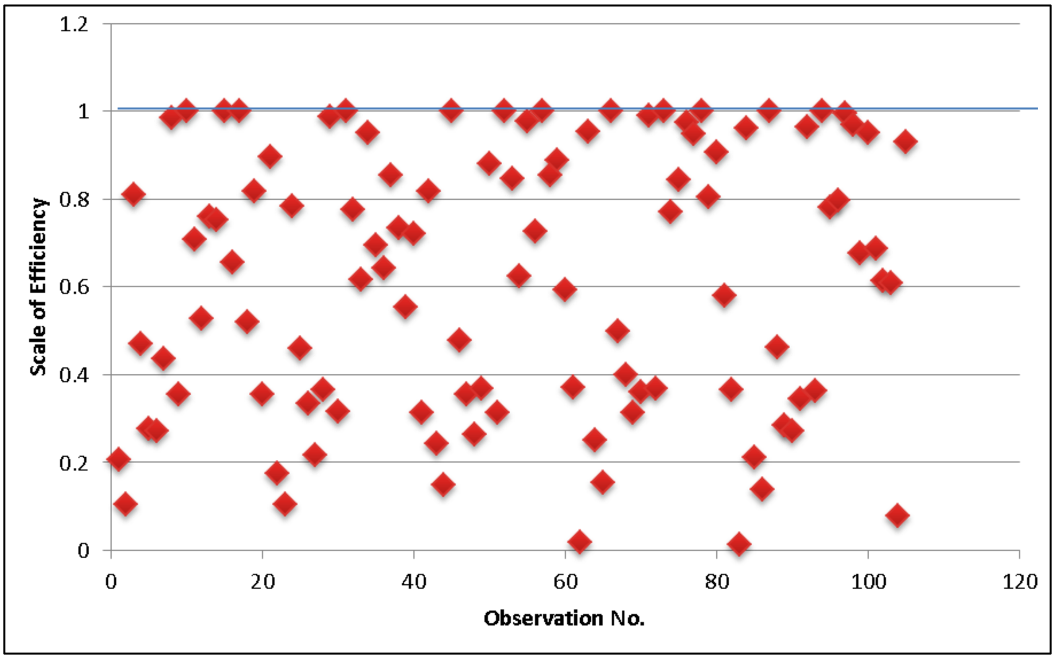

Figure 6. 5: Scale of Efficiency (SE) of Norwegian passenger car market based on number of observations

As discussed in chapter 2, score of 1 indicates scale efficiency whereas a score of less than 1 indicates otherwise (scale inefficiency). The horizontal line (in blue) across 1 from Figure 6.5 indicates the measure of SE. Thus, scale inefficiency (less than 1) is indicated by all the units below the line and units on the line show scale efficiency. About four units are on the line indicating scale efficiency. This is in line with the observations with regards to Table 6.6 where a total of four brands were scale efficient in some years and not in all years of observation. For example, brands such as CB3 (BMW), CB15 (Suzuki) and CB17 (Honda) are scale efficient in 2010-12; 2008, 2010-11 and 2008, respectively. To the contrary, CB10

(Mercedes-Benz), in the entire sample years has proven to be scale efficient implying that the combination of its inputs and output is efficient both under CRS and VRS.

6.3.4. The Scale of Operation in the Sector

Scale inefficiency in this case maybe as a result of either increasing or decreasing returns to scale. Thus, through inspection of the sum of weights under the CCR formulation (see equation 2.9), this scale inefficiency's cause can be determined. As illustrated on the right-hand side of Table 6.6, the result reveals that about half of the scale-inefficient brands (14 brands or 67%) are operating under decreasing returns to scale except for Mercedes-Benz (the 'reference' car brand) that operates with constant return to scale in all the years. By operating with DRS simply entails that a given proportional change in inputs utilised by such brands results in a proportional smaller change in their output. In contrast, since Mercedes-Benz operates with CRS in all the sample years, this implies that an increase in its inputs is matched by a proportionate increase in its output. Moreover, BMW operates with both DRS and CRS in the sample years; whereas Suzuki and Honda operate with both CRS and IRS.

It is also worth mentioning that brands (Mitsubishi, Kia, Citroen, Land Rover and Porsche) operate with both IRS and DRS. Land Rover for instance, operates with increasing return to scale (IRS) only in 2010 where its efficiency scores under VRS optimality is 100% but otherwise it operates with decreasing return to scale. This implies that in 2010, Land Rover operates with an increase in the input resulting in more than a proportionate increase in its output, hence the 100% efficiency score. For the other years (2008-2009 and 2011-2012) where it operates with decreasing return to scale, implies a proportional change in all its input result in a proportional smaller change in its output. The other interesting result is that of Mitsubishi and Kia in 2011 and 2012 respectively where they are both 100% scale efficient under the operation with IRS and scale inefficient with DRS though with insignificant variation. Therefore it can be assumed that the more the brand operate with IRS the more efficient it becomes whether in terms of VRS or scale optimality. It doesn't necessarily mean 100% efficiency only but it also means a higher efficiency score relative to the other years. This is evidenced with Citroen and Porsche where with respective years 2011 and 2012 have scores of 99.4% and 94% with DRS.

6.4. Productivity Growth in the Norwegian car market

Malmquist Productivity Index (MPI) is used in this study in order to investigate how the efficiency of Norwegian passenger car market has changed over time. Put differently, this section aims to address the second research question by analysing the productivity of the Norwegian car market using the moving base year technique[74] where productivity is measured with the previous year as a base year. This will show us the change in productivity from one year to the next. Furthermore, it will show which components of productivity leads to regress or progress as discussed earlier. The empirical results of the MPI and its successive components are shown in Table 6.7a.

No.	DMU Name	2008-2009			2009-2010			2010-2011			2011-2012			2008-2012		
		MPI	TEC	FS	MPI	TEC	FS	MPI	TEC	FS	MPI	TEC	FS	MPI	TEC	FS
CB1	Volkswagen	0.92	0.85	1.08	1.49	1.40	1.07	0.88	1.03	0.86	0.89	0.84	1.06	1.03	1.02	1.01
CB2	Toyota	0.88	1.12	0.79	1.08	1.13	0.96	0.77	0.87	0.88	1.17	1.11	1.06	0.88	1.23	0.72
CB3	BMW	1.07	0.88	1.22	1.43	1.41	1.02	1.06	1.00	1.06	0.93	1.00	0.93	1.36	1.24	1.10
CB4	Nissan	0.74	0.82	0.91	1.11	1.21	0.92	0.90	1.04	0.86	1.19	1.02	1.17	0.89	1.06	0.84
CB5	Volvo	1.75	1.73	1.01	0.91	1.08	0.84	0.94	1.12	0.84	0.76	0.66	1.14	1.44	1.40	1.03
CB6	Ford	0.95	0.88	1.08	1.35	1.17	1.16	1.04	1.26	0.83	0.79	0.78	1.01	1.05	1.01	1.05
CB7	Audi	0.77	0.71	1.08	0.99	0.98	1.01	1.00	1.18	0.85	0.97	0.93	1.05	0.79	0.76	1.04
CB8	Mitsubishi	0.59	0.55	1.08	1.11	0.97	1.15	1.81	2.17	0.84	0.56	0.55	1.02	0.67	0.63	1.06
CB9	Skoda	1.17	1.09	1.08	1.42	1.22	1.16	1.09	1.33	0.82	0.76	0.75	1.01	1.38	1.32	1.04
CB10	Mercedes-Benz	1.24	1.00	1.24	0.99	1.00	0.99	0.81	1.00	0.81	1.13	1.00	1.13	1.16	1.00	1.16
CB11	Peugeot	0.85	0.93	0.92	1.42	1.68	0.84	0.87	0.94	0.93	0.85	0.78	1.09	0.89	1.14	0.78
CB12	Opel	1.37	1.30	1.06	0.94	0.85	1.11	1.30	1.53	0.85	0.71	0.69	1.02	1.15	1.16	0.99
CB13	Kia	0.54	0.65	0.83	1.68	1.79	0.94	1.30	1.48	0.88	1.43	1.33	1.08	1.82	2.28	0.80
CB14	Citroen	0.84	0.78	1.08	1.62	1.42	1.14	1.55	1.82	0.85	1.03	1.01	1.02	2.15	2.02	1.07
CB15	Suzuki	0.51	0.64	0.79	1.52	1.56	0.98	0.93	1.00	0.93	0.67	0.68	0.99	0.48	0.68	0.70
CB16	Subaru	0.84	1.06	0.79	1.15	1.15	1.00	0.69	0.77	0.90	1.62	1.65	0.98	1.08	1.54	0.70
CB17	Honda	0.64	0.74	0.87	0.79	0.91	0.87	0.78	0.88	0.89	1.02	0.89	1.14	0.42	0.53	0.79
CB18	Hyundai	1.73	2.15	0.80	1.60	1.68	0.95	1.37	1.49	0.92	0.82	0.84	0.98	3.19	4.48	0.71
CB19	Land Rover	0.79	0.95	0.83	4.17	4.25	0.98	0.28	0.30	0.96	2.44	2.41	1.01	2.48	2.89	0.86
CB20	Chevrolet	0.95	0.88	1.08	0.07	0.06	1.16	0.61	0.73	0.83	6.68	5.85	1.14	0.21	0.22	0.96
CB21	Porsche	1.61	2.04	0.79	1.82	1.83	0.99	0.85	0.94	0.90	1.88	1.81	1.04	4.55	6.38	0.71
	Average	**0.99**	**1.03**	**0.97**	**1.37**	**1.37**	**1.01**	**0.99**	**1.14**	**0.88**	**1.35**	**1.26**	**1.05**	**1.38**	**1.62**	**0.91**
	Max	**1.75**	**2.15**	**1.24**	**4.17**	**4.25**	**1.16**	**1.81**	**2.17**	**1.06**	**6.68**	**5.85**	**1.17**	**4.55**	**6.38**	**1.16**
	Min	**0.51**	**0.55**	**0.79**	**0.07**	**0.06**	**0.84**	**0.28**	**0.30**	**0.81**	**0.56**	**0.55**	**0.93**	**0.21**	**0.22**	**0.70**
	S.D.	**0.37**	**0.44**	**0.15**	**0.75**	**0.77**	**0.10**	**0.34**	**0.40**	**0.06**	**1.30**	**1.14**	**0.06**	**1.01**	**1.43**	**0.16**

Table 6. 7 a: Productivity growth measured by the Malmquist productivity index (MPI) and its components

An interpretation of the indexes i.e. Malmquist index (MPI), technical efficiency change (TEC^i), and frontier shift index (FS^i) reported in Table 6.7a should be emphasised with

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[74] The first four periods are analysed using a moving base year technique, except for the fifth period (2008-2012) where 2008 is the only base year.

regards to their sizes. It is possible to have an index value that is greater than one, e.g. (M^i >1), implying that efficiency in period *t+1* is greater relative to that of the previous year (period *t*). In contrast, an index value of one (M^i =1) and less than one (M^i <1) indicate productivity stagnant and decline, respectively. This is not controversial at all with regards the efficiency performance score as discussed earlier; if greater than 1, it only means that efficiency in the succeeding year is greater than the preceding year.

6.4.1. Malmquist Productivity Index (MPI)

The summary results at the lower part of Table 6.7a reveal that there has been productivity growth in the Norwegian passenger car market in the years of the study period (2008-2012). The average total productivity for all the car brands is observed to be 38%. According to the Malmquist index; about 62% of the brands (13 out of 21 brands) show an increase in their average annual productivity (since MI >1), whereas the remaining brands have a productivity score that varies from 21% to 89%. Moreover, the descriptive statistics indicates that there is great variation between brands as the average standard deviation is seen to be 1.01. This relatively high standard deviation is due to the presence of outliers observed in the Malmquist index (i.e. Hyundai, Land Rover and Porsche).

When measuring the productivity changes between two periods, we notice different tendencies with regards to productivity. To be explicit, not all brands have equally experienced growth in productivity in all years of observation. Assessing the results for the periods 2008-09, 2009-10, 2010-11 and 2011-12, we can observe some remarkable trends with regards to productivity changes between brands. First, there is evidence of regression by 1% shown in both of the periods 2008-09 and 2010-11. Thus, this implies there has been a decrease of 28% in terms of average productivity as compared to the period before (2009-10). Furthermore, there is evidence of progression in 2009-10 and 2011-12 by 37% and 35% respectively (see Figure 6.6). For full overview of productivity change for each period, refer to the Appendix 4.

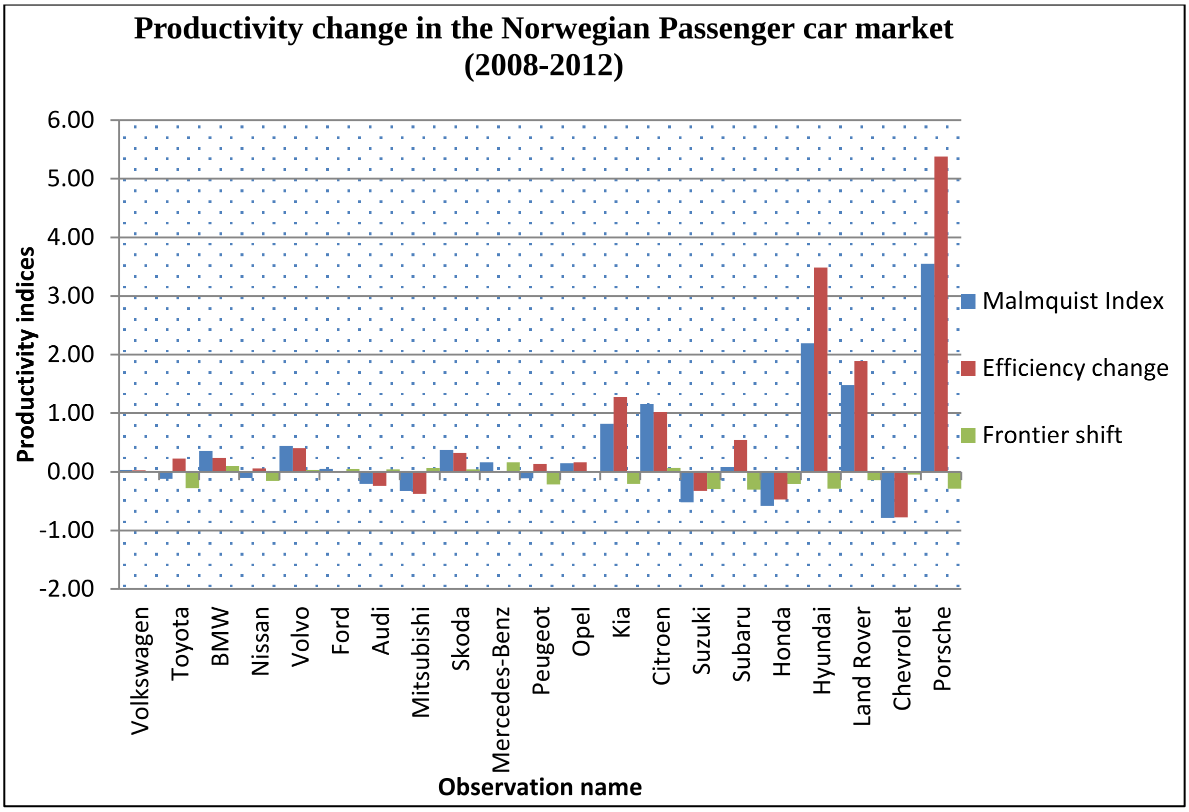
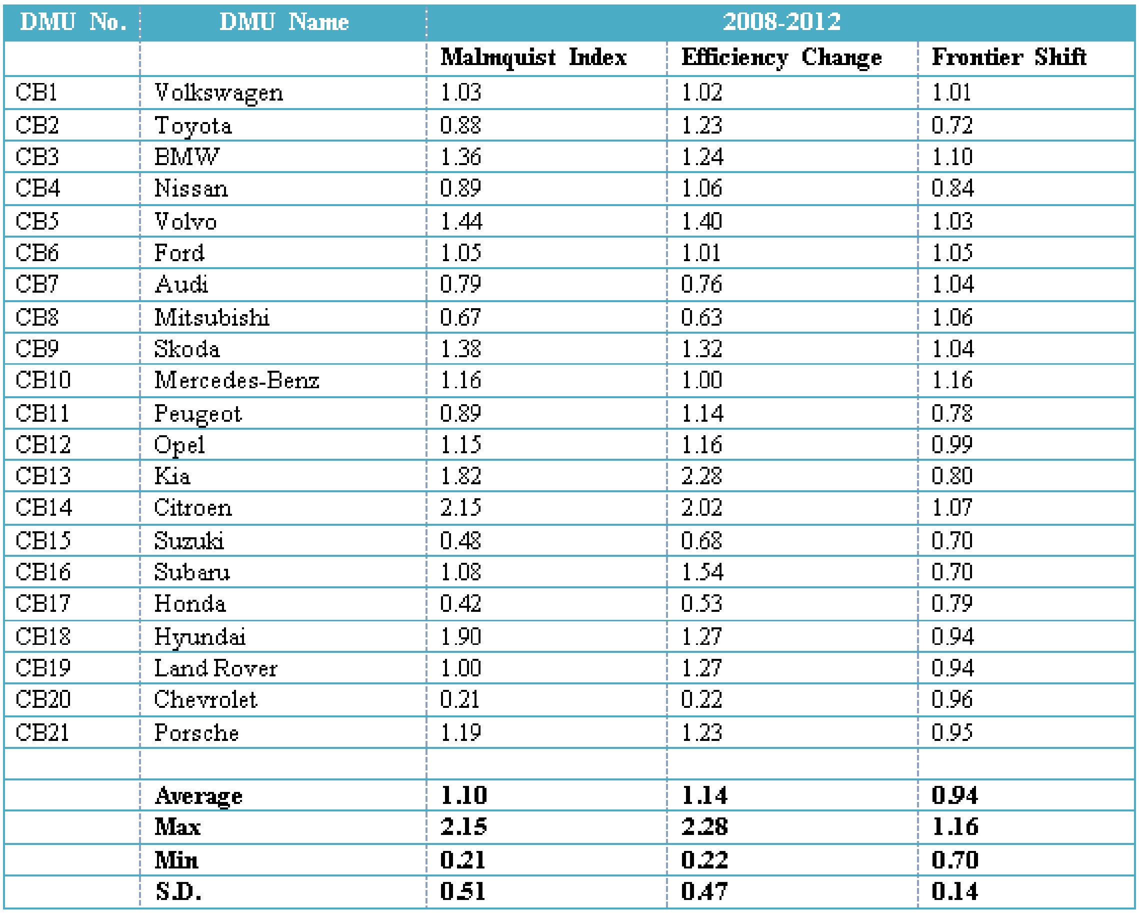


Figure 6. 6: Productivity change in the Norwegian Passenger car market

Considering individual car brands, it has been observed that the total productivity for an average unit indicates that about 50% of car brands show an increase in their performances in all the individual time periods. To be precise, 33% of the car brands have their performances improved in 2008-09, 43% in 2010-11 and 48% in 2011-12. Put simply, in 2009-10, it shows that most brands (about 71%) have productivity gains and this is the period with the highest productivity increase of 37%. Furthermore, it is interesting to note that CB5 (Volvo) exhibits unusual growth in productivity (75%) than the rest in 2008-09. Nevertheless, on average, CB5 shows a productivity decline in the rest of the intermediate periods (2009-10, 2010-11 and 2011-12) by 13%. This weaker performance is due to a gradual decrease in technical efficiency and technological change between each time period. Similar performance can be observed by Chevrolet but with different magnitude. Despite having negative productivity, Chevrolet's score is not far from achieving growth in productivity in the period 2008-2009. However, from 2009-2010 Chevrolet is considered the worst performer in terms of productivity and technical efficiency with scores of 0.07 and 0.06 correspondingly. Overall, none of the car brands has productivity gain in all the periods being studied as regards MPI. It is either they are productive in one or more than one period but not in all.

6.4.2. Technical Efficiency Change (TECi)

As already discussed in the theoretical framework section, Chapter 2, technical efficiency change (TEC^i) is also known as 'the catching up index', which relates to the degree to which a car brand improves or worsens its efficiency. This effect is determined by the efficiencies being measured by the distances from the respective frontiers. Table 6.7a indicates that on average, efficiency change has been a progression of about 62% from 2008-12. Actually, the average efficiency change in all the time periods shows an improvement. Thus, the progress in TEC^i is found to be 3%, 37%, 14% and 26% for the periods 2008-09, 2009-10, 2010-11 and 2011-12, respectively. It should however be accentuated that a judgment based on the average of efficiency change alone may be incorrect and misleading as data contains some outliers (i.e. Hyundai, Land Rover and Porsche). This is evidenced by a lower value of efficiency change obtained after interpolating data in Excel for these outliers based on the two previous time periods (2010-11 and 2011-12). Thus, the car market on average is seen to be 14% technically efficient, a value so much lower than 62% as portrayed in Table 6.7a. See Table 6.7b for the outliers' interpolated data.



DMU No.	DMU Name	2008-2012		
		Malmquist Index	**Efficiency Change**	**Frontier Shift**
CB1	Volkswagen	1.03	1.02	1.01
CB2	Toyota	0.88	1.23	0.72
CB3	BMW	1.36	1.24	1.10
CB4	Nissan	0.89	1.06	0.84
CB5	Volvo	1.44	1.40	1.03
CB6	Ford	1.05	1.01	1.05
CB7	Audi	0.79	0.76	1.04
CB8	Mitsubishi	0.67	0.63	1.06
CB9	Skoda	1.38	1.32	1.04
CB10	Mercedes-Benz	1.16	1.00	1.16
CB11	Peugeot	0.89	1.14	0.78
CB12	Opel	1.15	1.16	0.99
CB13	Kia	1.82	2.28	0.80
CB14	Citroen	2.15	2.02	1.07
CB15	Suzuki	0.48	0.68	0.70
CB16	Subaru	1.08	1.54	0.70
CB17	Honda	0.42	0.53	0.79
CB18	Hyundai	1.90	1.27	0.94
CB19	Land Rover	1.00	1.27	0.94
CB20	Chevrolet	0.21	0.22	0.96
CB21	Porsche	1.19	1.23	0.95
	Average	**1.10**	**1.14**	**0.94**
	Max	**2.15**	**2.28**	**1.16**
	Min	**0.21**	**0.22**	**0.70**
	S.D.	**0.51**	**0.47**	**0.14**

Table 6. 7 b: Interpolated data for Norwegian car market for period 2008-2012

Moreover, analysis of individual car brands shows interesting results. For example, CB10 (Mercedes-Benz) is seen to be the only brand that is efficient in each time period, thus, no technical efficiency change is indicated by TEC^i ($TEC^i = 1$). Nevertheless, it is important to take note particularly when a car brand is a frontier car brand in time period *t* and *t+1*. Although $TEC^i = 1$ implies no improvement in technical efficiency, Mercedes-Benz stands for the car market's best practice in each year. Hence, those car brands that show improvements in technical efficiency ($TEC^i > 1$) does not necessary mean they have a better performance in improving their technical efficiency relative to Mercedes-Benz.

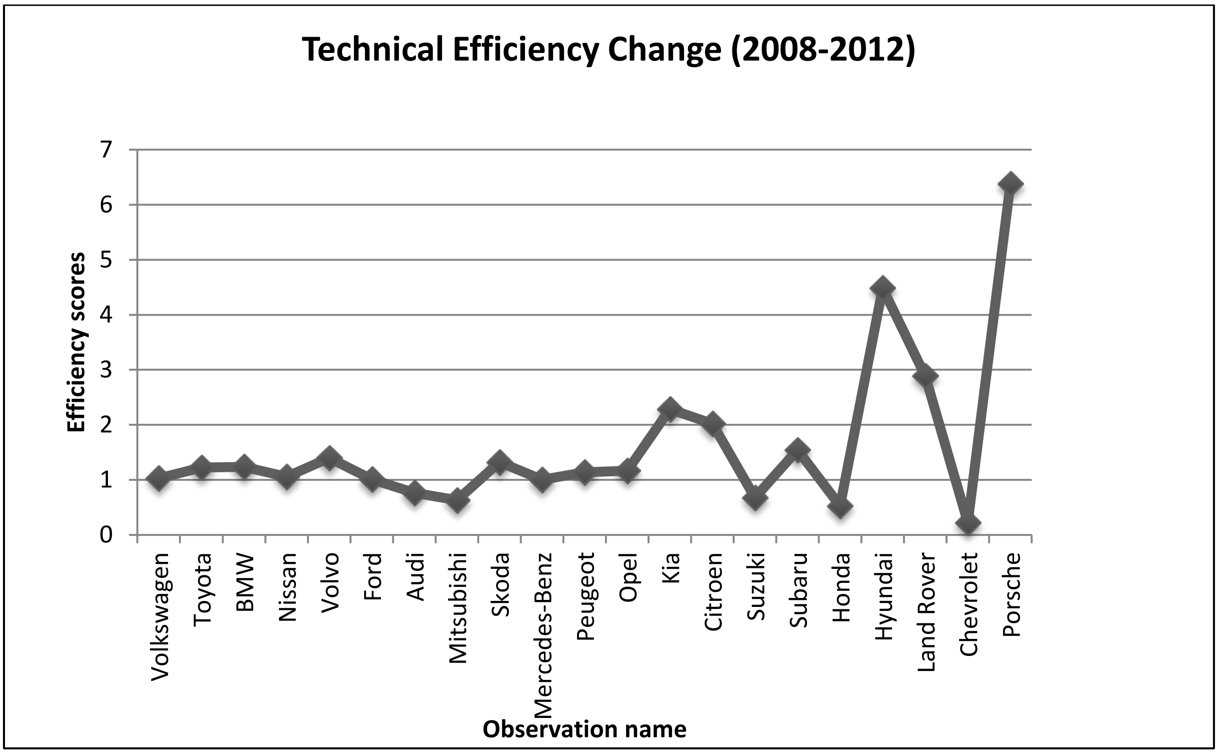


Figure 6. 7: Technical Efficiency Change for the period 2008-2012

Further analysis of individual car brands reveal that only one car brand (Chevrolet) has the highest regression of about 94% in 2009-10 and 78% in 2008-12 as illustrated in Figure 6.7. On the other hand, about 71% of the car brands (15 of them) have improvements above one indicating greater increase in their output over the entire period.

6.4.3. Frontier Shift (FS^i)

In order to fully evaluate the productivity change in Norwegian passenger car market, the frontier shift (innovation) should also be accounted for. Table 6.7a reports this Malmquist frontier shift component. It can be observed that on average, the FS^i regressed 9% from 2008-

12. Looking at the result on a period-by-period basis, FS^i regress is about 3% and 12% for the periods 2008-09 and 2010-11, correspondingly. On the flip side, FS^i progress is observed in the periods 2009-10 and 2011-12 by 1% and 5% respectively.

As indicated by FS^i index in Table 6.7a, from 2010 to 2011 all brands, with exception of BMW, exhibit no evidence of improvement in terms of frontier shift. As regards frontier shift in the period 2010-11, about 95% of the brands experience backward frontier shift, and this can be interpreted that most brands are unable to optimally combine inputs and outputs due to drop in technological efficiency. Hence, the level of output is negatively affected in the periods 2010-2011. This is illustrated in Figure 6.8.

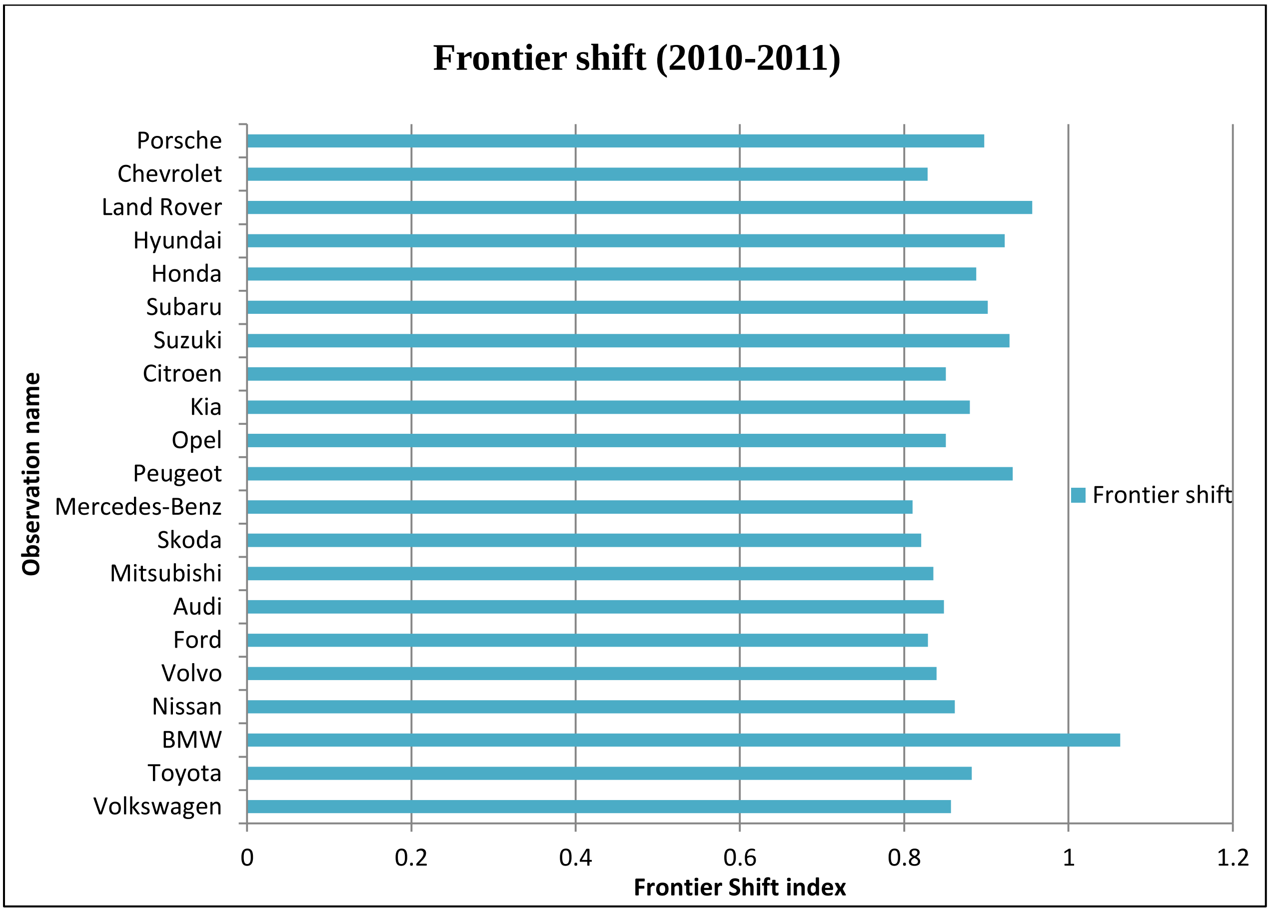


Figure 6. 8: Frontier Shift (FS^i) for the period 2010-2011

Additionally, it can be observed that a majority of the car brands (57%) show a negative shift and only nine brands (43%) show otherwise. Thus, the brands with negative shift range from a minimum of 8% (Peugeot) to a maximum of 21% (Toyota). A good example to illustrate this is CB16 (Subaru) that shows an improvement in technical efficiency by 54% but fails to maintain output increase technique. However, this doesn't affect Subaru's productivity growth as it shows 8% productivity gain from 2008-12. The same applies to the following brands BMW, Ford, Mitsubishi, Skoda, Opel, Kia, Citroen, and Hyundai, for instance, managed to increase their productivity despite having backward shift in frontier. Contrariwise, CB7 (Audi) experiences a progress in technological change but a regress in productivity due to diminishing efficiency in the entire period. Since MPI is the product of TEC^i and FS^i, TEC^i in this case of Audi, outweighs FS^i (i.e. 24% > 4%), hence making TEC^i a major determinant of productivity growth. Figure 6.9 shows frontier shift for all the periods.

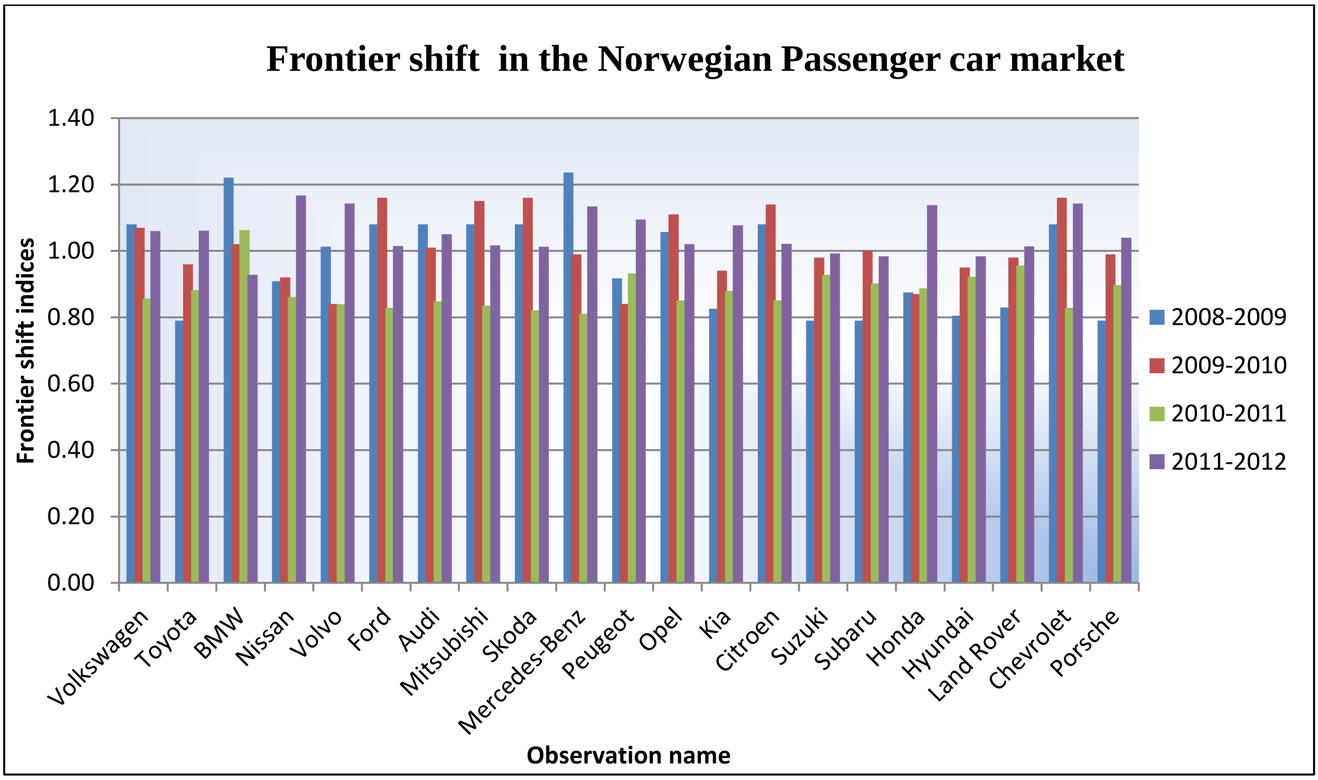


Figure 6. 9: Frontier Shift in the Norwegian passenger car market

In sum, a conclusion may be drawn based on these results that the major reason for productivity growth in this car market has been the technical efficiency change (see Figure 6.10). Thus, on average, TEC^i shows an overwhelming improvement of 62% that occurred from 2008-12, whereas FS^i shows a regress in the frontier technology by 9% within the same time period. The results based on interpolated data in Table 6.7b also give the same conclusion only with a different magnitude.

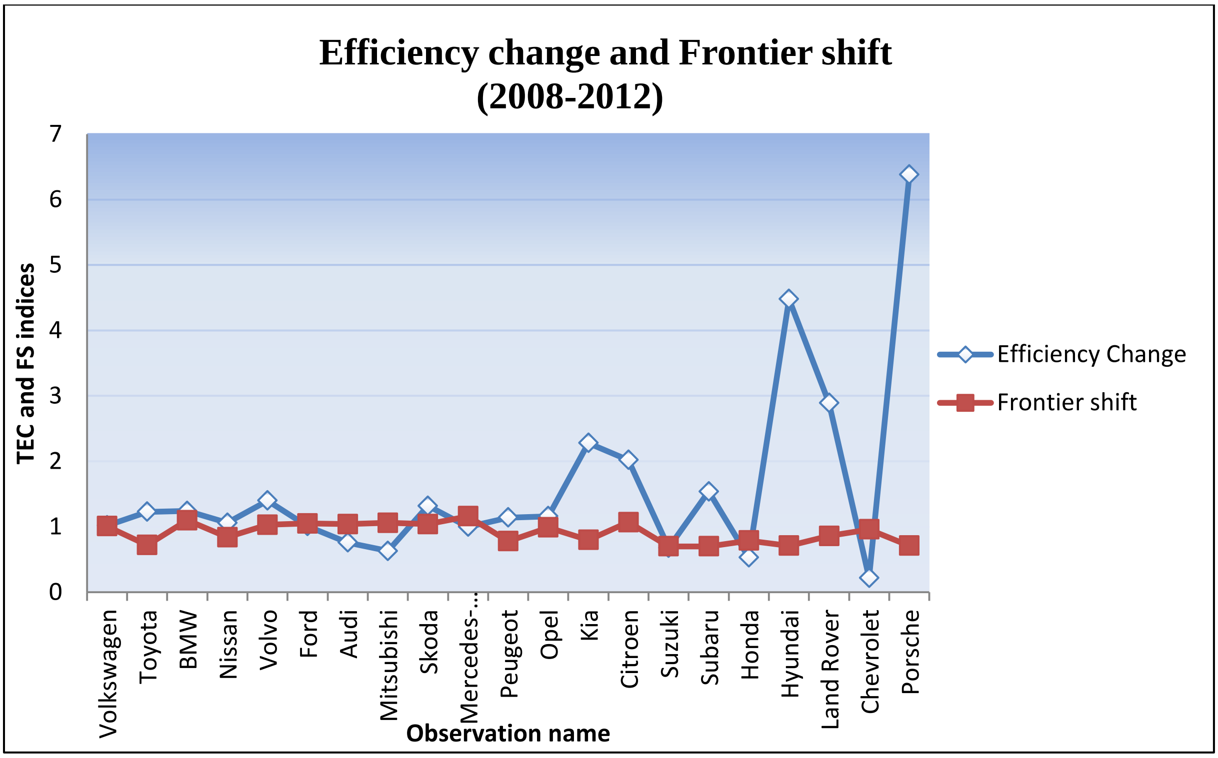


Figure 6. 10: Efficiency change and Frontier shift in the Norwegian passenger car market

6.5. Regression Analysis

This section attempts to answer the question “What impact does product variety have on the efficiency and productivity in the selected car brands?” In order to answer this question, the impacts of exogenous variables on the performances of car brands are discussed. These impacts were examined in a second-stage DEA analysis where the aforesaid variables were regressed on the efficiency and productivity scores as seen in Tables 6.8 and 6.9, respectively. The magnitude by which these exogenous variables may lead to the efficiency of some car brands is seen in the results of the coefficients indicated in Tables 6.8 and 6.9 below.

However, before this analysis was done, data was assessed as a way of checking the correlation between the independent variables[75]. The results showed that some variables were highly correlated with other variables. For example, number of models was highly correlated with chassis, engine and horsepower by 89%, 81% and 79%, respectively. See Appendices 2a and b for these results. Nonetheless, we did not just remove this highly correlated variable (number of models) to begin with, as this might have led to a bias in coefficient estimation.

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[75] According to Newbold et al., (2013), estimation of coefficients would be impossible if the independent variables were perfectly correlated. Thus, if such variables are highly correlated, then it implies that a change in one variable occurs simultaneously with a change in the other variable thereby making it hard to interpret which of the independent variables (X_1 and X_2) actually is related to the change in a dependent variable (Y).

Instead, a stepwise truncated regression was used where more variables, including number of models, were automatically removed from our model.

6.5.1. Efficiency Scores

As discussed in Chapter 4, the regression model used in this study was the truncated[76] regression model. This is due to the bounded nature of DEA whose range of values is substantially restricted, hence qualifying as a Limited Dependent Variable (LDV). Thus, DEA efficiency scores are typically defined on the interval [0, 1], where the scores are truncated to the left at zero and to the right at one. It is for this simple reason therefore that the traditional regression analysis that assumes data to include values below zero and above one wouldn't have been appropriate in this study. For previous analyses of this type of regression analysis, see for instance Simar and Wilson (2007) and Odeck (2006, 2008).

It is important to take note that a cross-section of all years was used, resulting to a total of 105 observations [21 × 5] being analysed. At first, the initial model including all the variables (see equation 4.8) was run, but it produced estimates where several variables showed insignificant coefficients[77]. We therefore proceeded with a stepwise truncated regression whereby variables are included stepwise until those that give significant results are the ones that are retained and the others are excluded. Hence, the initial model changes to the following:

$$\delta i = \beta_0 + \beta_1 chassis - \beta_2 engine + \beta_3 horsepower - \beta_4 age\ of\ brand + \varepsilon \qquad (6.1)$$

With respective coefficients:

$$\delta i = 0.12 + 0.58 chassis - 0.43 engine + 0.04 horsepower - 0.00 age\ of\ brand + \varepsilon$$

Table 6.8 indicates the results with regards to efficiency scores. As is evident in the table, only chassis, engine, horsepower and age of car brand were retained in the regression results while others were excluded. This implies that these retained variables, except age of car brand, explain the impact of product variety according to its detailed subcomponents which includes such things as variety in chassis, horsepower and engine.

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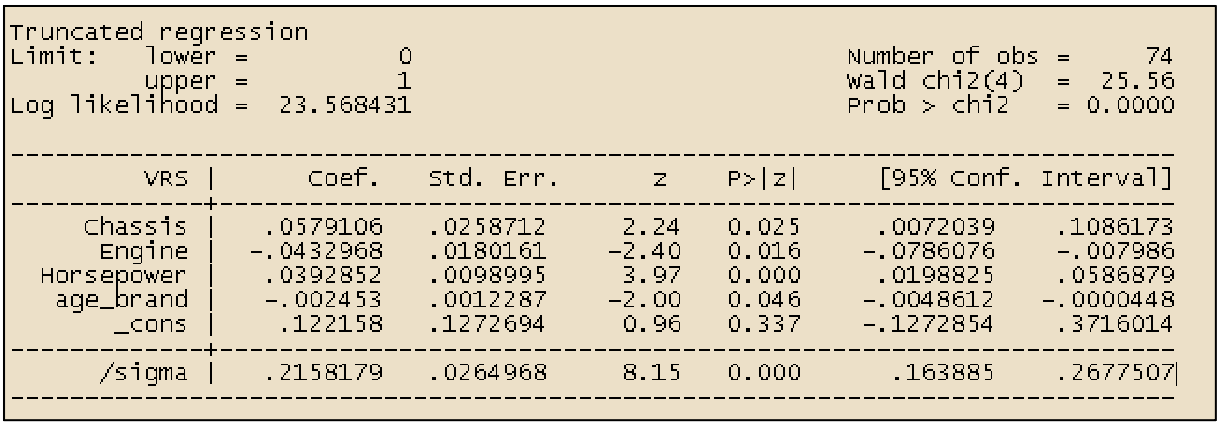
[76] A truncated sample is one which the values of the independent variables are observed only if the value of the dependent variable is observed (Judge et al., 1988).

[77] This may be due to the inclusion of the independent variables that were perfectly correlated with other independent variables in the model.

Looking at the results in Table 6.8, it is observed that the probability of obtaining the chi-square statistic given that the null hypothesis is true (Prob>chi^2) has a p-value of zero, which is less than the alpha (critical value) of 0.05[78]. This deduces that the whole model is statistically significant.

Further analysis based on these results indicates that all the exogenous variables in this model have a significant impact on the efficiency of car brands in the Norwegian passenger car market. Looking at their coefficients for example, chassis has a p-value of 0.03, which is less than 0.05, hence significant. The same applies to engine, horsepower and age of brand whose p-values are 0.02, 0.00 and 0.04, respectively. These results are interesting as it shows that these variables contribute to increased and decreased[79] inefficiency in one way or the other.



```
Truncated regression
Limit:   lower =          0                          Number of obs =      74
         upper =          1                          Wald chi2(4)  =   25.56
Log likelihood =  23.568431                          Prob > chi2   = 0.0000

------------------------------------------------------------------------------
         VRS |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     Chassis |   .0579106   .0258712     2.24   0.025     .0072039    .1086173
      Engine |  -.0432968   .0180161    -2.40   0.016    -.0786076   -.007986
  Horsepower |   .0392852   .0098995     3.97   0.000     .0198825    .0586879
   age_brand |  -.002453    .0012287    -2.00   0.046    -.0048612   -.0000448
       _cons |    .122158   .1272694     0.96   0.337    -.1272854    .3716014
-------------+----------------------------------------------------------------
      /sigma |   .2158179   .0264968     8.15   0.000      .163885    .2677507
------------------------------------------------------------------------------
```

Table 6. 8: Truncated regression of exogenous variables on the efficiency of Norwegian car market

Put differently, since the coefficients of chassis and horsepower is positive, this implies that these variables contribute to decreased inefficiency. It can also be said that these variables have a positive impact on efficiency. Consequently, engine and age of car brand have a negative impact on efficiency or that they contribute to increased inefficiency. In overall, from these results, it can be deduced that product variety may contribute to decreased inefficiency among car brands as is seen by its components (chassis and horsepower). Put simply, this implies that product variety in terms of chassis and horsepower[80] could enhance efficiency. This means that a car brand that provides a variety of chassis and horsepower is

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[78] The p-value, which is compared to a specified alpha level, is usually set at 0.05 or 0.01. In this study, it is set at 0.05.

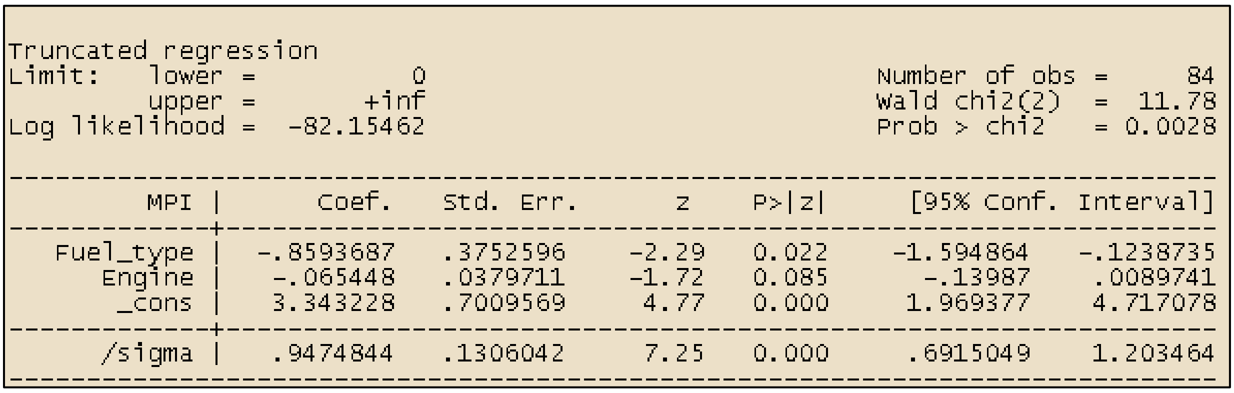
[79] If the exogenous variables are regressed on the efficiency scores, then if a coefficient of a variable is positive (negative), it means that the variable increases (decreases) efficiency. The opposite is true if regressed on the inefficiency scores (1-E).

[80] Engine is also a measure of product variety in this study, but this conclusion is drawn based on the results obtained where engine indicates a negative influence on the efficiency of car brands.

likely to perform better relative to those that have less number of chassis and horsepower. On the flip side, engine has a negative coefficient implying that brands that are diverse in engines lead to inefficiency. Thus, engine proves to be detrimental to efficiency performance implying that even if a brand provides different types of engines to the market, it doesn't gain efficiency as a result of it. It is surprising however that age of a car brand[81] has a negative coefficient and hence impacts efficiency negatively. A caution must be taken nonetheless in interpreting this result. First, an older brand should imply high efficiency due to the fact that the older the brand the more experienced it is over time. As a result, it means that particular brand is able to hold its costs at a minimal level while at the same time improve its quality (introducing new products i.e. product variety), which eventually improves efficiency. On the other hand, the older the brand the fewer the sales as the trend might be changing to having high demand in the new brands and not the old ones. This might lead to inefficiency as operating costs might be higher than the profit.

6.5.2. Productivity scores

The results of the regression analysis based on productivity scores are displayed in Table 6.9 below. Similarly, a stepwise truncated regression analysis was done for the same reason as efficiency scores with the exception that the productivity scores are only truncated from below at zero. Thus, the produced estimates revealed many variables with insignificant coefficients when the initial model was run (see equation 4.9). However, a stepwise truncated regression results show that only two variables were retained; fuel type and engine. The others were dropped as they were highly correlated with other explanatory variables (e.g. number of models) and not significant (e.g. market share, firm size, and GDP growth).



```
Truncated regression
Limit:   lower =          0                              Number of obs =      84
         upper =       +inf                              Wald chi2(2)  =   11.78
Log likelihood =  -82.15462                              Prob > chi2   =  0.0028

------------------------------------------------------------------------------
         MPI |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   Fuel_type |  -.8593687   .3752596    -2.29   0.022    -1.594864   -.1238735
      Engine |   -.065448   .0379711    -1.72   0.085      -.13987    .0089741
       _cons |   3.343228   .7009569     4.77   0.000     1.969377    4.717078
-------------+----------------------------------------------------------------
      /sigma |   .9474844   .1306042     7.25   0.000     .6915049    1.203464
------------------------------------------------------------------------------
```

Table 6. 9: Truncated regression of exogenous variables on the productivity of Norwegian car market

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[81] Age of car brand in this study implies how long the brand has been on the market.

See the new model after running a truncated regression:

$$\theta i = \beta_0 - \beta_1 fuel\,type - \beta_2 engine + \varepsilon \quad (6.2)$$

$$\theta i = 3.34 - 0.86 fuel\,type - 0.07 engine + \varepsilon$$

As observed from Table 6.9 above, given that the null hypothesis is true, the probability of obtaining the chi-square statistic (Prob>chi^2) has a p-value of zero, which is less than the critical value of 0.05. Hence, indicating the statistically significance of the overall model. Further analysis of these results, reveal that both variables (fuel type and engine) are significant but with negative coefficients. This entails that these variables explain the impact of product variety on the productivity of car brands in the Norwegian passenger car market.

The negative sign on the coefficients of both variables imply that they have a negative impact on productivity. In other words, fuel type and engine contribute to decreased productivity of car brands. In this study, both variables measure product variety and this means that product variety reduces productivity. Put differently, those car brands with high product variety (in terms of various types of fuel type and engine) are likely to progress less in productivity as compared to those with low product variety. This seems logical as high product variety implies high costs. Thus, there is a trade-off between high level of product variety and high cost, which may eventually lead to less productivity of car brands. This can be argued in terms of those costs incurred when importing different models of cars. Since the Norwegian dealers import cars from car manufacturers outside Norway, this may take longer particularly if the cars are of different models (high product variety). Obviously, high product variety means complex product mix which comes with additional parts, greater material handling, and greater chance of quality problems, among others. As a result, longer lead-time may affect the income of these dealers in question due to inability in realising economies of scale and thus, higher costs.

6.6. Chapter Summary

The chapter presented the analysis of the empirical data using Data Envelopment Analysis DEA and Malmquist Productivity Index (MPI). A truncated regression was performed in order to assess the impact of product variety on efficiency and productivity on the Norwegian car market. The findings show that on overall the aforesaid car market is inefficient by 40%

under variable return to scale assumption and 65% inefficient under constant return to scale optimality. Nevertheless, the findings show a progress in productivity by 38%. The subsequent chapter is an extension of this chapter as it discusses the findings presented in this section. It also delineates both the managerial and methodological implications, and outlines the limitations of this study and provides recommendations for future research.

CHAPTER 7

DISCUSSION OF FINDINGS, IMPLICATIONS AND FUTURE RESEARCH

7.1. Introduction

The prior section has presented the efficiency performance of the Norwegian passenger car market, in which twenty-one valid samples for the study were selected and the years 2008 to 2012 were used as the dimensions. The first part of this section will expatiate upon the summary of findings obtained from the data analysis. This will be followed by the results which will be used as a basis for discussion to verify whether there is a consistency between the results and the theories which were introduced in chapter two. The discussion is in accordance with the research objective and the research questions presented in chapter one. Conclusion, implications and future research of the study are also presented in this chapter.

7.2. Summary of Findings

The main purpose of this study was to elucidate how the relative efficiency of Norwegian passenger car market can be assessed and how the changes in productivity of this market by time can be observed in light of product variety. The study was also aimed to evaluate whether the differences in the efficiencies and productivity of this car market can be explained by product variety and other exogenous variables such as; firm size measured by number of dealers, age of car brands, GDP growth per capita and market share. The other purpose is to contribute to the efficiency literature as most studies on efficiency have been done on automotive industry from the manufacturing perspective, leaving out car market (dealership perspective). Thus, this study has taken a different approach by assessing efficiency of car dealers in the car market with a focus on product variety. It is also worth-mentioning that this study integrated product differentiation and production theories that discuss product variety and Data Envelopment Analysis (DEA), respectively, in light of car market. With this kind of market, car brand was used as a unit of analysis.

This research sought to find answers to a set of research questions of which the first was "Has the Norwegian passenger car market been efficient between the years 2008 to 2012?" This question was answered by using DEA technique. The results obtained from the DEA efficiency analysis under VRS assumption in the first stage indicate that the Norwegian car market is efficient by 60%. This implies that the output increasing potential for this market is 40%. However under CRS optimality, the efficiency scores of the overall market is lower relative to that of VRS. Thus, CRS shows 35% efficiency implying a need to augment output by 65% while keeping the input level constant. Further analysis reveals that four car brands are 100% efficient in all the years of observation years under VRS whereas only one brand is 100% efficient with CRS. Hence, it can be deduced that the most least efficient car brands are those analysed under CRS as compared to VRS.

The second research question "How Norwegian passenger car market's efficiency has changed from 2008 to 2012?" was answered by analysing Malmquist Productivity Index (MPI). In order to see the change in productivity from one year to the next, a moving base year technique where productivity is measured with the previous year as a base year was used in addressing this question. From the results, productivity growth in the said car market has been observed in the period 2008 to 2012. The total productivity for all the car brands on average is observed to be 38%. This implies that about 62% of the brands show an increase in their average annual productivity.

The second-stage DEA analysis where a truncated regression on efficiency and productivity scores was run reveals that all the exogenous variables in both the models (see equation 6.1 and 6.2) have a significant impact on the efficiency and productivity of car brands, respectively. Nonetheless, some variables from the initial models (see equations 4.8 and 4.9) that highly correlated with other explanatory variables were dropped. An overall assessment of both models 6.1 and 6.2 indicate the models are statistically significant based on the probability of obtaining the chi-square statistic given that the null hypothesis is true (Prob>chi^2) that has a p-value of zero, which is less than critical value of 0.05. Based on model 6.1, the results show that product variety contributes to decreased inefficiency among car brands as is seen by its components (chassis and horsepower). In this case, product variety enhances efficiency whereas age of car brand and type of engine prove to be detrimental to efficiency performance of car brands. Unlike model 6.1, the results based on model 6.2 indicate that car brands with high product variety (measured by fuel and engine types) are likely to progress less in productivity relative to those with low product variety.

7.3. Discussion

In this section, we will be discussing DEA analysis results obtained from the analysis. The first part of the section will mainly discuss results of efficiency and productivity, and the second part will discuss results obtained from the truncated regression analysis.

7.3.1. First-stage DEA efficiency analysis

The research findings suggest that the Norwegian passenger car market has poorly performed on the total efficiency, pure technical efficiency, and scale efficiency in all years of observation. These findings may be explained due to misallocation of resources that have been linked to higher costs in selling different models of passenger cars (high product variety) leading to inefficiency. These findings are in coherence with product differentiation theory which claims that product differentiation enhances customer welfare but simultaneously imposes a cost on the economy as firms do not produce at minimum average total cost (Holcombe, 2009). Moreover, the theory claims that firms that use product differentiation as part of their strategy to gain competitive advantage by improving the quality of their product will likely succeed in the market than those that use it to differentiate from others. This is because the monetary rate of return from firms differentiating their product is insignificant.

Based on the aforementioned statement, it may be said that inefficiency obstructs the development of the Norwegian passenger car market. In this context, there are significant efficiency gains to be made. Specifically, when most brands are operating on decreasing returns to scale under the VRS assumption, and this may be related by numerous reasons. Referring to the product differentiation theory as discussed earlier in Chapter two, the inefficiency in the Norwegian passenger car market may be caused by the incompetent of the market to reach the optimal quantity in light of product variety. Considering the product differentiation theory, one may assume that due to product variety the Norwegian passenger car market imports an amount of output where the marginal revenue equals to marginal cost, as a result of this there is excess capacity, and the market becomes inefficient (Tragakes, 2012). However, if the market was efficient enough it should have imported at the quantity where the average total cost equals the marginal cost. As depicted in Figure 7.1, currently the Norwegian car market is importing an amount of output at point Q1, whereas if the market was efficient the amount of output should have been at point Q2. The difference between Q2 - Q1 is regarded as excess capacity.

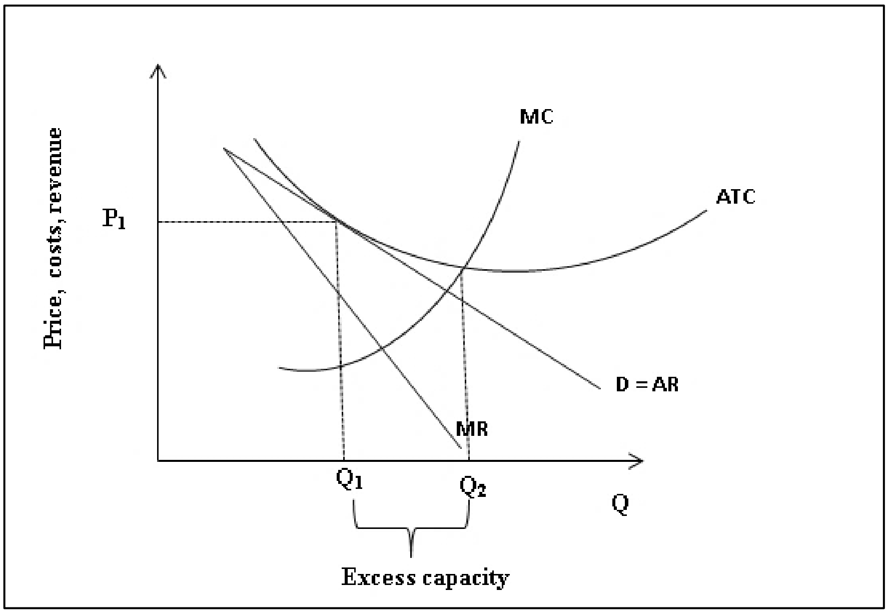

Figure 7. 1: The cost curve of production (Tragakes, 2012)

Furthermore, the ongoing financial crises, initial investment costs incurred on new equipment for repairing, upgrading the sales people's knowledge, skills and abilities on the electric cars may be considered as the core sources of the inefficiency. It can be said that in 2009 many car brands were caught by surprise as far as costs and sales are concerned. For example, the global crisis in 2009 has significantly affected the car market as the total sales in that year shrank for the most brands by 12%. In addition to this, it may be said that in the same year there has been political pressure on brands to develop their technology on electric cars as the Norwegian government had introduced monetary incentives. Based on these grounds, many brands have paid a high price for it. For example, in 2009 Mitsubishi reported that their global sales decreased due to economic crunch, and also expressed their interest in developing electric cars (Mitsubishi-motors, 2009). Similarly, Nissan has been heavily invested in electric cars in the Norwegian passenger car market (Grønnbil, 2014). As presented in the results, Nissan has been inefficient in both VRS and SE for all years of observation, but more remarkable in 2009 where the inefficiency was the lowest. This may be interpreted that the investment made by Nissan has caused inefficiency. When looking at the results found in the analysis, one may agree that poor scores in VRS and SE achieved by most car brands are justified by the grounds found above. Even though, the obtained results may be criticised on the way the sampling selection of the car brands was done in the study or in the worst case be judgmental on the accuracy of the results since the years of observation is short. But, this argument can be challenged on the fact that these selected brands own more than half of the

Norwegian passenger market share. Thus, the difference in the results wouldn't be very significant even if all cars brands were included in the study. Likewise, any procedure used in the study was carefully examined to prevent the study from being biased.

Another reason that explains the inefficiency is safety-related recalls that may certainly be the red-hot-button in the car business these days, and because of this various automakers paid a high price for this. For example, in 2009 Toyota was put in the headlines for announcing a recall action regarding 1.8 million vehicles sold in Europe due to faulty braking, sticky gas pedal and defective floor mats (CBS News, 2010). Furthermore, it may be noteworthy to underline that recently Toyota has been victim of applying differentiation strategy in a wrong way. Toyota's differentiation put emphasis on high quality product and variety as a way to differentiate itself from the rest. The attempt made by Toyota to differentiate its products has placed the company at a competitive disadvantage in the marketplace because the recall in 2009 has been ongoing even until today. Thus, we may assume that there has been a drop in quality with the vehicles, and this has added additional costs to the company. Based on this, one may say that consumers in the Norwegian market have built a bad perception on Toyota's products. Referring to product differentiation theory discussed in chapter two, it may be said that Toyota has wrongly implemented vertical differentiation due to the fact that there has been a drop in quality. This is devastating for Toyota especially considering that in the 1990s they used to be efficient and progressed well in productivity due to introduction of Toyota Production System (TPS) that eliminated the negative consequences of increased product variety on the company's performance (Monden, 1994).

However, it has succeeded in horizontal product differentiation since high variety has been provided by the company. Thus, the wrong use of the differentiation strategy used by Toyota has contributed to scale inefficiency in the Norwegian passenger car market.

On the contrary, the results show that Mercedes Benz is the only brand in the Norwegian passenger car market that has been efficient in all years of observation, and its performance may be justified by various reasons. The key lies in Mercedes Benz constantly minimizing the inputs cost (on average approximately 2.66% of the total sales) and operates at optimal level of scale efficiency, these points are considered as the key success factors in being efficient in the market. As found in the results, Mercedes Benz has been operating at constant returns to scale in all sample years, implying that it is equally efficient in operating in a small or large scale. It is reasonable to believe that the high Gross Domestic Product (GDP) growth rate per capita in the Norwegian economy may have contributed to the efficiency of Mercedes Benz, even though the regression results show that there is no significant correlation as regards efficiency and productivity. In this context, a high GDP per capita gives the Norwegian car consumers the freedom to choose for more expensive/luxury cars, which give them the feeling to have achieved the success on which their high self-esteem is built. In Economics, this refers to income substitution effect[82]. With great brand awareness that Mercedes-Benz has, consumers may be willing to pay for a high price in exchange for high product variety. As a result of this, Mercedes-Benz will be able to cover the additional costs incurred, and makes them efficient in the Norwegian passenger car market.

In addition to this, Land Rover has shown a remarkable improvement in VRS efficiency in 2010. In 2008 and 2009 Land rover was inefficient as regards VRS, during these two periods the company's efficiency under VRS was 0.11 and 0.12 respectively. However, in 2010 Land Rover showed a remarkable progress as its efficiency score was 1. Naturally, there were reasons associated with this impressive improvement. First of all, in 2010 Land Rover was bought by Tata Group and as a result of this many changes were made which may explain this impressive progress. For instance, there has been consistent increase in its sales since the launch of the 2010 model year range which boasts the latest, most efficient and technologically advanced line-up for Land Rover in its history (NewsroomLandRover, 2010).

Recalling production theory discussed earlier in chapter two, the theory assumes that firms have the flexibility to decide which inputs factors to use in the production process in order to get a certain quantity of commodities or services in the market. However, under the assumption of the production theory, a firm is efficient and productive when it is able to use minimum input and maximize output within a short time. The latter is directly related to productivity, which is going to be discussed next.

As shown in the results, the Norwegian passenger car market has been on average productive in all years of observation. Referring to production theory it can be said that most brands have been using their resources effectively based on the results. Indeed, the high productivity in the Norwegian car market may also be due to high sales of electric cars over the past few years. As mentioned earlier, the high initial investment costs for electric cars has started to pay off in the Norwegian passenger car market as it may not be obvious but in 2009 automakers

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[82] The income substitution effect refers to the effect due to change in real income. If the income, leaving the price ratio unchanged, consumer's purchasing power will go up.

incurred high costs and low sales. But, after 2010 many brands have taken advantage of the new technology and increased their variety. For example, Nissan was one of the few brands to have invested in electric cars, which may have significant losses in 2009, but after 2009 the company's productivity has significantly improved. This is evident in the boom of sales of Nissan Leaf, one of its models which even became the most sold model in September 2013 with about 145% increase in sales (NissanNews, 2014). Another example may be the one of Land Rover. Not only did the company show an impressive progress in efficiency in 2010, but their productivity in the same period show tremendous performance. As shown in the result from 2008 to 2009 the company's productivity was below the average; however in 2010 the company quadrupled its productivity.

Based on the above mentioned fact, one may claim that the reason for high productivity in the Norwegian passenger market is due to economy of scope. This implies that automakers have got all the skills it takes to produce electric vehicles in different models without making a big change.

7.3.2. Second-stage DEA efficiency analysis

Up to this time the discussion has been limited on efficiency and productivity in the Norwegian passenger car market. Numerous reasons were given why the market has been inefficient, and factors that may have contributed to the increase in productivity. Part two of our discussion will, however, focus on the role product variety is playing in these elements. As it can be noted, part one has only discussed product variety in general. But, the empirical results obtained from the truncated regression analysis, which explains product variety in great extent, will now be discussed.

Offering a variety of products to the consumers has been a cornerstone of most automobile manufacturers'/ dealers' strategies. There seem to be a steady increase of variety in the 1990's where General Motor's strategy of segmentation by price and value supported Alfred P. Sloan's rejoinder to Ford offering "a car for every purse and purpose" (Fisher and Ittner, 1999). Further increase in variety was also seen in the segmentation of size and design of cars by European and Japanese competitors. However, most studies show that higher product variety is associated with higher costs leading to poor performance of the firm. The finding of this study nevertheless doesn't support the prediction that car brands with lower product variety tend to be more efficient than those with high product variety. This finding revealed a positive impact between product variety and efficiency implying that high product variety may contribute to decreased inefficiency or rather increases efficiency. However, there seems to be a contradiction with product differentiation theory and findings of researchers from the accounting and operations management fields where they argue that higher product variety creates considerable challenges for the firm’s operations, and thus higher costs leading to inefficiency (see e.g. Miller and Vollman, 1985; and Cooper and Kaplan, 1999). Hill et al., (2014) also argues that the trade-off implicit in this idea is between unit costs of producing cars and product variety. Producing numerous different models of car brands implies longer lead times, which entails an inability to realise economies of scale, and thus higher costs. These arguments nonetheless are only applicable to car manufacturers and not car dealers who only sell finished products. Hence, the finding shows that the market seems to be more efficient when car dealers offer high product variety to the end customers.

This finding may be explained in terms of how much variety the car brands have as regards chassis, horsepower types, and year of operation (age). This is evident in the total number of such product variety measures seen in the car brands. For example, Mercedes-Benz is observed to be 100% efficient in all the years of observation and has a total of 39 and 152 types of chassis and horsepower within the five years (2008 to 2012). The same applies to BMW, which has a total of 30 chassis and 130 horsepower types and proves to be 100% efficient under VRS assumption. On the flip side, those with low variety indicate high inefficiency levels. For instance, Porsche and Citroen are 88% and 79% inefficient and yet they have low product variety in terms of chassis and horsepower types.

Further, the results based on model 6.2, show that car brands with low product variety tend to progress more in productivity relative to those with high product variety. This result was found to be significant when a truncated regression of product variety on productivity scores was performed. The result found a negative correlation between age and inefficiency in the Norwegian passenger car market, implying that the older the company, the more inefficient it is. This statement may be true because when looking at the results of efficiency from part one, it becomes apparent that older brands have been inefficient in all years of observation. For example, Opel[83] has been inefficient in all years of observation, despite of being the oldest brand in the business. The same applies for Peugeot and Skoda; both of these car brands were also found to be inefficient under VRS and SE. A social factor may have played an important

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[83] Opel is a German car manufacturer and has been in business for about 150 years

role in this case, as reported by Hannisdahl et al., (2013), automakers like Nissan, Citroen, and among others have made a big progress in their electric vehicles as far as conformability is concerned. Most electric vehicles today come with back seats, and air condition. These new and better equipped cars have now started to display their true potential. Nowadays, the buying decision for an electric car by Norwegian customers is done because friends, neighbours, and colleagues buy it.

The other reason that may explain their inefficiency in the market is due to demographic change and social shift. First of all, it may be said that old brands have been popular among baby boomers[84]. But according to Almås (2010), there has been a demographic change in the Norwegian society. Perloff (2004) argues that consumers are different and as such they value having a choice which to some extent may lead them prefer a new brand to existing ones. Based on this, one may claim that Generation Y[85] prefers younger and newer brands, which are most of the times costly due to the advanced technology invested in those brands. This finding is consistent with product differentiation theory where Holcombe (2009) argues that higher product variety means higher operational costs. Hill et al., (2014) further comments on this asserting that central to the concept of economies of scale is the idea that a lower cost structure, through importing a large volume of homogenous cars (implying less product variety), is the best way to achieve high efficiency, hence productivity gain. He argues further that high level of product variety makes it even harder for the car dealers to gain productivity and reduce their unit costs. According to this logic therefore, it means limiting product variety may lead to an increase in productivity and improvement in cost structure.

Nevertheless, this finding is contrary to that found in model 6.1 though both findings refer to product variety. The possible reason for this difference might be due to the fact that efficiency scores are only one component of total productivity and that factors affecting efficiency scores in terms of product variety (e.g. chassis and horsepower) haven’t significantly impact total productivity. This is seen clearly in both models where despite being significant, they have different exogenous factors that are impacting product variety differently.

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[84] Baby boomers are people born during the demographic Post-World war II baby boom between years 1946 and 1964.

[85] Generation Y is a segment of the population born between 1980 and 2000.

7.4. Conclusion

In this thesis, we examine the efficiency and productivity of the Norwegian passenger car market using DEA-based approach. Additionally, the study assesses the interaction of product variety with regard to the aforementioned elements. The findings from the first-stage analysis imply that 19% car brands were variable returns to scale technically efficient; and only one car brand achieved scale efficiency which roughly represents 5% of the sample size. On average, car brands have about 40%, 65% and 38% potential for efficiency gains in light of variable returns to scale, constant return to scale and scale efficiency, respectively. The difference between variable and constant returns to scale is very significant, whereas constant returns to scale and scale efficient do not differ much. Given this it may be concluded that most inefficiencies in the car market are derived from the constant returns to scale and scale efficiency.

Our second-stage analysis indicates that inducing product variety has two-fold effects. Increasing product variety is positively correlated with efficiency. This means that increasing product variety will enhance efficiency for the car dealers. On the flip side, increasing product variety reduces firm’s productivity as far as the car market is concerned.

Based on these results, the following conclusion may be drawn about the Norwegian passenger car market. First of all, the market faces a number of challenges including satisfying the needs of different segments and finding the optimal level of product variety in which efficiency and productivity in the market are enhanced. As found in the results, it can be concluded that the core reason for this inefficiency in the market is because the market is operating at the point where the average total cost is greater than the marginal revenue. However, the efficiency scores of VRS, CRS and SE indicate that the potential efficiency improvement among brands operating in the Norwegian market is not far achieving the efficiency level. In contrast, it can be concluded that the car market has a long way to go in order to achieve the fully efficient under assumption of constant returns to scale given that the room for improvement is greater than 50%.

Second, it may also be concluded that the government interference in the car market has also contributed to the market inefficiency. As indicated earlier, higher import taxes and providing different forms of incentives by the Norwegian government has weakened the competitiveness in the car market. Consequently, the firms (car dealers) do not have the incentive to invest in advanced technology in order to increase their productivity given that the monetary value of return will not be enough to cover the initial investment costs made by these firms.

Another point that can be concluded from the results is that the potential for efficiency gains is considerably low, which means less effort is required by firms in order to be fully efficient. Thus, allowing free market economy by reducing government interference will encourage or push competitive environment. Overall, competitive environment forces firms to find the best way how to operate efficiently and effectively, and failing to do so will incur losses, which will take them out of business. Because of this, firms will be stimulated to invest in innovation, increase their productivity and efficiency.

7.5. Managerial Implications

This study provides some valuable shrewdness for car managers, policy makers and the government at large on what essential factors they need to be aware of and pay much attention to in a bid to refurbish and boost the performance of the car market. First, the overall poor efficiency performance of the Norwegian passenger car market between 2008 and 2012 is a cause for major concern, as it is likely to have an impact on the society as a whole. As suggested in Microeconomics, an inefficiency market leads to a discrepancy between economic value and price (Salanie, 2000). Given that firms incur high cost in producing a commodity, the costs are transferred to the end consumers, which results to higher selling price. However, this selling price may not factually reflect the economic value of the commodity. For instance, most car dealers that are inefficient in this study incur more operational costs due to inefficient allocation of resources and/or failure to supply their cars at its lowest unit cost. Hence, the need for the authorities to step in and help the car dealers rethink their reform measures by stimulating more competition in the car market. Competition will make car dealers have the incentive to improve their efficiency performance (increased market share and higher profitability) through adoption of innovative technology.

Additionally, the findings of the study reveal that the main reason behind inefficiency in this car market is scale inefficiency. Thus, with scale efficiency measure, many car brands seem to be inefficient. Hence, in order to be scale efficient, such scale inefficient car brands need to learn to optimize their scale operations efficiently by trimming down their size of operations.

Moreover, the positive impact of product variety (measured by chassis and horsepower types) on efficiency suggests that the car brands that provides a variety of chassis and horsepower are likely to perform better relative to those with less variety. Therefore, the inefficient car brands need to rethink their reform measures by incorporating such variety in their models or find other forms of variety that may contribute to attend the efficiency point.

Furthermore, it has been discussed in this study that ‘safety-related recalls’ are believed to explain the inefficiency for some brands in this market. This is costly on the dealers’ perspective as costs are incurred in sending back the cars to the manufacturers and also longer lead-times can be observed, hence higher costs. Alternatively, the car dealers need to have a contingency plan for mitigating such uncertainties, given the investment objectives and risk tolerance. Simply put, severe consequences for such dealers can emanate from inadequate risk management and this is why it is essential to handle the ‘recalls’ in a way best-suited to the dealers’ investment objectives.

7.6. Methodological Implications

The study employed DEA and Malmquist Productivity Index (MPI) approaches in evaluating efficiency and productivity of Norwegian car market, correspondingly. It should be underlined that the DEA analysis was used specifically in this study because of the following reasons: it was straightforward and more robust in estimating the frontier efficiency of the of each car brand in the Norwegian passenger car market, it enabled us to find role models (benchmarks) that the inefficient car brands can emulate to improve their performance, and it also helped us in exploring useful information in managing performance of the operating car brands, such as measuring optimal scale size. More importantly, DEA was very applicable to our study due to the nature of our variables, i.e. multiple inputs and a single output, which could not have been possible with parametric approaches.

Besides, MPI was used as well due to the nature of DEA of being unable to estimate changes in productivity. The combination of these two methods enabled us to analyse both the efficiency and changes in productivity of the Norwegian car market. Hence, it is recommended to use both methods as they are inseparable.

7.7. Limitations of the study

This study, as any other empirical study, has its own limitations which may impact the observed results. The major limitation of this study is the availability of selling price data for all the selected car brands. There is no single reliable database that contains noise-free data regarding selling prices of car brands in the Norwegian market. Hence, the close proxies have been used in this study to estimate the selling price of each brand.

Moreover, time dimension used for this study covers only five years. This is due to missing data of some car brands in years before 2008 and beyond 2012. Otherwise, for a thorough analysis of the market, ten years could have been a better representative of that even though the study makes interesting findings regarding efficiency and productivity.

Further, the study's criteria of selecting car brands depend only on the franchised dealers. Thus, only those brands that are independent, that do not belong to an 'umbrella' group have been used as a sample. As such, when selecting them it turned out to be even harder than anticipated since most of the brands own other brands as well. Hence, an extreme proper care was taken in obtaining financial data for such brands in order to avoid including data for the unselected brands.

Lastly, this study used only DEA-based approach, making it susceptible to biased efficiency estimates. Thus, DEA doesn't allow measurement or specification of errors as such efficiency estimates may be biased.

7.8. Areas of Future Research

In order to deepen the understanding of efficiency and productivity in the Norwegian passenger car market, the results and limitations of this study suggest some avenues for further research. Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI) have been used in this study in assessing the efficiency and productivity of the car market, respectively. One possibility for future research is to employ the bootstrap DEA approach in addressing one of the limitations of this study, for instance, including the car brands as a group and not as independent as we did in this study. With bootstrap DEA approach, one is lest assured of correcting DEA efficiencies for bias and estimate confidence intervals for them as a way of recognising that data is subject to random noise.

Another possibility would be to assess efficiency and productivity of car market for different countries such as Scandinavian countries. This would highlight the differences in efficiency levels, changes in productivity and the factors that may explain such differences. Besides, a longer time dimension for these car markets would make possible a closer investigation of efficiency and changes in productivity. This would yield more detailed and specific information regarding those exogenous factors that may explain the efficiency and productivity of the aforesaid market, making it easier to apply strategies that will enhance performance of the market.

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APPENDICES

APPENDIX 1a-1e Descriptive statistics of inputs and output for all the years of observation (2008 to 2012)

2008	Labour	Capital	Depreciation	Other expenses	Total Sales
Mean	110182391,5	43023403,36	7131290,833	89954663,24	1536965301
Median	62524777	16187652	5532088	52493907	1034560741
Standard Deviation	131650202,4	55235634,68	8876062,932	105554501,3	1394053215
Kurtosis	2,225176169	2,743021724	9,029286365	3,803085161	0,163757266
Skewness	1,672616185	1,790583321	2,699437473	1,903262566	0,982997997
Minimum	6149471,974	391552	112104	4357433	41998375
Maximum	486427295	204363932	39700244	419853777	4998364858
Count	21	21	21	21	21

2009	Labour	Capital	Depreciation	Other expenses	Total Sales
Mean	108584498,2	43135053,24	6769898,026	82490282,97	1347218499
Median	64181384	20928401	3221161	52832936	987361018
Standard Deviation	130701007,1	56749811,66	8981458,845	97661018,07	1210916970
Kurtosis	2,982971492	2,0523028	10,54232108	5,387603513	-0,651054871
Skewness	1,801958931	1,709312238	2,952921902	2,177139467	0,79209027
Minimum	6832936	614161	133652	4133652	61442959
Maximum	500786794	199561655	40766905	406448687	4023021599
Count	2280274463	905836118	142167858,5	1732295942	28291588483
Count	21	21	21	21	21

2010	Labour	Capital	Depreciation	Other expenses	Total Sales
Mean	115423284,5	46596495,11	6851929,957	94010721,7	1732168617
Median	66871118	25449534	3263199	57947981	979587578
Standard Deviation	137636970,1	61097472,87	9142668,851	104246013,8	1589680917
Kurtosis	3,516108606	1,515038725	11,54158712	4,423615915	0,640503866
Skewness	1,883124122	1,629683065	3,105067779	1,964091958	1,083357274
Minimum	7461956,522	204193	320652	4984472	10111067
Maximum	540349379	197334627	42089286	428173913	5890180217
Count	21	21	21	21	21

2011	**Labour**	**Capital**	**Depreciation**	**Other expenses**	**Total Sales**
Mean	126192813,3	51634092,89	7095493,671	103478710,1	1786786271
Median	69371933	23195552	2785276	57713957	1392672393
Standard Deviation	149696644,3	70995422,68	9591710,074	117026590,3	1567944493
Kurtosis	3,311401533	2,184336678	10,71359588	4,181237389	0,531204419
Skewness	1,846048491	1,761877333	2,988777724	1,960392278	1,013511732
Minimum	7842024,54	1878834	483896	5138036,81	7072814
Maximum	583565951	243971626	43515337	472494632	5815221074
Count	21	21	21	21	21

2012	**Labour**	**Capital**	**Depreciation**	**Other expenses**	**Total Sales**
Mean	134363992,3	54460498,68	7683481,863	109370287,8	1825025907
Median	75452816	24987062	3117960	62660578	1247364650
Standard Deviation	158129251	70589417,04	9560640,409	118621212,3	1567873073
Kurtosis	2,866517283	1,797694372	6,850389931	4,127117593	0,041486257
Skewness	1,777035002	1,650590435	2,380139772	1,883771274	0,981615122
Minimum	7757230	1742009	458143	5364536	42114136
Maximum	604910959	247336377	40996956	486793760	5679221689
Count	21	21	21	21	21

APPENDIX 2a Correlation of exogenous/independent variables

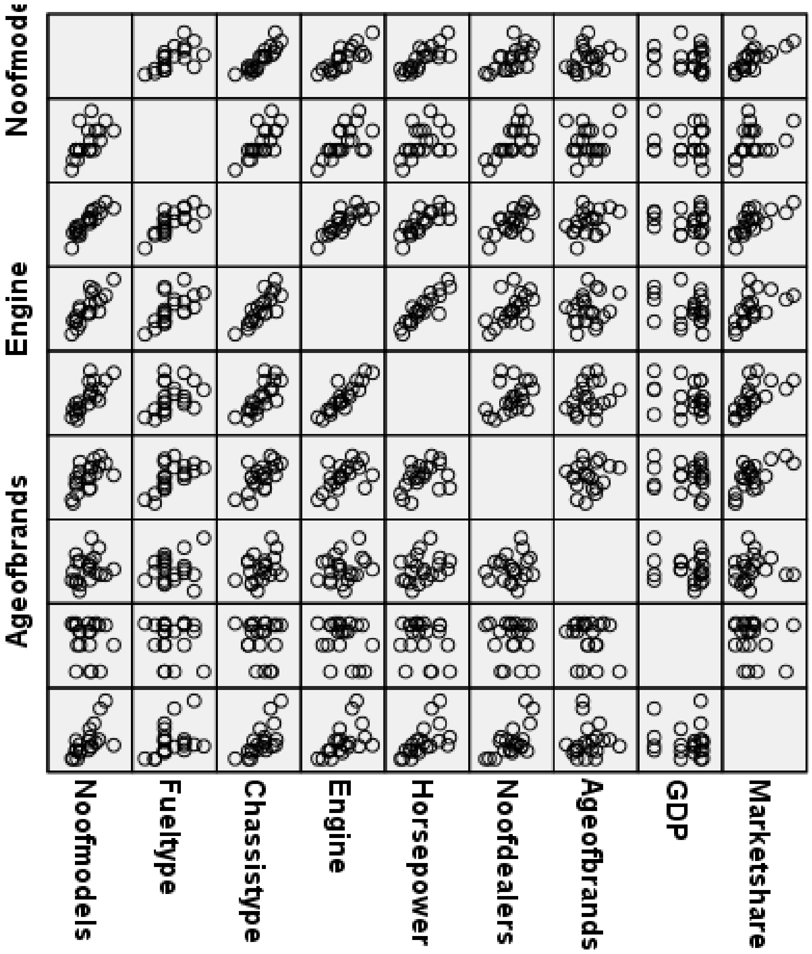
Correlations

		No of models	Fuel type	Chassis type	Engine	Horsepower	No of dealers	Age of brands	GDP	Market share
No of models	Pearson Correlation	1	.614**	.891**	.811**	.795**	.602**	.242	-.129	.648**
	Sig. (2-tailed)		.003	.000	.000	.000	.004	.290	.576	.001
	N	21	21	21	21	21	21	21	21	21
Fuel type	Pearson Correlation	.614**	1	.724**	.607**	.389	.611**	.203	-.105	.371
	Sig. (2-tailed)	.003		.000	.004	.081	.003	.377	.650	.098
	N	21	21	21	21	21	21	21	21	21
Chassis type	Pearson Correlation	.891**	.724**	1	.814**	.770**	.632**	.365	-.143	.696**
	Sig. (2-tailed)	.000	.000		.000	.000	.002	.104	.537	.000
	N	21	21	21	21	21	21	21	21	21
Engine	Pearson Correlation	.811**	.607**	.814**	1	.895**	.524*	.218	-.276	.547*
	Sig. (2-tailed)	.000	.004	.000		.000	.015	.343	.226	.010
	N	21	21	21	21	21	21	21	21	21
Horsepower	Pearson Correlation	.795**	.389	.770**	.895**	1	.385	.272	-.221	.614**
	Sig. (2-tailed)	.000	.081	.000	.000		.085	.233	.335	.003
	N	21	21	21	21	21	21	21	21	21
No of dealers	Pearson Correlation	.602**	.611**	.632**	.524*	.385	1	.138	-.114	.633**
	Sig. (2-tailed)	.004	.003	.002	.015	.085		.550	.624	.002
	N	21	21	21	21	21	21	21	21	21
Age of brands	Pearson Correlation	.242	.203	.365	.218	.272	.138	1	-.207	.063
	Sig. (2-tailed)	.290	.377	.104	.343	.233	.550		.369	.785
	N	21	21	21	21	21	21	21	21	21
GDP	Pearson Correlation	-.129	-.105	-.143	-.276	-.221	-.114	-.207	1	-.135
	Sig. (2-tailed)	.576	.650	.537	.226	.335	.624	.369		.559
	N	21	21	21	21	21	21	21	21	21
Market share	Pearson Correlation	.648**	.371	.696**	.547*	.614**	.633**	.063	-.135	1
	Sig. (2-tailed)	.001	.098	.000	.010	.003	.002	.785	.559	
	N	21	21	21	21	21	21	21	21	21

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

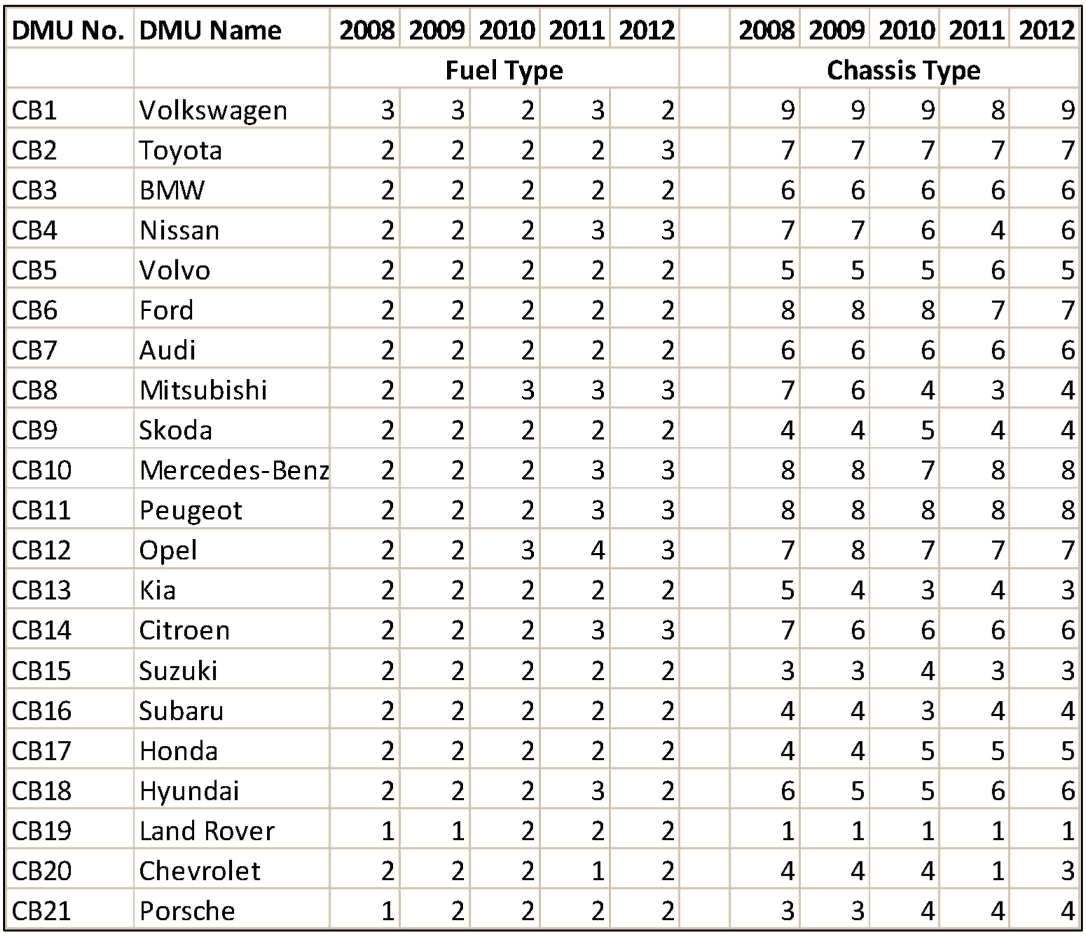
APPENDIX 2b Scatterplot showing correlation of exogenous variables



APPENDIX 3a Number of models and variants for the selected car brands

DMU No.	DMU Name	Number of Models						Number of Variants				
		2008	**2009**	**2010**	**2011**	**2012**		**2008**	**2009**	**2010**	**2011**	**2012**
CB1	Volkswagen	15	15	13	14	15		395	391	352	332	317
CB2	Toyota	12	14	14	15	16		142	181	200	218	198
CB3	BMW	8	9	10	10	10		245	325	346	448	460
CB4	Nissan	10	12	13	12	10		140	272	248	181	137
CB5	Volvo	9	8	10	10	7		123	297	310	281	413
CB6	Ford	12	12	11	11	13		285	211	300	353	514
CB7	Audi	9	9	10	11	10		200	244	253	235	290
CB8	Mitsubishi	6	6	7	7	7		76	56	51	49	55
CB9	Skoda	4	5	5	5	6		147	145	252	341	233
CB10	Mercedes-Benz	14	12	12	16	16		155	107	187	291	271
CB11	Peugeot	12	11	11	11	12		174	134	155	150	193
CB12	Opel	10	9	9	9	11		267	246	179	143	152
CB13	Kia	6	4	4	5	5		36	27	40	53	53
CB14	Citroen	9	7	8	10	12		68	38	59	76	136
CB15	Suzuki	6	6	7	6	6		41	32	25	27	38
CB16	Subaru	5	4	4	4	4		18	13	12	16	18
CB17	Honda	4	5	5	5	5		39	45	49	47	66
CB18	Hyundai	9	7	8	9	8		47	40	53	63	87
CB19	Land Rover	3	4	4	3	4		45	94	43	23	66
CB20	Chevrolet	7	5	1	2	1		34	30	8	15	13
CB21	Porsche	4	5	5	5	4		21	31	62	60	35

APPENDIX 3b Measures of product variety (fuel and chassis types) for the selected car brands



DMU No.	DMU Name	2008	2009	2010	2011	2012		2008	2009	2010	2011	2012
		Fuel Type						Chassis Type				
CB1	Volkswagen	3	3	2	3	2		9	9	9	8	9
CB2	Toyota	2	2	2	2	3		7	7	7	7	7
CB3	BMW	2	2	2	2	2		6	6	6	6	6
CB4	Nissan	2	2	2	3	3		7	7	6	4	6
CB5	Volvo	2	2	2	2	2		5	5	5	6	5
CB6	Ford	2	2	2	2	2		8	8	8	7	7
CB7	Audi	2	2	2	2	2		6	6	6	6	6
CB8	Mitsubishi	2	2	3	3	3		7	6	4	3	4
CB9	Skoda	2	2	2	2	2		4	4	5	4	4
CB10	Mercedes-Benz	2	2	2	3	3		8	8	7	8	8
CB11	Peugeot	2	2	2	3	3		8	8	8	8	8
CB12	Opel	2	2	3	4	3		7	8	7	7	7
CB13	Kia	2	2	2	2	2		5	4	3	4	3
CB14	Citroen	2	2	2	3	3		7	6	6	6	6
CB15	Suzuki	2	2	2	2	2		3	3	4	3	3
CB16	Subaru	2	2	2	2	2		4	4	3	4	4
CB17	Honda	2	2	2	2	2		4	4	5	5	5
CB18	Hyundai	2	2	2	3	2		6	5	5	6	6
CB19	Land Rover	1	1	2	2	2		1	1	1	1	1
CB20	Chevrolet	2	2	2	1	2		4	4	4	1	3
CB21	Porsche	1	2	2	2	2		3	3	4	4	4

APPENDIX 3c Measures of product variety (engine and horsepower types) for the selected car brands

DMU No.	DMU Name	2008	2009	2010	2011	2012		2008	2009	2010	2011	2012
		Engine Type						Horsepower Type				
CB1	Volkswagen	16	12	17	13	13		26	26	29	25	26
CB2	Toyota	14	15	14	11	12		23	23	26	20	19
CB3	BMW	12	8	8	10	11		25	24	27	25	29
CB4	Nissan	14	12	11	14	12		21	18	17	19	16
CB5	Volvo	13	11	10	9	8		21	18	17	19	16
CB6	Ford	17	18	17	14	12		26	25	30	28	23
CB7	Audi	21	15	15	15	15		33	25	31	32	36
CB8	Mitsubishi	13	12	12	10	10		12	13	13	12	12
CB9	Skoda	9	9	11	8	9		15	14	16	14	15
CB10	Mercedes-Benz	24	19	16	17	14		32	26	35	31	28
CB11	Peugeot	12	11	8	10	11		16	16	16	16	17
CB12	Opel	16	14	17	14	13		24	22	24	20	18
CB13	Kia	14	9	9	12	10		16	12	15	17	18
CB14	Citroen	9	12	9	9	12		14	14	14	15	15
CB15	Suzuki	5	8	9	8	7		9	12	14	14	9
CB16	Subaru	7	7	7	9	10		14	13	9	8	11
CB17	Honda	8	8	10	6	8		8	9	9	8	11
CB18	Hyundai	12	12	12	14	11		16	19	18	22	23
CB19	Land Rover	5	4	7	5	4		5	6	9	10	8
CB20	Chevrolet	9	6	6	1	9		9	8	5	1	9
CB21	Porsche	9	6	10	7	9		13	8	12	11	15

APPENDIX 4 Productivity change for all car brands for each period of time