New energy vehicle development in China

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Abstract: As one of the important step to solve the environment pollution problems, Chinese Government pays much attention to the development of new energy vehicle industries. However, the situation is not satisfied. The paper studied the current situation and efficiency of new energy vehicle in Chinese market. We find that Chinese consumers are not ready to accept the new energy vehicles because of their high price, shortage of infrastructural and supporting policies. On the other hand, the domestic new energy vehicle manufactures still need to improve their new energy vehicles' technical efficiency in order to compete with the other traditional gasoline vehicles.

Keywords: new energy vehicle; supporting policies; environmental protection; industrialisation; hybrid vehicles; data envelopment analysis; scale efficiency; technical efficiency; China.

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1 Introduction

In recent years, the issues of climate change were highly paid attention to. The continuing increase in energy consumption, the mid-depletion point of conventional oil and of the re-concentration of crude oil production in the Near East will compel industrialised as well as developing nations to make more efficient use of energy (IEA and OECD, 2003). Technical improvements still are the most important way for energy savings (Berkhout et al., 2000; Herring, 2006). As there is no doubt that the challenges will increase within the next few decades, and as the re-investment cycles of the passenger fleet, the production capacities, and infrastructures have to be considered, early actions and long-term perspectives by governments and technology producers become increasingly important (Haan et al., 2007). Although China is a developing country and the average greenhouse gas emission is low, the total energy consumption has already ranked second in the world because of large population and rapid development. A survey showed that about 25% CO_2 emission and 42% environmental pollution came from automobile and fuel vehicle respectively. Advanced vehicle technologies such as hybrids and alternative fuels such as ethanol are frequently touted as a means of curbing petroleum use and greenhouse gas emission from light-duty vehicles so placing a much greater emphasis on reducing fuel consumption rather than improving vehicle performance can greatly reduce the required market penetration rates (Bandivadekar et al., 2008). Therefore, if China can take the lead in new energy automobile industry, Chinese passive position on climate change will be changed.

For automobile manufactures, some people think that the strengths and opportunities outperform their risk factors (Fildes et al., 2007). In China, there are three main limiting factors for energy-technology leapfrogging based on evidence from the Chinese automobile industry:

1 un-strategic and inconsistent policies

2 weak domestic technological capabilities

3 an apparent unwillingness of more advanced multinational auto firms to transfer cleaner or more efficient technologies beyond those simply required by standards (Gallagher, 2006).

However, the automobile industry still offers a fertile terrain for progress of the uncompleted theory building process of innovation, especially with the introduction of alternative fuels and alternative powertrain technologies, including hybrids, biofuels and hydrogen power (Zapata and Nieuwenhuis, 2010).

According to the current research, there is a strong relationship between gasoline prices and hybrid adoption, but a much weaker relationship between incentive policies and hybrid adoption in US new energy automotive market. Incentives that provide payments upfront also appear to be the most effective (Diamond, 2009). However, in

China, the situation is different. It is necessary to develop new energy automobile industry because it is the best way for the development of automobile industry. The development of new energy automobile industry will be a revolution in automobile technology and quicken the pace of industrial upgrade in order to promote the development of emerging industries.

2 The supporting policies on new energy automobile industry

Since 2004, the development of new energy automobile industry and technology has been emphasised many times in the country's long-term energy policy planning. First of all, we have insisted on the principle of combining self-development and technology introduction. Secondly, the development of energy-saving vehicles has been guided and encouraged by the government. At the same time, the research and industrialisation on electric vehicles and battery will be highly promoted while the development of hybrid vehicle technology has been currently focused on. The government stimulates hybrid vehicles' production and consumption in scientific research, technological innovation, industrialisation, consumption and even environmental policies. Meanwhile, it has encouraged automobile manufactures to produce new energy vehicles through supporting the research and development of alcohol fuel, natural gas, mixed fuel, hydrogen fuel, and other new types of fuel. Moreover, the automobile industry and the other related industries need to focus on the development and application of new technology which could improve the condition of present vehicles.

From 2005, China has not only issued a series of policies which optimised structure of the automobile industry and promoted the development of clean cars, but also supported the battery industry, bio-fuel industry and other related industries, because the rapid development of an industry need to be supported by the entire industry chain. The State Council (2006, 2007), which is the chief administrative authority of China, further announced a 'decision to enforce energy-conservation' in 2006 and a 'comprehensive work programme on energy-conservation and pollution reduction' in 2007. In order to help automobile industry well developed, the National Development and Reform Commission and the Ministry of Finance issued two notices in December 2006, which clarified that the government not only need to encourage the development of energy saving vehicles but develop domestic products and upgrade automobile industry through technological innovation as well.

In October 2007, China began to implement the revised 'Energy Conservation Law', which clearly pointed out that in the field of transportation we need to implement the transport energy planning, construct energy-saving transport system, and expand the use of the clean fuel or new energy vehicles. The rules of new energy vehicles production access clarified the concept of new energy vehicles and adopted different management styles for new energy vehicles which were in different technical stages. Meanwhile, these rules made detailed provisions in assessment, manufacturers and product management. In other words, this meant that new energy automobile industry had its own guidelines. In addition, it was also taken as the beginning of the new energy vehicles market and was regarded as a milestone in the development process of new energy automobile industry in China.

In 2009, the development of new energy automobile industry in China was highly supported. In January, the State Council principally approved the 'auto industry promotion plan', which proposed strategy for new energy vehicles at first and arranged ten billion Yuan to support the new energy automobile industries. In February, the Department of Science and Technology with the Ministry of Finance launched a plan which specified that 30,000 new energy vehicles will be running in public transportation in 30 cities in three years. Meanwhile, a demonstration programme of EV deployment into 13 Chinese cities is also launched, together with a 'plan on shaping and revitalising the auto industry' (hereafter referred to as 'revitalisation plan') that aims at the development of the AFV industry (Ministry of Finance and Ministry of Science and Technology, 2009). It is a very important step for the industrialisation of new energy automobile industry after the 2008 Olympic Games in Beijing.

It is an important year to spread the consumption of new energy vehicles in China in 2010. For government procurement, government procurement agencies at all levels were asked to give priority to the energy-saving products, especially the domestic products; for private consumption, the central finance will not only give private consumers grant for buying, registering and driving new energy vehicles but also supply appropriate financial subsidy for infrastructure construction; for public service, several ministries decided to expand the use of new energy vehicles in public services. That is, there will be seven cities more, such as Tianjin, Guangzhou, on the basement of the existed 13 cities to use new energy vehicles in public transportation.

3 The industrialisation of new energy vehicles development

3.1 The new energy vehicles development in general

As early as 2001, China had already launched electric vehicles plan in '863 Project' (Chinese advanced technology research, development and demonstration programme launched in March 1986) (Ministry of Science and Technology, 2009) and granted 880 million Yuan to support the development of new energy vehicles projects, including electric vehicles, hybrid vehicles and fuel cell vehicles. These three types were taken as 'three plumbs'. On the other hand, powertrain control, drive motor and power battery were taken as 'three levels'. In the 'eleventh five-year plan (2006–2010) compendium for the national economic and social development of China', the Chinese Government set the target of reducing energy use per GDP by 20% and the gross pollution level by 10% within the five-year period (Xinhuanet, 2006). During this period, the Department of Science and Technology has spent more than 10 billion Yuan on research and development of new energy vehicles.

From 2006 to 2007, electric vehicles, hybrid vehicles and fuel cell vehicles were produced one after another independently; hybrid vehicles and pure electric buses production achieved the scale; the research of fuel cell vehicle was into the world's advanced level. In 2008, from January to June, the total sales of new energy vehicles in China were 366, with an increase of 107.95% comparing to the former year and 100 vehicles were sold only in June. During the period of 2008 Olympic Games in Beijing, the Ministry of Science and Technology organised relevant domestic automobile manufacturers to supply about 500 new energy vehicles and these vehicles were all independent innovation products which were supported by '863' Project. As assumed, these products had a good foundation in reliability and security. More than 500 new energy vehicles were displayed and used in Olympic Games making the year 2008 known as 'the first year of new energy vehicles in China'.

It is the breaking year for new energy automobile industry in China in 2009. The supporting policies were unprecedented and the government began to promote the industrialisation and commercial application of new energy vehicles. On March 13th, the first new energy vehicles industry alliance in China – Beijing New Energy vehicles Industry Alliance – established and the other automobile union which seated in other provinces may rely on local automobile manufactures, such as BYD, Dongfeng and Chery. This situation indicates that the new energy vehicles industry in China form region-wide cooperation step by step in the development, manufacture, application and other aspects. With the gradual establishment of manufacturing system of new energy vehicles in China, the independent innovation ability was largely increased. Many domestic enterprises have begun to set foot in the new energy vehicles related industries, such as batteries, motors and other key components. As a result, the technical gap between in domestic and foreign was narrowing.

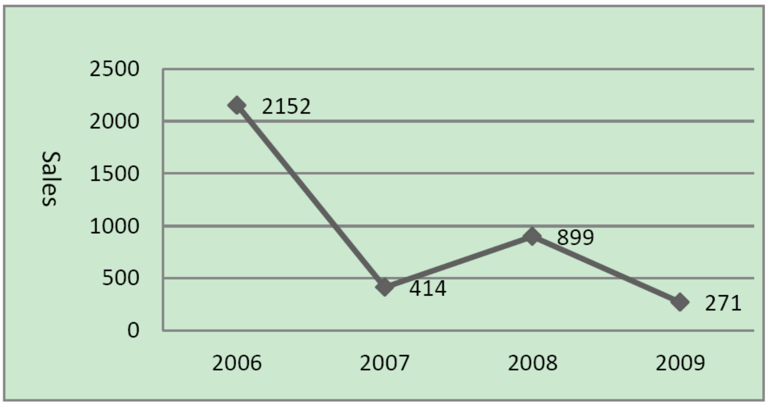
By 2010, there were around 1,017 kinds of new energy vehicles running at the Expo site, including 321pure electric vehicles which can be divided into 120 pure electric buses, 61 super capacitor buses and 140 electric venue vehicles; 500 hybrid electric vehicle which can be divided into 150 hybrid buses and 350 hybrid cars; 196 fuel cell vehicles which can be divided into six fuel cell buses, 90 fuel cell cars and 100 tourism fuel cell vehicles. It was well interpreted the Expo target using new energy vehicles to achieve zero emissions of public transport in Expo site. This is the showcase of new energy vehicles which was the largest commercial operation of new energy vehicles after 2008 Olympic Games in Beijing in China.

3.2 The basic situation of the development and the statues of industrialisation of new energy vehicles

3.2.1 Hybrid vehicles

Hybrid vehicles are now more advanced than the other kinds of new energy vehicles and they are the transition from traditional vehicle to pure electric vehicles. Currently, most automobile manufacturers have produced hybrid vehicles, such as Toyota, Honda, Buick and BYD. Among them, Toyota Prius were sold more than two million around the world, which was taken as the global leader in this area. But in China, from year 2006 to 2009, only 3,733 hybrid vehicles were sold. From the current statistical data, the domestic production of Prius in 2006 was 2,248 and 2,152 of them were sold. However, in 2007, only 414 were sold, in which only nine were sold in December. In order to increase sales, in March 2008, the price of Prius was cut by 24,000 Yuan. Later, the manufacture adjusted the sales target of Prius down to 1,000 in 2008 but the real sales was still below it. In 2009, with the effect of 'recalled scandal', the sales of Prius in China were further down, only 271 (Figure 1). Facing with such low sales, Toyota Company decided to suspend sales of Prius in China. Furthermore, the price of Prius is above two hundred thousand Yuan. Therefore, the large price difference between hybrid vehicles and gasoline vehicles will slow down the promotion of HEVs in China, and therefore it may need more than 14 years to reach 5% share of the total vehicles population. As a result, the contribution for GHG reduction and energy saving should be quite limited to the HEVs due to its low total number.

Figure 1 The sales of Prius in China (see online version for colours)



For the PHEVs, Chinese BYD auto made its F3DM – world's first mass-produced plug-in gas-electric hybrid-available to the permission of dual-mode electric vehicles at the end of 2008 and personal sales at the end of March 2010. The F3DM has an official range of 60 miles on electric-only power. In recent years, the government has gradually increased the support of research and sales for new energy automobile industry so that the domestic automobile manufactures constantly entered this field but BYD has always at the forefront of new energy vehicles' research because of its leading technology in batteries. Furthermore, its dual-mode electric vehicle was successful since it is the first type of vehicles in the world which does not rely on electric vehicle charging station and it will be two or three years earlier than the other international auto giants to commercialise PHEV. This is the first time that Chinese firms can play the lead role in this field.

However, as can be seen from the current statistical data, the BYD F3DM has not enjoyed success since its launch. From March 2010 to November 2011, the total sales were rising slowly (Figure 2). It is clearly seen that its sales only shared below 0.35% in every month among the total sales of BYD (Figure 3).

Figure 2 F3DM sales for months in Chinese market from March 2010 to November 2011 (see online version for colours)

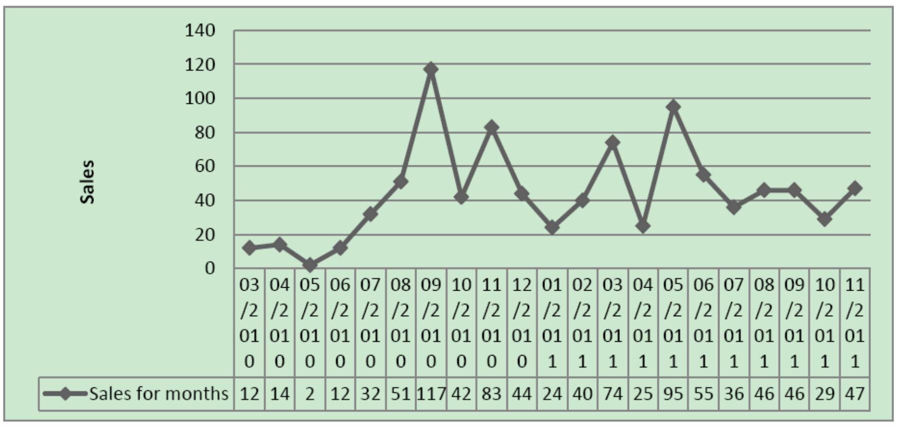
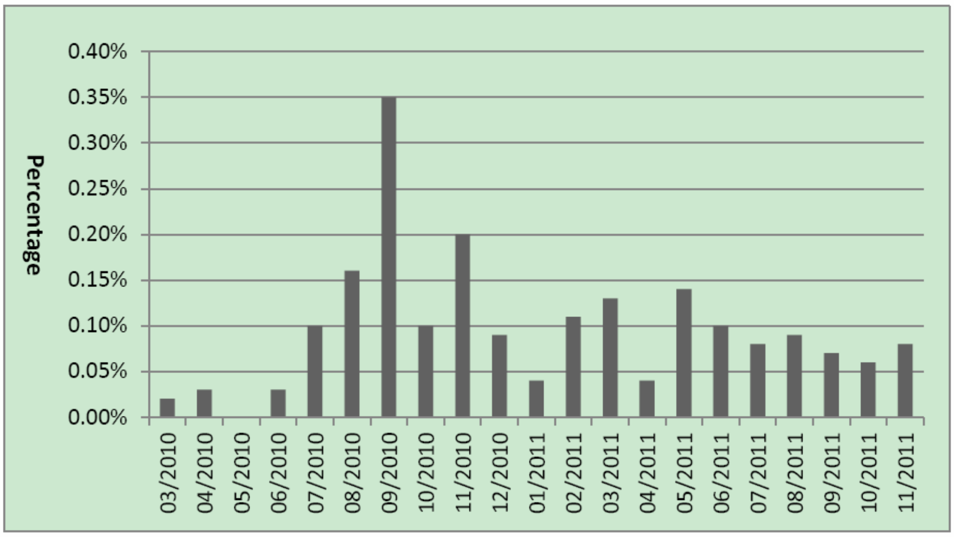


Figure 3 The market share of F3DM among the total market share of BYD from March 2010 to November 2011 (see online version for colours)



Therefore, it also faces the same problem as do Prius: how to convince the general public to choose the PHEV version for about one hundred thousand Yuan instead of the standard gasoline model for about half of that. PHEVs achieve greater petroleum energy savings with increased electric range. Conversely, more GHG emissions are produced with increased electric range unless renewable or non-fossil electricity generation is used for recharging (Elgowainy et al., 2010).

3.2.2 Electric vehicles

Today, pure electric vehicles are being proposed in China as one of the potential options to satisfy the skyrocketing energy demand from on-road transportation. EVs might cut the dependence on petroleum using other energy sources such as coal, hydro, nuclear, wind, etc., to provide the required electricity. Furthermore, there are no tailpipe GHG emissions or other harmful gas emissions for EVs and less noise pollution than an internal combustion energy vehicle.

Electric vehicles do represent a very promising solution to energy issues due to their solid merits in substituting petroleum fuels. However, it should be noted that the technology breakthrough in batteries is another critical problem to the wide utilisation of EVs because many electric designs are limiting the driving range due to the low energy density of batteries compared to ICEVs (Yao et al., 2011). Furthermore, EVs also often have long recharge times compared to the relatively fast process of refuelling a tank. As a result, although the domestic automobile manufacturers have largely invested on research and development of pure electric vehicles and some of them have put the products into market, the respond was not very well. Take BYD as an example. The electric vehicles-E6-have been sold only 356 until October 2011 (Table 1). And to everyone's surprise, none of them was sold in several months, showing the bleak market prospect.

Table 1 The sales of E6 from March 2010 to October 2011

Month/ year	12/2010	11/2010	10/2010	9/2010	8/2010	7/2010	6/2010	5/2010	4/2010	3/2010
Sales	9	0	2	0	6	16	0	20	0	10
Month/ year	10/2011	9/2011	8/2011	7/2011	6/2011	5/2011	4/2011	3/2011	2/2011	1/2011
Sales	17	10	262	0	0	0	1	0	0	3

4 The evaluation of scale efficiency of hybrid vehicles in China

According to the study above, we can see the poor market prospects of new energy vehicles in China. It is different from the new energy vehicles study of the other countries. In USA, to promote consumer adoption of hybrid vehicles, the US Government has been providing hybrid vehicle buyers with income tax incentives to offset the significantly higher cost of hybrid vehicles relative to their non-hybrid counterparts. The empirical analysis shows that both recent increases in gasoline prices and federal income tax incentives contribute significantly to the growing market share of hybrid vehicles (Beresteanu and Li, 2011). In Korea, the current hybrid vehicles on the market are still at lower competitive advantage than traditional car models with conventional combustion engines and we can suggest a mix of incentive polices to promote the competitiveness of hybrid vehicles. In addition, two distinctive trends of hybrid vehicle development, environment-oriented hybrid vehicles and performance-oriented hybrid vehicles, are identified. It implies that the government should take account of development trends of hybrid vehicles to achieve the policy goals in designing support schemes and automobile companies that are willing to develop hybrid vehicles can also gain some insights for making strategic decisions (Choi and Oh, 2010). But in China, the government support policies seem not very supportive. So what is the main reason? From the study of the new energy vehicles potential consumer groups features in China and the main factors of the new energy vehicles potential consumers in buying cars we can know that gender, life circle and residential place do not significantly impact the new energy vehicles potential consumers choices while age, education level, number of family members, number of vehicles, the opinion of peers, maintenance cost, degree of safety, income and occupation are the important factors affecting them (Zhao, 2010; Zhang et al., 2011). Lack of charging station and a non-established reasonable charging price also influence the consumer's desire to own a new energy vehicle (Li and Quyang, 2011). Moreover, whether a consumer chooses an EV is significantly influenced by the number of driver's licenses, number of vehicles, government policies and fuel price. The timing of consumers' purchases of an EV is influenced by academic degree, annual income, number of vehicles, government policies, the opinion of peers and tax incentives (Zhang, et al., 2011). But none of the current research studied the efficiency of new energy vehicles themselves. At this part, we choose hybrid vehicles as the representative of new energy vehicles in China and evaluate the efficiency of them.

4.1 Methodology

To evaluate vehicle efficiencies and the effect of promotion policies, we utilised the DEA model (Charnes et al., 1978, 1979, 1981; Banker et al., 1984). The DEA is a non-parametric methodology, primarily used to estimate the efficiency of production units under study, based on multi-input and multi-output information. Using linear programming to determine the best practice frontier, the DEA calculates efficiencies as a distance or ratio between units and best practice frontier in the input-output space. The efficiencies of car models can be calculated using the DEA, regarding the sales as an output and the various quality attributes of the car models – e.g., engine capacity, gasoline consumption and gasoline saving rate – as inputs (Doyle and Green, 1991; Papahristodoulou, 1997; Fernandez-Castro and Smith, 2002; Lee et al., 2005). The following sections explain the methodology used in this research, in greater detail.

4.1.1 The data envelope analysis model of hybrid vehicles

The DEA model is a multi-factor productivity analysis model for measuring the relative efficiencies of a homogenous set of decision making units (DMUs) and construed how efficiently producers make their products during the manufacturing process. In the presence of cost information about multi-inputs, the concept of technical efficiency, allocative efficiency, and overall efficiency are elaborated on the production side (Cooper et al., 2000). The term defined as technical efficiency is utilised commonly in the literature to describe the performance level of a production unit with regard to its utilisation of input resources in generating a given set of outputs. Technical efficiency is defined as a state in which it is technically impossible to increase output without simultaneously reducing another output or increasing inputs (Koopmans, 1951). The overall efficiency measures, referred to as technical efficiency and allocative efficiency measures, referred to as technical efficiency and allocative efficiency (Farrel, 1957). A method also proposed by which technical efficiency could be measured as the maximum equi-proportional reduction in all inputs consistent with the equivalent production of observed output. Allocative efficiency measures the degree to which the current mix of input matches the cost minimising input mix. Even in cases in which a production units technically efficient, it may not be allocatively efficient. Similarly, these methodologies and concepts used to evaluate efficiencies of production units can also be applied to measure the level of efficiency of a product purchased by money. To allow for applications to a wide variety of activities, we use the term DMU to refer to any entity that is to be evaluated in terms of its abilities to convert inputs into outputs. We use the constant returns to scale (CRS) model in input-oriented versions to evaluate the technology efficiency of hybrid vehicles [equation (4.1)]:

$$CRS\begin{cases}\min_{\theta,\lambda}\theta, \\ \text{st.} - y_i + Y\lambda \geq 0, \\ \theta x_i - X\lambda \geq 0, \\ \lambda \geq 0, \end{cases} \tag{4.1}$$

where θ is a scalar and λ is an $N * 1$ vector of constants. The value of θ obtained will be the efficiency score for the i^{th} DMU. It will satisfy $\theta \leq 1$, with a value of 1 indicating a point on the frontier and hence a technically efficient DMU, according to the Farrell definition. Note that the linear programming problem must be solved N times, once for each DMU in the sample. A value of θ is then obtained for each DMU.

The CRS assumption is only appropriate when all DMU's are operating at an optimal scale. Imperfect competition, constraints on finance, etc., may cause a DMU to be not operating at optimal scale. Banker et al. (1984) suggested an extension of the CRS DEA model to account for variable returns to scale (VRS) situations. The use of the CRS specification when not all DMU's are operating at the optimal scale, will result in measures of TE which are confounded by scale efficiencies (SE). The use of the VRS specification will permit the calculation of TE devoid of these SE effects.

We also use the VRS model in input-oriented versions to evaluate the technical efficiency of hybrid vehicles [equation (4.2)]. The CRS linear programming problem can be easily modified to account for VRS by adding the convexity constraint: $N1'\lambda = 1$ to (4.1) to provide:

$$VRS \begin{cases} \min_{\theta,\lambda} \theta, \\ \text{st.} - y_i + Y\lambda \geq 0, \\ \theta x_i - X\lambda \geq 0, \\ N1'\lambda = 1 \\ \lambda \geq 0 \end{cases} \tag{4.2}$$

where $N1$ is an $N * 1$ vector of ones. This approach forms convex hull of intersecting planes which envelope the data points more tightly than the CRS conical hull and thus provides technical efficiency scores which are greater than or equal to those obtained using the CRS model.

4.1.2 Calculation of scale efficiencies

Many studies have decomposed the TE scores obtained from a CRS DEA into two components, one due to scale inefficiency and one due to 'pure' technical inefficiency. This may be done by conducting both a CRS and a VRS DEA upon the same data. If there is a difference in the two TE scores for a particular DMU, then this indicates that the DMU has scale inefficiency, and that the scale inefficiency can be calculated from the difference between the VRS TE score and the CRS TE score.

Figure 4 attempts to illustrate this. In this figure, we have a one-input one-output example and have drawn the CRS and VRS DEA frontiers. Under CRS the input orientated technical inefficiency of the point P is the distance PP_C, while under VRS the technical inefficiency would only be PP_V. The difference between these two, P_CP_V, is put down to scale inefficiency. One can also express all of this in ratio efficiency measures as:

$$\begin{aligned} &TE_{I,CRS} = AP_C / AP \\ &TE_{I,VRS} = AP_V / AP \\ &SE_I = AP_C / AP_V \end{aligned} \tag{4.3}$$

where all of these measures will be bounded by zero and one. We also note that

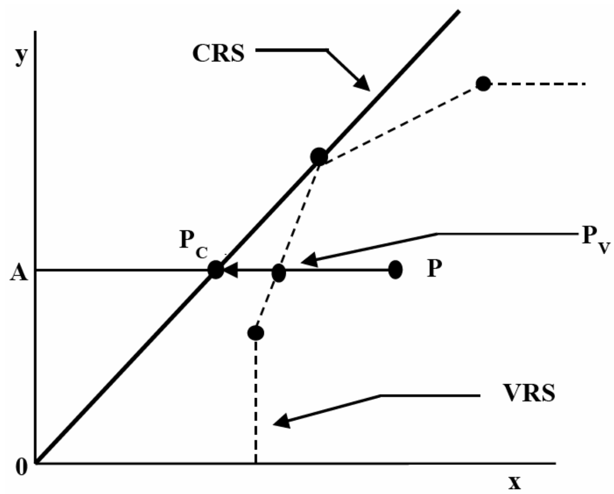
$$TE_{I,CRS} = TE_{I,VRS} \times SE_I \tag{4.4}$$

because

$$AP_C / AP = (AP_V / AP) \times (AP_C / AP_V). \tag{4.5}$$

That is, the CRS technical efficiency measure is decomposed into 'pure' technical efficiency and scale efficiency.

Figure 4 Calculation of scale economies in DEA



4.2 Evaluation index system of efficiency of hybrid vehicles

Our research is based on the data envelopment analysis. In this paper, we choose seven types of hybrid vehicles which are sold in Chinese automobile market, such as Prius, Civic hybrid, LaCrosse ECO-hybrid, BYD F3DM, Chery A5 BSG, Escalade and Lexus GS450h. They covered the different strength of hybrid vehicles and they are all the representatives of hybrid vehicles in different brand. They are the good choice to fully reflect the efficiency of hybrid vehicles in Chinese market.

According to the life cycle of hybrid vehicles, the cost mainly includes the purchase cost and running cost. For customers, the purchase cost can be equalled to the price they paid for the vehicles. And the running cost includes the gasoline cost, repairing cost, tax and government subsidies. To simplify the analysis, we ignore the tax and repairing cost which is difficult to be calculated because it depends on specific vehicle situation and may be fluctuate all the time. The price in Table 2 is the sales price minus the government subsidies. Therefore, we decided to choose price, engine capacity, gasoline consumption, gasoline saving rate and sales as the evaluation index and evaluate the efficiency of hybrid vehicles. We collect all data of price, engine capacity and gasoline consumption from official websites of automobiles companies. The gasoline consumption is defined as general status of gasoline consumption but not suburb or urban status. The sale number comes from the database of sina and sohu website. The data were listed in Table 2.

Table 2 The indexes and data of evaluating the scale efficiency of hybrid vehicles

Types of hybrid vehicles	*Engine capacity (L)*	*Gasoline consumption (L/100 kilometres)*	*Gasoline saving rate (%)*	*Sales (vehicles)*	*Price (10,000 Yuan)*
Prius	1.5	4.7	31.3	3733	27.98
Civic hybrid	1.3	4.7	16.3	290	26.68
LaCrosse ECO-hybrid	2.4	7.2	15	313	26.99
BYD F3DM	1	2.7	33	879	11.98
Chery A5 BSG	1.6	7.5	10	250	7.18
Escalade	6	11.2	18	875	131
Lexus GS450h	2.4	8.1	14.2	125	89.8

4.3 Estimation results

We select several different types of hybrid vehicles from different price level and group them into three categorisations according to their sale price. The low-grade hybrid vehicles' brand includes BYD F3DM and Chery A5 BSG which are both domestic brands. The middle-grade hybrid vehicles' brands are Prius, Civic hybrid and LaCrosse ECO-hybrid which sales price are around three hundred thousand Yuan while the high-grade hybrid vehicles' brands are Escalade and Lexus GS450h which their sale price are above eight hundred thousand Yuan. Assume the efficiency of hybrid vehicles as a homogenous set of DMU, sales and price as the outputs and the other three indexes as the inputs. According to the data and indexes in Table 2, the result can be seen from Table 3.

Table 3 The efficiency of hybrid vehicles

DMU	*CRS TE*	*VRS TE*	*Scale*	*Scale efficiency*
Prius	1	1	1	Efficiency
Civic hybrid	0.830	1	0.830	Inefficiency
LaCrosse ECO-hybrid	0.451	0.896	0.504	Inefficiency
BYD F3DM	0.588	1	0.588	Inefficiency
Chery A5 BSG	0.255	1	0.255	Inefficiency

From Table 3 we can see only three types of hybrid vehicles are in scale efficiency and they are all from the foreign automobile manufacture. For the two domestic hybrid vehicles manufactures (BYD and Chery) which also play a leading role in R&D and production of new energy vehicle, they both reach the VRS technical efficiency but the CRS technical efficiency still can be further improved especially for Chery because its CRS technical efficiency is only 0.255. That is the direction which the domestic hybrid vehicles manufacture should work towards.

In the meantime, we find that the two types of high-grade hybrid vehicles are all efficiency while the two types of low-grade hybrid vehicles are all inefficiency. This might indicate that although the two domestic hybrid vehicles manufacture, BYD and Chery, their technologies are not yet mature enough, there is still a large technology gap between the domestic vehicle brands and foreign high-grade vehicle brands. Therefore, the domestic hybrid vehicles manufactures should not only focus on R&D of related technology, but also focus on technology transition. Indeed, our results present that domestic hybrid vehicles do not achieve the efficiency level. This implies that even with low efficiency, an effort by the government to improve their product efficiency would be justified and widely supported because hybrid vehicles provide subsidiary benefits. In this context, promotion of hybrid vehicles through government supports is recommended as a sound alternative. As we expected, Prius is well-deserved for the leader of hybrid vehicles and the other hybrid vehicles in the middle-grade also still need to be improved from technical efficiency.

5 The problems for the development of new energy vehicles industrial

5.1 High price

With advanced technology and huge R&D cost, the price of new energy vehicles is much higher than traditional gasoline vehicles. Although Toyota Company is regarded as the best company controlling cost of hybrid car in the world, the price of Prius is still 20% higher than traditional gasoline vehicles in the same level while it was raised to 30% due to the low rate of localisation in China. Even if consumers approved of environment-friendly products, the decision whether to buy the hybrid vehicles or not still largely depended on the price. Therefore the high price of these vehicles kept the consumers away.

In fact, from appearing on the market to stopping production, Prius were only sold for 3,733 in China, while CIVIC were sold less than 100 from January to March in 2009. Although these types were sold a lot overseas, in domestic market the sales was low and it clearly means that it is not ready for Chinese to accept hybrid vehicles.

5.2 Lack of core technology

In China the supply chain for new energy vehicle components has not been formed yet so the key components still dependent on foreign companies. As a result, this directly affects the development of new energy automobile industry, especially for the domestic manufactures. Although there is breakthrough in battery technology for domestic firms such as BYD, most domestic enterprises still do not get the core ability in battery comparing to Johnson Controls, Bosch and other famous foreign companies. In the progress of large-scale production of batteries, there are still a number of problems waiting to be solved, such as security and stability, consistent standard, the high ability of recharging and the life cycle. It is hard for domestic manufactures to achieve large-scale production and industrialisation if these problems have not been solved. Therefore, as long as the cost of new energy vehicles cannot be reduced, it is difficult for consumers to accept new energy vehicles.

5.3 Infrastructural facilities have not well been developed

Hybrid vehicles and pure electric vehicles all required special charging station to charge and fuel cell vehicles also need hydrogen filling station. However, the poor establishment of infrastructure for new energy vehicle in China cannot meet the demands which hold back the industrialise process of new energy automobile industry. Based on current energy prices and battery costs, charging stations are unable to make profit, and the pricing shortfall is up to 0.78 RMB Yuan $(kWh)^{-1}$. Only with a 25% increase in energy price or 25% reduction in battery cost can charging stations become profitable. It is estimated the reasonable number of chargers in Beijing is approximately 6,000, distributed among 672 stations (Li and Quyang, 2011).

5.4 Supporting policies were not improved

Supporting policies were not improved was taken as an important reason for new energy automobile industry slowly upgraded in China.

To begin with, the support for new energy vehicles research and development is not enough. At present, the manufacturing costs of hybrid vehicles in China are 30% higher than traditional gasoline vehicles and it is hard to reduce the costs only through traditional ways. On the other hand, consumers also need a period of adjustment to accept new products and the length of this period determines the length for cost-recovery of new energy vehicle.

Moreover, there is little financial and tax benefits for the purchase of new energy vehicles. At the end of May in 2008, hybrid vehicles which belonged to Toyota Company have been sold for 1,047,000 all over the world and 70% of them were Prius. The results can be largely attributed to the appropriate policies in Japan and the USA. In details, the US Department of Energy decided to grant 20 million dollars to strengthen the research for plug-in hybrid electric vehicles between 2008 and 2009 while identify tax reduction according to the fuel consumption of hybrid electric vehicles. In addition, hybrid vehicles can be travelled on any roads in the USA. For Japanese Government, subsidy was different in accordance with different types of hybrid vehicles and fuel duty was largely reduced.

6 Conclusions and suggestions

This study analyses the product efficiency of hybrid vehicles employing DEA model and sum up government supporting policies for new energy vehicle along with general new energy vehicle development situation with special focus on the Chinese automobile market. In view of the DEA results, not only the market of new energy vehicles is one obstacle for the new energy vehicles development, but also the new energy vehicles themselves. The future development of new energy automobile industry is not optimistic even if it seems that the new energy automobile industry is the only way to upgrade the auto industrial structure in China. First of all, although we are ahead in some technologies of the new energy automobile industry, there is still a wide gap in some key technologies such as battery from foreign top automobile manufactures. Secondly, the market for new energy vehicles in China is not mature and the new energy vehicles were not widely accepted by consumers. Furthermore, the industrialisation of new energy cars in our country was far more affected by many external factors than the industrialisation of new energy buses so that the application of new energy vehicles can be gradually promoted in our country from the public transportation in cities.

The results suggest the following: The market of new energy vehicles in our country has great potential. Most of China's new energy vehicles technology is still in the transitional period from research and development to industrial production. Currently, the new energy automobile industrial development needs the establishment of a series of technical experiments and demonstration projects to analyse and investigate market development experience, and then form complete sets of equipment design and manufacturing, the cultivation and collection of technology development capabilities. Also, regulations should be established to provide a solid foundation for the large-scale development of China's new energy vehicle. It can be seen from experience of other countries that the market development of new energy vehicles requires the strong support of government policies at first no matter for research, consumption or infrastructural facilities. Therefore, the supporting policies need to be further improved. As one of the emerging industries, the new energy automobile industry has the characteristic of sustainable development although it does not go well in the early stage. However, with the rising awareness of environmental protection and the promotion of sustainable development, the development of new energy vehicles will be better than before.

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