Advances in Economics, Business and Management Research, volume 215
Proceedings of the 2022 7th International Conference on Social Sciences and Economic Development (ICSSED 2022)

The Impact of Oil Prices on the Sales of New Energy Vehicles in China: Empirical Study of Different Vehicle Models

Chen Gong [1, *]

[1] *Chinese Academy of Finance and Development, Central University of Finance and Economics, Beijing 100000, China*
[*] *Corresponding author. Email: guanghua.ren@gecacdemy.cn*

ABSTRACT
This paper analyses the effect of Brent crude oil price on the sales of new energy vehicles based on the data of new energy vehicles (divided into pure electric vehicles and plug-in hybrid vehicles) in China from March 2016 to February 2021. This paper finds that there is a significant positive correlation between crude oil price and new energy vehicle sales, and there is a lag effect of crude oil price on new energy vehicle sales. At the same time, there is no strong asymmetric effect of rising and falling crude oil prices on the sales of new energy vehicles. Further study finds that there is also a significant positive correlation between domestic gasoline prices and new energy vehicle sales in China, and the impact of gasoline prices is greater than that of crude oil prices. The results of this paper have positive implications for exploring the market factors that affect the sales of new energy vehicles and for the future development of corporate strategies by new energy vehicle enterprises.

Keywords: *Oil price, new energy vehicle, sales, China.*

1 INTRODUCTION

1.1 Background

As global energy shortages come to the fore, epidemic shocks, and extreme weather effects, the energy market is becoming increasingly tense in terms of supply and demand, leading to significant increases in energy prices. This not only affects the commodity market but also causes certain shocks to the global economy. Therefore, addressing the vulnerability of the energy market is a problem facing all of humanity. At this stage, more and more attention is being paid to the development of the new energy sector, to alleviate the shortage of traditional energy sources as well as solve problems such as environmental pollution. In this context, the renewable energy industry has been growing rapidly in the past decade [1]. China is the world's largest energy consumer and plays a pivotal role in the global energy transition phase. China's new energy market also continues to expand with significant economic benefits [2]. The development of new energy vehicles in the new energy industry has attracted much attention as it alleviates global energy shortages and environmental pollution. It is environmental and energy security concerns that have led the US, China, India, and some European countries to turn to electric vehicles as an alternative to gasoline vehicles [3]. Nevertheless, as an emerging force in the world, the new energy vehicle industry will be affected and disturbed by various factors in the process of development. This paper will analyze the impact of crude oil prices on the sales of new energy vehicles in China.

1.2 Related research

The market factors that influence the development of an industry are often supply and demand. Among many market factors that affect the new energy industry, this paper focuses on the substitution influences that affect the sales of new energy vehicles. Considering the substitution relationship between traditional and new energy sources, rising oil prices will prompt consumers to shift their demand to the production and use of new energy sources [4]. Therefore, there is an intrinsic link between the crude oil market and the new energy market, and it is important to study this interaction for the development of the new energy market. To explore the mechanism of this intrinsic linkage, previous pieces of

literature focus on the role of crude oil prices on the new energy stock market. Zhu et al. investigated at the firm level that crude oil prices have a positive correlation on new energy stocks, while different new energy sectors generate heterogeneous performance [4]. Irene Henriques and Perry Sadorsky studied the sensitivity of the financial performance of alternative energy companies to the increase in crude oil prices on the basis that crude oil prices can stimulate the financial performance of alternative energy companies [5]. Apart from that, changes in oil prices can also generate certain risks for the new energy market [6]. These previous pieces of literature have exhaustively studied the impact of crude oil prices on the new energy industry from various perspectives. In this paper, the most direct impact of crude oil prices on new energy vehicle sales is examined in more depth.

1.3 Objective

The previous pieces of literature have focused more on the corporate level, using stock prices to measure the financial performance of new energy companies. This paper further studies the level of different new energy models of new energy vehicle companies, using the sales of different models as the most intuitive indicator to measure the performance of the new energy vehicle industry. Specifically, this paper takes the monthly sales of different new energy vehicle models as the research object to further study the impact of international crude oil prices, a market shock, on China's new energy vehicle industry.

Existing new energy vehicles are mainly divided into pure electric vehicles and plug-in hybrid vehicles. Pure electric vehicles are powered entirely by rechargeable batteries, such as lithium-ion batteries, while plug-in hybrids have two sets of power equipment: one is the engine used by traditional fuel cars, and the other is the battery power equipment used by pure electric vehicles. Although both are the types of new energy vehicles being promoted in the market today, they have many differences. Pure electric vehicles are more environmentally friendly, but still limited by technology, such as their poor range. Plug-in hybrid vehicles are well-positioned to serve as a transitional model between fuel vehicles and pure electric vehicles. The advantages and disadvantages of the two different types of new energy vehicles become factors for consumers to consider when making their purchase choices. Therefore, this paper will study pure electric vehicles as well as plug-in hybrid vehicles separately to further investigate the different effects of crude oil prices on the two types of vehicles.

According to the literature of Peng et al., there is a cumulative lag effect on the impact of crude oil shocks on stock prices [7]. Because consumers need a certain reaction time to receive, process, and decide on this information of crude oil price change, there may be a lag effect for the market to digest this shock of crude oil price change. Therefore, this paper constructs a distribution lag model to further explore the lag effect of crude oil price on new energy vehicle sales. Meanwhile, according to the literature of Zhu et al., there is an asymmetric effect of crude oil prices on the new energy industry, which can better explain the positive relationship between crude oil price changes and the excess returns of new energy industry stocks when oil prices rise, but this relationship is not well explained when oil prices fall [4]. This paper considers that there may also be asymmetric effects of crude oil prices on new energy vehicle sales, so the samples are further divided into sub-samples for research.

Although the international crude oil price has become an important indicator in the commodity market, Chinese consumers of new energy vehicles concern more about domestic gasoline prices. However, the trends of domestic gasoline prices and international crude oil prices in China are not the same. For example, in 2008, the international crude oil price reached $147 but then showed an obvious downward trend in the following 10 years. At that period, domestic gasoline prices in China were still in the rising stage. In addition, the pricing of domestic refined oil products in China is not fully market-oriented, so the two trends are inconsistent. Based on the reason that the most direct impact for the domestic auto consumers when considering buying a car still comes from gasoline prices, this paper continues to explore the impact of domestic gasoline prices on new energy vehicle sales in China.

2 THEORY ANALYSIS AND RESEARCH HYPOTHESIS

There is a substitution effect between conventional and electric vehicles that is driven in part by the price of oil [8]. Rising gasoline prices will shift consumer demand to the most fuel-efficient vehicles [9]. Nathan Parker et al. showed that although the median cost of ownership of electric vehicles is higher than that of comparable fuel vehicles, the purchase of electric vehicles can save more than 17% of households considering the complete distribution of vehicle miles traveled [10]. Purchasing new energy vehicles as one of the best options to save fuel can reduce the purchase cost of consumers. Based on this substitution relationship, when there is a shortage of energy, energy prices will rise sharply, and the performance of crude oil prices is particularly significant at this time. Then, consumers who want to buy fuel cars will consider future costs and reduce their enthusiasm for fuel cars. Because the demand for cars is more elastic, people will choose to buy new energy cars as a substitute. As a result of this relationship, the sales of new energy vehicles will rise due to the increase in crude oil prices. Thus, the following hypothesis is proposed in this paper.

H: Crude oil prices have a positive correlation with sales of new energy vehicles.

3 EMPIRICAL DESIGN

3.1 Sample selection and data sources

The research sample in this paper is different models of new energy vehicles from March 2016 to February 2021 (a total of 60 months), while the sample is divided into a pure electric vehicle sample and a plug-in hybrid vehicle sample according to the different internal structure and power sources. The monthly sales data of different models in this paper are obtained from the China Passenger Car Association. Brent crude oil spot prices (the Spot Price FOB), China domestic gasoline price, Brent crude oil futures settlement prices, the average ROE of the automobile manufacturing industry, monthly production of new energy vehicles, Chinese GDP, and Chinese CPI (Monthly year-on-year) data are obtained from the Choice financial terminal database. RMB/USD exchange rate data are from the RESSET database.

3.2 variable definition and model setting

To analyze the impact of crude oil prices on the sales of different new energy vehicle models, this paper uses a fixed-effects model for regression. The model is as follows.

$$Sale_{i,t} = \lambda_i + \beta_1 Oil\ price_t + \sum_{k=2}^{n} \beta_k x_{k,i,t} + \epsilon_{i,t} \quad (1)$$

Oil price is the Brent crude oil spot price. The control variables are subdivided into micro variables that control the industry: the average ROE of the automobile manufacturing industry, monthly production in the new energy vehicle industry; and macro-control variables: GDP, CPI, and RMB/USD exchange rate.

To investigate the effect of gasoline prices on the sales of different new energy vehicle models in China, the variables of crude oil prices in the above model are again replaced with gasoline prices. Other control variables remain unchanged.

Table 1 Variable definition

Variables	Definition
Oil price	Brent crude oil spot prices (The Spot Price FOB) (USD/barrel)
Gasoline price	China domestic Gasoline price (Yuan/ton)
ROE	The average ROE of the automobile manufacturing industry (%)
Production	Monthly production in the new energy vehicle industry (Vehicles)
GDP	China Gross Domestic Product (quarterly cumulative value) (Billion Yuan)
CPI	Consumer Price Index (Monthly year-on-year) (%)
ER	RMB/USD exchange rate (Yuan/USD)
Lag x	Lagged x-period value of crude oil prices (USD/barrel)

4. EMPIRICAL RESEARCH

4.1 Descriptive statistics

The descriptive statistics of the variables are shown in Table 2. The results show that the mean value of monthly sales of pure electric vehicles is around 1174 vehicles, while the mean value of monthly sales of plug-in hybrid vehicles is around 783 vehicles. The mean crude oil price is $55.881/barrel with a standard deviation of 12.755 and the coefficient of variation can be calculated as 0.228, while the mean gasoline price is 7322.438 yuan/ton with a standard deviation of 735.69, and the coefficient of variation can be calculated as 0.100, indicating that crude oil prices are more volatile than gasoline prices.

Table 2 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Sale (Pure Electric Vehicles)	2844	1174.697	2262.298	1	36762
Sale (Plug-in Hybrid Vehicles)	1100	783.373	1102.826	1	7599
Oil price	17820	55.881	12.755	18.47	81.03
Gasoline price	16038	7322.438	735.69	6080	8972.5
ROE	17226	.69	.083	.59	.82
Production	17523	90488.864	50549.579	6900	235000
GDP	17820	180261.44	89089.283	54136.67	338662.07
CPI	17820	2.275	1.907	-1	7.9
ER	17820	6.761	.217	6.288	7.132

4.2 Analysis of regression results

4.2.1 The impact of crude oil prices on new energy vehicle sales

Table 3 analyzes the impact of crude oil prices on the sales of new energy vehicles. The first three columns are for the pure electric vehicle sample, and the last three columns are for the plug-in hybrid vehicle sample. From the regression results, the first and fourth column regressions explore the direct relationship between crude oil price and new energy vehicle sales, and the coefficients of the oil price are 17.35 and 11.18, respectively, which are significant at the 1% level, initially proving the hypothesis of this paper that crude oil price has a positive relationship with new energy vehicle sales. The second and fifth column regressions add industry control variables based on the first and fourth column regressions, and the third and sixth column regressions add macro variables based on the second and fifth column regressions. The coefficients of the oil price are all positive and significant at the 1% level, which verifies the hypothesis.

Table 3 regression results of crude oil prices and the sales of new energy vehicles

	Y=Sale					
	Pure Electric Vehicles			Plug-in Hybrid Vehicles		
	(1)	(2)	(3)	(4)	(5)	(6)
Oil price	17.35***	15.20***	15.63***	11.18***	10.90***	11.64***
	(3.966)	(4.029)	(4.488)	(3.286)	(2.964)	(3.269)
ROE		788.1	998.6		2,133**	2,146**
		(1,105)	(1,090)		(1,037)	(961.6)
Production		0.00847***	0.0102***		0.00417***	0.00536**
		(0.00139)	(0.00199)		(0.00144)	(0.00246)
GDP			-0.00113			-0.00107
			(0.000731)			(0.000792)
CPI			8.477			-26.54
			(35.41)			(31.77)
ER			77.48			69.67
			(300.0)			(398.0)
Constant	232.9	-1,039	-1,705	168.6	-1,634**	-1,992
	(215.3)	(796.8)	(2,463)	(180.7)	(755.6)	(2,829)
Observations	2,844	2,580	2,580	1,100	990	990
R-squared	0.023	0.101	0.103	0.035	0.129	0.139
Number of observation	294	283	283	100	97	97

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.2 Lagged effect of crude oil prices on new energy vehicle sales

To avoid the problem of multicollinearity between variables with different lags, two-period lagged values, four-period lagged values, and six-period lagged values are included in the regressions in Table 4. In the pure electric vehicle sample, the regression results show that when the lagged variables of the crude oil price are included, the coefficient of crude oil price in the current period is still significant at the 5% level. Only the four-period lagged variables are significant at the 10% level. This indicates that there is no strong lag effect of crude oil price on the sales of pure electric vehicles. In the plug-in hybrid sample, the crude oil price in the current period becomes insignificant after the inclusion of the lagged variables. Both the second and sixth period lagged variables are significant at the 1% level, respectively. This reflects a strong lag effect. Hence, there is a more significant lagged performance of plug-in hybrids by crude oil prices compared to pure electric vehicles. This may be since plug-in hybrids are hybrid structures where the engine and electric motor can drive the car separately and the buyer of such cars can also refuel the car to meet the travel requirements. Hence, they have a more conservative attitude towards the change of crude oil price. Therefore, consumers who want to buy a plug-in hybrid car usually have more time to consider the purchase than those who prefer to buy a pure electric car.

Table 4 regression results of crude oil prices in the lagging period and sale of new energy vehicles

	Pure Electric Vehicles						
	Oil price	Lag 2	Lag 4	Lag 6	ROE	Production	
Y = Sale	8.194**	2.740	5.643*	5.560	902.2	0.00928***	
	(3.471)	(3.553)	(3.280)	(3.602)	(1,080)	(0.00187)	
	GDP	CPI	ER	Constant	Observations	Number of observation	R-squared
	-0.000200	2.919	-352.3	842.4	2,580	283	0.109
	(0.000692)	(41.16)	(321.6)	(2,465)			
	Plug-in Hybrid Vehicles						
	Oil price	Lag 2	Lag 4	Lag 6	ROE	Production	
Y = Sale	4.032	3.768***	1.676	8.523***	1,946**	0.00429*	
	(3.018)	(1.348)	(2.606)	(2.535)	(957.1)	(0.00223)	
	GDP	CPI	ER	Constant	Observations	Number of observation	R-squared
	-0.000137	-46.46	-327.5	448.9	990	97	0.154
	(0.000764)	(33.19)	(431.9)	(2,914)			

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.3 Symmetrical effect of rising and falling crude oil prices on new energy vehicle sale

In Table 5, the samples are classified into rising crude oil price samples and falling crude oil price samples. The classification criterion is that when the crude oil price in period T is higher than or equal to the crude oil price in period T-1, it is classified as a rising crude oil price sample, otherwise, it is classified as a falling crude oil price sample. The first and third column regressions use pure electric vehicle samples, while the second and fourth column regressions use plug-in hybrid vehicle samples. The regression results show that the coefficients of the oil price are all positive and significant at the 1% level, and the results are not significant when comparing coefficients between samples using fisher's permutation test, indicating that there is no significant difference in the effect of crude oil price on new energy vehicle sales between the rising and falling crude oil price samples. Thus, there is no strong asymmetric effect.

Table 5 regression results of rising and falling crude oil prices and sale of new energy vehicles

	Y=Sale			
	Rising		Falling	
	(1)	(2)	(3)	(4)
Oil price	16.56***	17.45***	11.55***	11.62***
	(5.846)	(4.297)	(3.532)	(3.700)
ROE	342.9	2,568	1,728*	3,273***
	(994.9)	(1,561)	(953.4)	(1,109)
Production	0.00853***	0.0113***	0.00619**	0.00404
	(0.00208)	(0.00275)	(0.00269)	(0.00287)
GDP	-0.000436	-0.00245***	-0.00150	-0.000469
	(0.000823)	(0.000873)	(0.00128)	(0.000474)
CPI	28.63	-73.14	-13.32	-43.70
	(44.40)	(46.12)	(26.07)	(72.32)
ER	-322.0	1,576***	-80.88	475.2
	(301.3)	(470.2)	(386.4)	(542.9)
Constant	1,363	-12,702***	-753.1	-5,413
	(2,441)	(3,759)	(2,712)	(3,879)
Observations	1,595	985	596	394
R-squared	0.091	0.159	0.119	0.187
Number of observation	276	199	95	65

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.4 The impact of gasoline prices on sales of new energy vehicles

To compare the degree of influence of crude oil price and gasoline price on new energy vehicle sales, the data of crude oil price as well as gasoline price are standardized in this paper. The result of the first regression shows the relationship between gasoline price and new energy vehicle sales, and the coefficient of the standardized gasoline price is 199, which is significant at the 1% level, fully verifying the positive relationship between gasoline price and new energy vehicle sales. The second regression adds the standardized crude oil price to the first one. The result displays that the coefficient of gasoline price is 158.8, which is significant at the 10% level; the coefficient of crude oil price is 41.01, which is smaller than the coefficient of standardized gasoline price, indicating that gasoline price has more influence on the sales of new energy vehicles, consistent with the above conjecture. Gasoline is refined from crude oil, and there are many other chemical oils obtained by processing crude oil, which have different roles and functions in other fields. But for consumers of automobiles, the most direct indicator of the cost of purchasing a car is the price of gasoline, meaning that the price of gasoline is a better indicator of the substitution between fuel and new energy vehicles than crude oil. Figure 1 shows the trend of Brent crude oil prices and domestic gasoline prices in China over the sample period. Chinese domestic petroleum prices trend slightly later than international crude oil prices. This time lag is caused by international crude oil, whose price changes daily, and Chinese domestic refined petroleum products, which typically take 10 business days to price. Besides, because of the upper and lower ceilings set for domestic regulation of gasoline prices in China, the drop in domestic gasoline prices in China was relatively small when crude oil prices plunged in April 2020. Although international crude oil prices move in roughly the same direction as gasoline prices, some of the factors mentioned above lead to trends that are not completely indistinguishable from each other. As discussed in section 4.2.2 of this paper, there is a lagging effect of new energy vehicle sales on crude oil price changes, and because domestic gasoline prices in China also lag international crude oil prices, this could also indicate that gasoline prices have a greater impact on new energy vehicle sales.

Table 6 regression results of Standardized crude oil and gasoline prices and sale of new energy vehicles

	Standardized Gasoline Price	ROE	Production	GDP	CPI	
Y=Sale (1)	199.0***	734.2	0.00761***	-0.000190	1.561	
	(49.22)	(818.7)	(0.00151)	(0.000572)	(29.77)	
	ER	Constant	Observations	Number of observation	R-squared	
	-469.7	3,076	3,120	378	0.098	
	(295.6)	(2,085)				
	Standardized Gasoline Price	Standardized Oil Price	ROE	Production	GDP	
Y=Sale (2)	158.8*	41.01	843.7	0.00782***	-0.000356	
	(81.10)	(61.22)	(794.3)	(0.00160)	(0.000697)	
	CPI	ER	Constant	Observations	Number of observation	R-squared
	1.852	-377.8	2,387	3,120	378	0.098
	(29.69)	(367.9)	(2,563)			

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

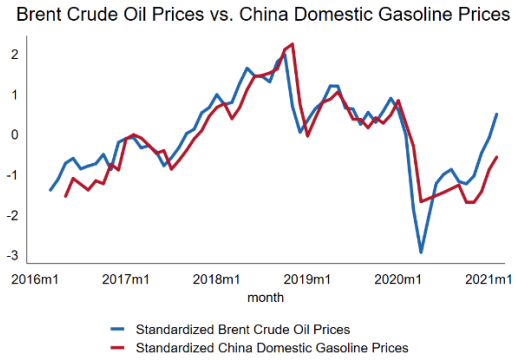

Figure 1 Brent Crude Oil Price vs. China Domestic Gasoline Price

4.3 Robustness test

Considering that there is a positive correlation between the spot price of crude oil and futures price, this paper replaces the main explanatory variable with Brent crude oil futures settlement price for regression. The regression results show that there is a positive correlation between crude oil futures price and new energy vehicle sales, and the coefficients are all significant at the 1% level. Therefore, the results of this paper are robust.

Table 7 Regression results of Brent Crude Oil Futures Settlement Price and sales of new energy vehicles

	Y=Sale					
	Pure Electric Vehicles			Plug-in Hybrid Vehicles		
	(1)	(2)	(3)	(4)	(5)	(6)
Oil futures price	18.80***	16.67***	16.95***	12.88***	12.61***	13.28***
	(4.368)	(4.452)	(4.903)	(3.731)	(3.380)	(3.678)
ROE		688.0	885.4		2,052**	2,058**
		(1,100)	(1,080)		(1,028)	(951.3)
Production		0.00850***	0.0102***		0.00418***	0.00533**
		(0.00139)	(0.00199)		(0.00143)	(0.00244)
GDP			-0.00107			-0.00104
			(0.000724)			(0.000784)
CPI			10.94			-26.29
			(35.38)			(31.68)
ER			54.10			66.20
			(296.8)			(396.3)
Constant	141.4	-1,067	-1,570	66.55	-1,684**	-2,014
	(240.1)	(803.1)	(2,446)	(207.7)	(757.7)	(2,821)
Observations	2,844	2,580	2,580	1,100	990	990
R-squared	0.023	0.102	0.104	0.040	0.133	0.143
Number of observation	294	283	283	100	97	97

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

5. CONCLUSION

Using new energy vehicle data, this paper investigates the relationship between crude oil prices and new energy vehicle sales of different models. The paper divides the sample into two subsamples, pure electric vehicles, and plug-in hybrid vehicles, according to the different internal structures and power sources. It is found that when the crude oil price rises, the sales of new energy vehicles also rise. In this paper, considering the lagged effect of crude oil price on the sales of new energy vehicles, the lagged variables of the crude oil price are included in the regression. The results show that this lag effect is not significant in the pure electric vehicle sample but is more significant in the plug-in hybrid vehicle sample. To investigate whether there is an asymmetric effect of rising and falling crude oil prices on the sales of new energy vehicles, the paper further divides the two subsamples into a rising crude oil price sample and a falling crude oil price sample. The regression results

show that the relationships between rising and falling crude oil prices and new energy vehicle sales are both significant at the 1% level, so there is no strong asymmetric effect. Because the trends of crude oil price and domestic gasoline price in China are not the same, and the price of gasoline is more closely related to new energy vehicle consumers, this paper further investigates the relationship between domestic gasoline price and new energy vehicle sales in China, standardizing the crude oil price and gasoline price data. The results of the study show that the relationship between new energy vehicle sales and gasoline prices is also significantly positive, and gasoline prices have a greater impact on new energy vehicle sales than crude oil prices.

This paper has positive implications for the response and development of the new energy vehicle industry to exogenous factors in the market. As the global consumption of traditional energy intensifies and the signal of traditional energy depletion becomes stronger, new energy is a great choice to solve the future energy supply problem of people, which can also effectively alleviate the problem of environmental pollution. As an emerging force in the automotive industry, the new energy vehicle market has seen significant development in recent years, but at this stage it is affected by a variety of factors, meaning that future development still has many uncertainties. Therefore, in addition to effective government support and further improvement of automobile technology, automobile manufacturers still need to develop corporate strategies to deal with the exogenous impact of market factors, as well as a good balance of alternative relationships with fuel vehicles.

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