# The Impact of Lithium Price on Electric Vehicle Supply Chain Based on Multi-factors Fama-French Models

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**Abstract.** Based on the dynamic changes in the price of raw Lithium and the vital application of lithium on an electric vehicle, the impact of lithium price on the stock return of the Electric Vehicle Supply Chain are investigated in this paper. Specifically, the Fama-French five factors model would be used to evaluate the impact of lithium price on stock return of Electric Vehicle Supply Chain, and stock return correlation test is applied to measure the impact of changes in lithium price on the stock return of Electric Vehicle Supply Chain. According to the analysis, the lithium price only has a negative impact on the stock return of upstream industry in the Electric Vehicle Supply Chain. In addition, the changes in lithium price only have a negative effect on the stock return of downstream industry in the Electric Vehicle Supply Chain. These results extend the researches for the lithium price impacts on corresponding industry and provides a different perspective on the study of the Electric Vehicle Supply Chain.

**Keywords:** Lithium Price · Stock Return · Electric Vehicle Supply Chain · Fama-French Five Factors Model

## 1 Introduction

Ensuring the supply of strategic metals is essential for the growth of industrialised countries. One of these strategic metals is Lithium, which is used in various high-tech products and everyday items [5]. Specifically, Lithium has found widespread use in next-generation technologies such as energy storage, electric vehicles and cordless devices [8]. Among those applications, one of the most pervasive applications of Lithium is the storage of energy through the manufacture of batteries. Specifically, primary batteries (single discharge batteries) use lithium metal as the negative electrode and offer the

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D. Qiu et al. (Eds.): ICBBEM 2022, AHIS 5, pp. 813–826, 2023.
https://doi.org/10.2991/978-94-6463-030-5_80

advantages of high charge density, low weight and long life, but at a high unit cost; and secondary batteries (rechargeable batteries) use lithium compounds as the electrode material, with Lithium as the electrolyte and two electrodes. Among secondary batteries (rechargeable batteries), lithium-ion batteries (LIBs) are considered the most likely candidate for clean energy based on their longer lifespan and higher energy and power densities in the context of fossil fuels depletion and climate change pending threats. However, this is an important limitation of a large market for Li-ion storage, which means the mass introduction of Li-ion batteries as primary storage systems in renewable energy is limited due to populations' revenues [3]. The electric vehicle market appears to be the strongest driver for the development of LIB capable of revolutionising renewable energy. Because LIB can be widely used in electric vehicles based on their high energy/power density, and the market expansion of the electric car needs the mass production of LIB [2]. In other words, the future of renewable energy and LIB may be looked at as tightly correlated with the future of electric vehicles. Besides, the Chinese government's support for buying electric vehicles has contributed to the growth in demand for Lithium [9, 11]. Overall, lithium metal is mainly used in lithium-ion batteries (LIBs) and electric vehicles (EVs).

Furthermore, the consumption-production imbalance of Lithium cause changes in the price of raw Lithium. In detail, there is a basic tension between the supply of extractable lithium deposits on the one hand and the quality and price demands of battery manufacturers on the other [10]. There is evidence that the rapid consumption of Lithium in battery applications (growing 73%) and comparatively low growth (28%) in the production of Lithium during the period from 2010 to 2014 period, which increases the price of raw Lithium and also played a role in determining the market expansion of the electric car [1]. Therefore, it would be meaningful to study the dynamics price of Lithium.

There are several pieces of literature that study the impact of lithium price on the EV market. Specifically, Mo and Jeon [9] examines the dynamics of LIB raw material prices (cobalt, Lithium, nickel, and manganese prices) with EV demand using the Vector Error Correction Model (VECM) method and found that EV demand is important in the short-run dynamics of lithium prices, but the EV demand shock to Lithium prices is relatively small in the long-run equilibrium. It indicates that a short-term increase in lithium prices has been caused by increasing EV demand, but increasing EV demand has no significant impact on the long-term dynamics of lithium prices. Similarly, Narins also notes the Lithium price is a constraint factor that can create uncertainty about the rate of growth and expansion of the global EV sector based on the increase in lithium prices coupled with a simultaneous slowdown in lithium production during the period from 2015 to 2016 [10]. Besides, some other literature exam the impact of lithium price on battery mass and the manufacturing cost of LIB. Ciez and Whitacre found that Lithium is a relatively small contributor to both the battery mass and manufacturing cost and LIB cost [1]. Specifically, the use of more expensive lithium precursor materials results in less than 1% increases in the cost of lithium-ion cells considered, and more significant fluctuations in the global lithium price (from \$0 to \$25/kg from a baseline of \$7.50 per kg of Li2CO3) do not change the cost of lithium-ion cells by more than 10%.

Existing literature has examined the impact of lithium prices on the electric vehicle market and the battery market, respectively. This study would explore the impact of the price of Lithium on the lithium industry, EV market and LIB market, which extends the literature on lithium price. Besides, the stock return of the Lithium market, EV market and LIB market are focused, which provides a different perspective on the study of the Lithium market, EV market and LIB market. In a word, this paper will examine the impact of lithium prices on stock returns in the EV supply chain, including the lithium industry, the battery industry and the EV industry. In addition, this study provides additional evidence with respect to about the impact of lithium price on stock return of electric vehicle supply chain by using Fama-French five factors model and stock return correlation analysis approach. It is assumed that extreme fluctuations in the lithium price could dramatically affect the stock return in the lithium industry, the battery industry, and the EV industry.

The rest of the paper is organized as follows. Section 2 will state the sample and its selection process and introduce the method used in this paper. Section 3 will demonstrate and discuss the result of the data analysis and present the limitations of this study. The last section will conclude this paper briefly.

## 2 Data and Method

### 2.1 Data

To examine the stock returns of the energy vehicle supply chain in the Chinese market, we selected several Chinese companies related to lithium, battery manufacturing, and electric vehicles based on their market capitalization. Chengxin Lithium, Tianqi Lithium, and Ganfeng Lithium have been chosen for the lithium industry. SUNWODA, Gotion High-Tech and DESAY have been selected for the battery manufacturing sector. SAIC MOTOR, CHANGAN AUTO, and BYD have been chosen for the electric vehicles industry. In addition, we use weekly data on lithium spot prices and stock returns from 2015 to 2021. Overall, there are approximately 353 samples has been included. Wind Database has been used to collect the weekly stock price and the spot price of Li. Additionally, CSMAR database has also been used to construct the Fama-French five factors about A-shares.

### 2.2 Adjusted Fama-French Five Factors Model

The dependent variable is the stock return of the supply chain of new energy vehicles, which is the stock return of the lithium industry, battery manufacturing industry and energy vehicles industry. For the independent variables, Lithium price is mainly variables to exam the impact of lithium price on stock return. Besides, based on the stronger explanatory power of the Fama-French five-factor model than that of CAPM and the three-factor model for Chinese data [7], the Fama-French five-factor model would be used to study the lithium industry, battery manufacturing industry and electric vehicle industry. Thus, HML (High Minus Low Book to Market ratio), SMB (Small Minus Big according to market capitalization), MP (Market Premium), RMW (Robust Minus Weak), CMA (Conservatively Minus Aggressively) in Fama-French Five Factors Model would be included as independent variables. In addition, Li found that the aggregate market return, size, and price-to-earnings ratio capture over 90% of the variations in cross-sectional stock returns [6]. Thus, MKT-CAP (Market Capitalization), PE (Price to Earnings ratio), PB (Price to Book ratio) also are included to explain variations in cross-sectional stock returns. Besides, based on Carhart Four Factor Model, the addition of the Momentum (UMD) factor boosted the explanatory power of the model to 95%, thus UMD has also been included [4]. Moreover, COVID is also included to test the impact of COVID on the stock return of the electric car supply chain.

To test the impact of lithium price on stock return of electric car supply chain accurately, we run the following three models to study the impact on lithium companies, battery manufacture companies and electric car companies, respectively. The models with efficient factors are given as follows and Table 1 lists all the definition of the variables.

Model 1 is used to measure the lithium price on the stock return of upstream in the electric vehicle supply chain. Five factors in Fama-French Five Factors Model would be included. Besides, the momentum factor (UMD) would also be included to increase the explanatory power of stock return. We expect lithium related factors have a significant proportion coefficient, based on the nature of lithium mining and preliminarily processing. The mathematical descriptions of model 1 are given in follows:

$$\begin{gathered}\mathrm{Stock\ Return}_{I.t} = a_i + \beta_1 li_{I.t} + \beta_2 \mathrm{MKTPR}_{I.t} \\ + \beta_3 \mathrm{HML}_{I.t} + \beta_4 \mathrm{SMB}_{I.t} + \beta_5 \mathrm{UMD}_{I.t} + \beta_6 \mathrm{CMA}_{I.t} \\ + \beta_7 \mathrm{RMW}_{I.t} + \varepsilon_{I.t}\end{gathered} \tag{1}$$

**Table 1.** Definition of Variables

| | |
|---|---|
| Dependence Variables | |
| Stock Return | Weekly Stock Return is calculated by logarithmic difference.<br>The Formula is $\mathrm{Ln}(\text{Adjusted Close Price}_t) - \mathrm{Ln}(\text{Adjusted Close Price}_{t-1})$. |
| Independence variables | |
| Li | Weekly lithium spot price |
| COVID | A dummy variable equals 1 if after December 2019 |
| HML | High minus low Book-to-Market ratio |
| SMB | small minus big according to market capitalization |
| MKTPR | Market premium is calculated by market return minus risk free rate |
| RMW | Return spread of the most profitable firms minus the least profitable |
| CMA | Return spread of firms that invest conservatively minus aggressively |
| UMD | Return spread of the highest performing stocks minus the return of the lowest performing stocks. |
| MKTCAP | Industry market capitalization |
| P/B Ratio | Industry P/B ration that be calculated based on the weight of market capitalization of companies |
| P/E ratio | Industry P/E ration that be calculated based on the weight of market capitalization of companies |

here $\beta_1$ is able to measure the coefficients between stock return of lithium industry and lithium price, and $\beta_2$ can assess the coefficients between the stock return of lithium industry and market premium of A-share market, and $\beta_3$ can measure the coefficients between the stock return of lithium industry and Book-to-Market ratio of A-share market, and $\beta_4$ evaluates the coefficients between the stock return of lithium industry and market capitalization of A-share market, and $\beta_5$ estimates the coefficient between the stock return of lithium industry and momentum value of A-share market. $\beta_6$ measures the coefficient between the stock return of lithium industry and investment level of A-share market.$\beta_7$ can evaluate the coefficient between the stock return of lithium industry and profitability level of A-share market. In a word, $\beta_2$–$\beta_7$ explain the impact of market premium, Book-to-Market ratio, market capitalization, momentum value, investment level and profitability level on the stock return of lithium industry, respectively.

Model 2 aims to examine lithium price's effect on the stock return of midstream in the electric vehicle supply chain. The factors in Fama-French Five Factors Model would be included. Market capitalization has also been included to explain variations in cross-sectional stock returns of battery manufacturing industries. Besides, the momentum factor (UMD) would also be included to increase the explanatory power of stock return.

$$\begin{aligned} \text{Stock Return}_{I.t} = a_i + \beta_1 li_{I.t} + \beta_2 MKTPR_{I.t} \\ + \beta_3 HML_{I.t} + \beta_4 SMB_{I.t} + \beta_5 UMD_{I.t} + \beta_6 CMA_{I.t} + \beta_7 RMW_{I.t} \\ + \beta_8 \text{Market Cap}_{I.t} + \varepsilon_{I.t} \end{aligned} \tag{2}$$

where $\beta_1$ is to measure the coefficients between the stock return of the battery manufacturing industry and the lithium price. Similar to model 1, the effect of market premium, Book-to-Market ratio, market capitalization, momentum value, investment level and profitability level of A-share market on the stock return of battery manufacturing industry are explained by $\beta_2$–$\beta_7$, respectively. Besides, $\beta_8$ is also to evaluate the coefficient between the stock return and market capitalization of the battery manufacturing sector.

Model 3 is used to determine whether the return of downstream of the electric vehicle supply chain is influenced by lithium price and market-driven. Among five factors in the Fama-French model, only the value factor (HML), investment factor (CMA), and profitability factor (RMW) has been included based on the correlation test. Besides, momentum factor and market capitalization are included to explain the impact of momentum value of share price and market capitalization on stock return of electric vehicle sector. In addition, Covid-19 is also included to measure the effect of Covid-19 on the stock return of the electric vehicle sector.

$$\begin{aligned} \text{Stock Return}_{I.t} = a_i + \beta_1 li_{I.t} + \beta_2 HML_{I.t} + \beta_3 UMD_{I.t} \\ + \beta_4 CMA_{I.t} + \beta_5 RMW_{I.t} + \beta_6 \text{Market Cap}_{I.t} + \beta_7 \text{Covid}_{i.t} + \varepsilon_{I.t} \end{aligned} \tag{3}$$

Where $\beta_1$ is to measure the coefficients between the stock return of electric vehicle industry and lithium price, $\beta_2$ can assess the coefficients between the stock return of electric vehicle sector and Book-to-Market ratio of A-share market, and $\beta_3$ estimates the coefficient between the stock return of electric vehicle sector and momentum value of A-share market, and $\beta_4$ evaluates the coefficients between the stock return of electric vehicle industry and investment level of A-share market, and $\beta_5$ estimates the coefficient between the stock return of electric vehicle industry and profitability level of A-share market, $\beta_6$ measures the coefficient between the stock return of electric vehicle industry and market capitalization of electric vehicle sector, $\beta_7$ evaluates the coefficients between Covid-19 and the stock return of electric vehicle industry.

# 3 Results and Discussions

## 3.1 Correlation Analysis

Table 2 report the correlation result about model 1. It shows that the lithium price has a negative and significant effect on the stock return of the lithium mining and processing industry, which means the higher price is likely to decrease the stock return of the lithium industry. The possible reason is the increasing price decrease demand of lithium, and investors withdraw the money and lead the stock declining. Besides, the Fama-French five factors model works for new energy car supply chain companies because all five factors have a significant impact on the stock return of lithium companies. In addition, the market cap, P/E ratio and P/B are also less likely to explain variations in cross-sectional stock returns of lithium companies. Moreover, the covid-19 may not impact the stock return of lithium industry due to low correlation. Overall, we constructed a regression model based on outstanding factors in correlation results for the upstream industry, which includes LI, MKTPR, RMW, CMA, HML, SMB, and UMD.

Table 3 reports the correlation result of Model 2. The negative association between lithium price and stock return of battery manufacturing companies means the increasing lithium price may cause a lower stock return in the battery manufacturing industry. However, it shows that the lithium price has an insignificant impact on the stock return of the battery manufacturing industry. Besides, the Fama-French five factors model works for the battery manufacturing industry because all five factors have a significant impact on the stock return of the battery manufacturing industry. Moreover, the MKTCAP has a positive and significant impact on the stock return of the battery manufacturing industry, which means higher market capitalisation of the battery manufacturing industry can

**Table 2.** The lithium industry correlation test result

| | SR | LI1 | COVID | MKT_CAP | MKTRF | PB | PE | RMW | SMB | UMD | HML | CMA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SR | 1.000 | −0.118 | 0.067 | 0.046 | 0.462 | 0.068 | 0.005 | −0.196 | 0.120 | 0.160 | −0.191 | −0.226 |
| LI1 | −0.118 | 1.000 | −0.257 | 0.244 | −0.063 | 0.194 | 0.070 | 0.075 | −0.113 | 0.067 | 0.097 | 0.048 |
| COVID | 0.067 | −0.257 | 1.000 | 0.651 | 0.047 | 0.314 | 0.163 | 0.009 | −0.019 | 0.101 | −0.033 | −0.046 |
| MKT_CAP | 0.046 | 0.244 | 0.651 | 1.000 | 0.028 | 0.753 | 0.095 | −0.018 | −0.033 | 0.065 | 0.046 | 0.034 |
| MKTRF | 0.462 | −0.063 | 0.047 | 0.028 | 1.000 | 0.037 | 0.066 | −0.403 | 0.332 | 0.204 | −0.205 | −0.122 |
| PB | 0.068 | 0.194 | 0.314 | 0.753 | 0.037 | 1.000 | 0.114 | −0.031 | −0.025 | 0.053 | 0.090 | 0.039 |
| PE | 0.005 | 0.070 | 0.163 | 0.095 | 0.066 | 0.114 | 1.000 | −0.035 | −0.020 | 0.094 | 0.042 | 0.065 |
| RMW | −0.196 | 0.075 | 0.009 | −0.018 | −0.403 | −0.031 | −0.035 | 1.000 | −0.898 | 0.286 | 0.213 | −0.310 |
| SMB | 0.120 | −0.113 | −0.019 | −0.033 | 0.332 | −0.025 | −0.020 | −0.898 | 1.000 | −0.338 | −0.269 | 0.260 |
| UMD | 0.160 | 0.067 | 0.101 | 0.065 | 0.204 | 0.053 | 0.094 | 0.286 | −0.338 | 1.000 | −0.205 | −0.327 |
| HML | −0.191 | 0.097 | −0.033 | 0.046 | −0.205 | 0.090 | 0.042 | 0.213 | −0.269 | −0.205 | 1.000 | 0.621 |
| CMA | −0.226 | 0.048 | −0.046 | 0.034 | −0.122 | 0.039 | 0.065 | −0.310 | 0.260 | −0.327 | 0.621 | 1.000 |

**Table 3.** The lithium battery manufacturing industry correlation test

| | SR | LI1 | COVID | MKT_CAP | MKTRF | PB | PE | RMW | SMB | UMD | HML | CMA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SR | 1.000 | −0.070 | 0.082 | 0.119 | 0.582 | 0.018 | 0.041 | −0.278 | 0.255 | 0.116 | −0.368 | −0.305 |
| LI1 | −0.070 | 1.000 | −0.257 | 0.009 | −0.063 | −0.429 | −0.040 | 0.075 | −0.113 | 0.067 | 0.097 | 0.048 |
| COVID | 0.082 | −0.257 | 1.000 | 0.757 | 0.047 | −0.201 | 0.030 | 0.009 | −0.019 | 0.101 | −0.033 | −0.046 |
| MKT_CAP | 0.119 | 0.009 | 0.757 | 1.000 | 0.057 | 0.000 | 0.394 | −0.035 | 0.021 | 0.052 | 0.023 | 0.000 |
| MKTRF | 0.582 | −0.063 | 0.047 | 0.057 | 1.000 | 0.023 | 0.018 | −0.403 | 0.332 | 0.204 | −0.205 | −0.122 |
| PB | 0.018 | −0.429 | −0.201 | 0.000 | 0.023 | 1.000 | 0.576 | −0.168 | 0.179 | −0.137 | 0.011 | 0.085 |
| PE | 0.041 | −0.040 | 0.030 | 0.394 | 0.018 | 0.576 | 1.000 | −0.140 | 0.152 | −0.112 | 0.001 | 0.105 |
| RMW | −0.278 | 0.075 | 0.009 | −0.035 | −0.403 | −0.168 | −0.140 | 1.000 | −0.898 | 0.286 | 0.213 | −0.310 |
| SMB | 0.255 | −0.113 | −0.019 | 0.021 | 0.332 | 0.179 | 0.152 | −0.898 | 1.000 | −0.338 | −0.269 | 0.260 |
| UMD | 0.116 | 0.067 | 0.101 | 0.052 | 0.204 | −0.137 | −0.112 | 0.286 | −0.338 | 1.000 | −0.205 | −0.327 |
| HML | −0.368 | 0.097 | −0.033 | 0.023 | −0.205 | 0.011 | 0.001 | 0.213 | −0.269 | −0.205 | 1.000 | 0.621 |
| CMA | −0.305 | 0.048 | −0.046 | 0.000 | −0.122 | 0.085 | 0.105 | −0.310 | 0.260 | −0.327 | 0.621 | 1.000 |

significantly increase the stock return of the battery manufacturing industry. It should also be noted that the Covid- 19 also has no association with the stock return of battery manufacturing industry. Overall, we constructed a regression model based on outstanding factors in correlation results for the mid-stream industry, which include RMW, CMA, MKT-CAP, HML, SMB, and UMD. And lithium price, as mainly independent, has also been included.

Table 4 shows the correlation result of model 3. Lithium prices have an insignificant impact on the stock return of the electric vehicle industry, and lithium price has the least impact on the electric vehicle industry through the supply chain. Besides, among five factors in the Fama-France model, only market premium, UMD, HML and CMA have a significant impact on the stock return of the electric vehicle industry, which means the market level, value level, investment level, and momentum level of electric vehicle industry can well explain the stock return of electric vehicle industry. Specifically, the HML and CMA are significantly negatively correlated with the stock return, which means the higher value and investment of the electric vehicle industry are more likely to cause the lower stock return of the electric vehicle industry. In addition, the Covid-19 is more likely to influence the electric vehicle industry. Therefore, we constructed a model based on their outstanding factors of correlation result for the downstream industry, which includes Covid, CMA, MKT-CAP, HML, Market premium and UMD. And lithium price, as mainly independent, has also been included.

### 3.2 Regression Results

Table 5 shows the regression result of model 1. The P-value of 0.47 of lithium price suggests that lithium prices have a significant and negative impact on the stock return of the lithium industry, which means the increased lithium price would decrease the stock return of the lithium industry. Tables 6 and 7 reports the regression result of model 2 and model 3, respectively, the P-value of lithium price on model 2 and model 3 is 0.894 and 0.204, respectively, indicating that no significant impact of lithium price on stock return of battery manufacturing industry and electric vehicle sector.

**Table 4.** The new energy car manufacturing companies' correlation test

| | SR | LI1 | COVID | MKTCAP | MKTRF | PB | PE | RMW | SMB | UMD | HML | CMA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SR | 1.000 | −0.088 | 0.149 | 0.140 | 0.510 | 0.013 | −0.095 | 0.031 | −0.066 | 0.235 | −0.242 | −0.312 |
| LI1 | −0.088 | 1.000 | −0.257 | 0.174 | −0.063 | −0.073 | 0.405 | 0.075 | −0.113 | 0.067 | 0.097 | 0.048 |
| COVID | 0.149 | −0.257 | 1.000 | 0.606 | 0.047 | −0.162 | −0.411 | 0.009 | −0.019 | 0.101 | −0.033 | −0.046 |
| MKTCAP | 0.140 | 0.174 | 0.606 | 1.000 | 0.057 | −0.116 | −0.212 | −0.015 | −0.040 | 0.062 | 0.047 | 0.023 |
| MKTRF | 0.510 | −0.063 | 0.047 | 0.057 | 1.000 | −0.003 | −0.014 | −0.403 | 0.332 | 0.204 | −0.205 | −0.122 |
| PB | 0.013 | −0.073 | −0.162 | −0.116 | −0.003 | 1.000 | 0.030 | −0.036 | 0.017 | −0.055 | −0.119 | −0.061 |
| PE | −0.095 | 0.405 | −0.411 | −0.212 | −0.014 | 0.030 | 1.000 | −0.022 | 0.033 | −0.021 | 0.096 | 0.123 |
| RMW | 0.031 | 0.075 | 0.009 | −0.015 | −0.403 | −0.036 | −0.022 | 1.000 | −0.898 | 0.286 | 0.213 | −0.310 |
| SMB | −0.066 | −0.113 | −0.019 | −0.040 | 0.332 | 0.017 | 0.033 | −0.898 | 1.000 | −0.338 | −0.269 | 0.260 |
| UMD | 0.235 | 0.067 | 0.101 | 0.062 | 0.204 | −0.055 | −0.021 | 0.286 | −0.338 | 1.000 | −0.205 | −0.327 |
| HML | −0.242 | 0.097 | −0.033 | 0.047 | −0.205 | −0.119 | 0.096 | 0.213 | −0.269 | −0.205 | 1.000 | 0.621 |
| CMA | −0.312 | 0.048 | −0.046 | 0.023 | −0.122 | −0.061 | 0.123 | −0.310 | 0.260 | −0.327 | 0.621 | 1.000 |

**Table 5.** Regression result of model 1

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.039 | 0.019 | 2.057* | 0.040 |
| LI | 0.000 | 0.000 | −1.991* | 0.047 |
| MKTRF | 1.063 | 0.165 | 6.427* | 0.000 |
| RMW | −1.502 | 0.462 | −3.255* | 0.001 |
| HML | 0.505 | 0.437 | 1.156 | 0.248 |
| SMB | −1.138 | 0.550 | −2.070* | 0.039 |
| UMD | 0.205 | 0.228 | 0.900 | 0.369 |
| CMA | −1.802 | 0.504 | −3.575* | 0.000 |
| R-squared | 0.274 | Mean dependent var | | 0.004 |
| Adjusted R−squared | 0.260 | S.D. dependent var | | 0.105 |
| S.E. of regression | 0.090 | Akaike info criterion | | −1.952 |
| Sum squared resid | 2.806 | Schwarz criterion | | −1.864 |
| Log likelihood | 352.445 | Hannan-Quinn criter. | | −1.917 |
| F-statistic | 18.624 | Durbin-Watson stat | | 1.974 |
| Prob(F-statistic) | 0.000 | | | |

Significant at the 0.05 probability level

Based on the coefficient value of HML of 0.505, −0.450 and 0.070 in upstream, midstream and downstream of the electric vehicle supply chain, respectively, the value factor (HML) has a significant impact on the entire electric vehicle supply chain. Furthermore, a positive HML beta (value factor) means a portfolio has a positive relationship with the value premium. On the other hand, if the beta is negative, the portfolio behaves

**Table 6.** Regression result of model 2

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | −0.011 | 0.012 | −0.947 | 0.344 |
| LI | 0.000 | 0.000 | −0.134 | 0.894 |
| MKTCAP | 0.000 | 0.000 | 2.275* | 0.024 |
| MKTPR | 0.911 | 0.091 | 10.031* | 0.000 |
| RMW | −0.226 | 0.254 | −0.892 | 0.373 |
| HML | −0.450 | 0.240 | −1.872 | 0.062 |
| SMB | 0.036 | 0.302 | 0.118 | 0.906 |
| UMD | −0.147 | 0.125 | −1.175 | 0.241 |
| CMA | −0.904 | 0.277 | −3.262* | 0.001 |
| R-squared | 0.433 | Mean dependent var | | 0.002 |
| Adjusted R-squared | 0.420 | S.D. dependent var | | 0.065 |
| S.E. of regression | 0.050 | Akaike info criterion | | −3.148 |
| Sum squared resid | 0.844 | Schwarz criterion | | −3.049 |
| Log likelihood | 564.569 | Hannan-Quinn criter. | | −3.108 |
| F-statistic | 32.892 | Durbin-Watson stat | | 2.071 |
| Prob(F-statistic) | 0.000 | | | |

Significant at the 0.05 probability level

more like a growth stock portfolio. Specifically, the upstream and midstream companies have a positive coefficient, which reveals value stocks (high book-to-market ratio) enjoy higher returns than growth stocks (low book-to-market ratio). And growth stocks have higher returns than value stocks in the lower industry with negative HML.

The coefficient value of SMB in upstream, midstream of electric vehicle supply chain is −1.138 and 0.036, respectively, which means SMB only significantly impacts upstream industry's stock return, and the negative association between SMB and upstream industry's stock return means big-size companies actually earn a higher return.

The coefficient value of RMW in upstream and midstream industries is −1.502 and −0.226, respectively, which means the RMW has a significant and negative impact on the stock return of upstream and midstream sectors. The negative coefficient indicates higher profitability generate lower profit. Profitability can be calculated in several ways to reflect a company's ability to earn. Although a company can realize a profit, this does not necessarily mean that the company is profitable.

Based on the coefficient value of UMD in upstream, midstream and downstream of the electric vehicle supply chain (0.205, −0.147, 0.142, respectively), the UMD has a significant impact on the entire electric vehicle supply chain. A positive UMD beta means a company can continue in an upward trend. However, the negative one is a downward trend. The upstream and downstream's coefficient value's UMD is positive,

**Table 7.** Regression result of model 3

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | −0.001 | 0.012 | −0.108 | 0.914 |
| LI | 0.000 | 0.000 | −1.274 | 0.204 |
| COVID | 0.004 | 0.008 | 0.446 | 0.656 |
| MKTCAP | 0.000 | 0.000 | 1.798 | 0.073 |
| MKTPR | 0.794 | 0.078 | 10.135* | 0.000 |
| HML | 0.070 | 0.195 | 0.358 | 0.720 |
| UMD | 0.142 | 0.115 | 1.239 | 0.216 |
| CMA | −0.966 | 0.225 | −4.289* | 0.000 |
| R-squared | 0.346 | Mean dependent var | | 0.006 |
| Adjusted R-squared | 0.333 | S.D. dependent var | | 0.061 |
| S.E. of regression | 0.050 | Akaike info criterion | | −3.133 |
| Sum squared resid | 0.861 | Schwarz criterion | | −3.046 |
| Log likelihood | 561.046 | Hannan-Quinn criter. | | −3.099 |
| F-statistic | 26.079 | Durbin-Watson stat | | 1.910 |
| Prob(F-statistic) | 0.000 | | | |

Significant at the 0.05 probability level

hence the well-performed companies in these fields may continue to do well. Meanwhile, the well-performed companies in the battery industry may not have as much return as they used to.

The coefficient value of CMA in upstream, midstream, and downstream of the electric vehicle supply chain is −1.802, −0.904 and −0.966, respectively, which means the CMA has a significant impact on the entire electric vehicle supply chain. Furthermore, the positive CMA beta (investment factor) indicates that the returns of companies that invest conservatively are more than those that invest aggressively. The whole supply chain shows a negative value in CMA, suggesting the better performance of the aggressive companies (higher return).

Based on correlations result between COVID-19 and stock returns of upstream, midstream and downstream in electric vehicle supply chain (0.067, 0.082 and 0.149, respectively), the Covid-19 has only been included in model for downstream industry. The coefficient value of Covid-19 is 0.004, which shows that Covid-19 has no significant impact on stock return of electric vehicle sectors.

The P- value of the MKTCAP is 0.024 and 0.073 for the midstream and downstream industry, respectively, meaning the market capitalization can positively explain the stock return of battery manufacturing industry and electric vehicle industry. Besides, the positive correlation may be result of order of magnitude difference between capitalization and stock return.

### 3.3 Correlation Test of the Influence of Rate of Return

For the development of lithium industry, lithium battery manufacturing, electric cars, three industry of the relationship between the rate of return on equity and lithium metal prices are investigated, as well as the relationship between their yields, granger causality test, and sample heteroscedasticity and serial correlation test, to find the influence of the relationship between the yield between them. On the basis of the above mentioned, the first order logarithmic difference of lithium metal price is carried out to obtain the rate of return of lithium metal price.

First, the stationarity of the four time series was tested. The test results are shown in the Table 8, where the test results of the three industries' index returns and lithium metal returns are significant at the confidence level of 1%, indicating that all time series are stable.

As the four return rate time series shown in the above time series test are all stationary series, Granger causality test is conducted on the relationship between the price of lithium metal and the return rate of the three industries to preliminarily determine their relationship. The test results are shown in the Table 9. According to the analysis, in the Granger test of whether the price of lithium metal is the Granger cause of stock return rate changes in the three industries, the test results reject the null hypothesis at the confidence level of 5%, indicating that the price of lithium metal is the Granger cause of stock return rate of the new energy vehicle manufacturing industry. In the Granger test of whether the price of lithium metal is the development of lithium ore and the change

**Table 8.** Stationary test of time series

| | ADF statistics | PP statistics | 1% level | 5% level | 10% level |
|---|---|---|---|---|---|
| Lithium mine development industry | −17.988 | −17.989 | −3.449 | −2.870 | −2.571 |
| Lithium battery manufacturing industry | −18.833 | −18.908 | −3.449 | −2.870 | −2.571 |
| new energy vehicle manufacturing industry | −17.602 | −17.649 | −3.449 | −2.870 | −2.571 |
| Lithium metal price | −9.393 | −17.648 | −3.449 | −2.870 | −2.571 |

**Table 9.** Granger causality test

| | F-Statistic | Prob |
|---|---|---|
| Li price dose not Granger cause Lithium mine development industry stock yield | 1.005 | 0.367 |
| Li price dose not Granger cause Lithium battery manufacturing industry stock yield | 0.480 | 0.619 |
| Li price dose not Granger cause new energy vehicle manufacturing industry stock yield | 6.090 | 0.003 |

**Table 10.** Heteroscedasticity and sequence correlation test

| | Lithium mine development industry | Lithium battery manufacturing industry | new energy vehicle manufacturing industry | Lithium metal price |
|---|---|---|---|---|
| Heteroscedasticity Arch(10) | 0.2494 | 1.188 | 2.981 | 2.920 |
| Prob.F | 0.991* | 0.298* | 0.001* | 0.002* |
| Q(10) | 7.9399 | 14.962 | 18.257 | 100.71 |
| Prob | 0.635* | 0.133* | 0.051* | 0.000* |

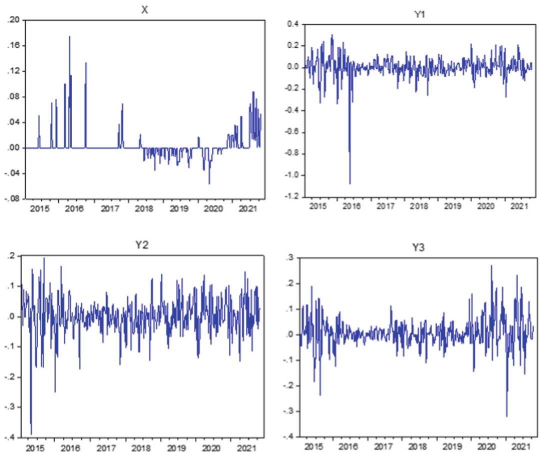


**Fig. 1.** Yield time series for X, Y1–Y3, respectively

of return rate of lithium battery manufacturing index, the test result is not significant, and the original hypothesis is accepted, indicating that the price of lithium metal is not the Granger cause of the change of return rate of lithium battery manufacturing stock (Table 10).

However, the conclusion of Granger causality test is only a prediction, not a causal relationship in the real sense, and cannot be used as the basis for confirming or denying the causal relationship between the two. Therefore, sample heteroscedasticity and sequence correlation tests were carried out to further determine the relationship between them (Fig. 1).

According to the test results, the p-values of both lithium mine development industry and lithium battery manufacturing industry are at the significance level of >5%. Consequently, the original hypothesis is accepted, i.e., the sequence is pure random sequence, that is, white noise sequence. However, the ARCH test results of ev stock return rate and lithium metal return rate time series reject the null hypothesis that there is no ARCH effect in time series, i.e., these two return rate time series are heteroscedasticity. Nevertheless, there is no ARCH effect in the two time series of lithium mine development and lithium battery manufacturing. Only the downstream stock return rate and lithium metal have sequence autocorrelation, the others have no sequence autocorrelation.

Overall, through the test, it can be seen that the price return rate of lithium metal affects the stock return rate of new energy vehicle manufacturing industry to a certain extent. Whereas it has no relation with the stock return rate of lithium mining development industry and lithium battery manufacturing industry.

### 3.4 Limitation

Limitations of this study should be acknowledged, which also provides opportunities for future research. There are two important limitations about the sample and data. Firstly, considering that China's new energy vehicles started late, the sample size may be insufficient and irrelevant. Secondly, the companies selected in the study are the largest in each industry group, limiting the generalizability of the results. Future research can be expanded to examine smaller firms. Besides, the current methodology was limited by a non-linear relationship, meaning we only study the linear relationship between lithium price and stock return of the electric vehicle supply chain. In addition, the dummy variables of the pandemic are also hard to reflect its influence, meaning the impact on stock returns could be bigger than thought. Moreover, it does not explain why the negative relationship between lithium price and stock return of upstream in the electric vehicle supply chain and between changes in lithium price and stock return of downstream in the electric supply chain, which should be further explored.

## 4 Conclusion

In summary, we investigate the lithium price's impact on the stock return of electric vehicle supply chain based on the Fama-French model, which extends the literature on lithium price and provides a different perspective on the study of the Lithium market, EV market and LIB market. Based on the Fama-French model, it seems that lithium price can affect the stock return of the lithium industry and are less likely to influence the stock return of the battery manufacturing industry and electric vehicle industry. Besides, most of factors on the Fama-French model can explain the stock return of lithium industry and battery manufacturing industry, and stock return of electric industry only can be explained by a market factor (Market premium), value factor (HML), investment factor (CMA), and momentum factor (UMD). Based on Granger test and ARCH test, the return rate of lithium metal only has a certain impact on the stock return of electric vehicle industry, while its return rate has no correlation with the development of lithium industry and lithium battery manufacturing industry. Overall, the lithium price only has significant impact on the stock return of lithium industry, and the changes in lithium price only have a significance impact on stock return of electric vehicle industry. These results offer a guideline for further study focusing on lithium price and shed light on digging out the inherit relationship between lithium price and stock return of the relevant industry.

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