“How oil prices affect investments by firms in the Taiwanese green energy industry?”

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Abstract

This paper uses pooled estimation regression and Differential Slope Estimation to explore contemporary investment practices in the Taiwanese green energy industry. Results suggest that when companies have higher sales profits and greater opportunities for growth, green energy firms invest in them more readily. Similarly, when oil prices are high, green energy firms invest more in both R&D and physical materials, indicating a substitution effect between green energy products and oil products. Furthermore, in an analysis related to firm heterogeneity, we show that green energy firms have lower investment-cash flow sensitivity. This indicates that because of an extremely competitive LED market and the slow cash flow that results from it, green energy firms tend to leverage external financing options such as bank loans rather than finance projects internally. The Taiwanese government's low interest rates on bank loans also support the development of green energy LED firms.

Keywords: pooled estimation, Differential Slope Estimation, oil prices, green energy industry, firm investment.
JEL Classification: C32, C33, G10.

Introduction

Since Hamilton (1983) demonstrated that the rise and volatility in the price of oil has a substantial influence on the macroeconomy, changes in oil price have attracted the attention of researchers and practitioners. Extant literature in this area reveals that changes in oil prices often prompt significant economic responses (Mork, 1989; Lee, Ni and Ratti, 1995; Ferderer, 1996; Hamilton, 2000; Hooker, 2002). Kim and Loungani (1992) supported the notion that oil price shocks play an important role in these economic fluctuations. Since World War II, individuals' dependence on oil energy for use in their daily lives has continued to increase. Globally, major oil-exporting countries dominate the supply of oil and regulate prices to repeatedly induce an "oil crisis". Massive global oil consumption not only increases the volatility of oil prices, but also influences the world macroeconomy and the environment. In response to these issues, the late 20th and early 21st century has been marked by a global trend toward reducing energy consumption and emissions of greenhouse gases that threaten the environment through the adoption of energy-saving and carbon-reducing measures.

In 1997, widespread adoption of the Kyoto Protocol[1] was followed by acceptance of the "Global Green New Deal", a governmental policy-making initiative proposed by the United Nations in 2008. In 2009, the reduction of greenhouse gases was definitively addressed by COP15 in Copenhagen[2]. Many countries enthusiastically adopted the cause of energy conservation and participated in discussions regarding carbon reduction by accelerating investments in the green energy industry. This step forward has indicated that there is an urgent and growing demand for green investment all over the world. Generally, green investment consists of green architecture, energy regeneration, sustainable agriculture, and the development of a green economy, which forms the core of the Green New Deal. Green investment is related to a number of critical environmental issues, from the oil crisis to energy regeneration in the 21st century, and thus is concerned with research and development in green energy and environmentally-sound financing strategies. As such, the green energy industry will undoubtedly become the favored industry of the coming era.

Relative to other energy sources, oil currently represents the largest portion of world energy consumption. Most Asian countries are net importers of oil. Taiwan, for example, is largely dependent on oil imports, relying on supply from foreign countries for 99.2% of its oil requirements. Because of this dependence, coupled with its highly developed economy, Taiwan is heavily exposed to oil price volatility. Given this, Taiwan urgently needs to develop new and diversified energy industries. Recently, the Taiwanese government has emphasized the development of the green energy

[1] The Kyoto Protocol treaty is a legally binding agreement under which industrialized countries will reduce their collective emissions of greenhouse gases.

[2] COP15 was an important meeting of international governments to reconcile international protocols on climate change at the fifteenth Conference of the Parties in 2009. Decision-makers worked towards attaining a comprehensive policy for responding to climate change on a global scale, to develop a consensus that will aid in setting of related government policy. Their ultimate purpose was to develop the green energy industry for the benefit of mankind through environmental conservation.

industry to lower the country's dependence on oil energy imports and conserve Taiwan's environment. Green energy is considered an emerging and favored industry, which demands significant capital and manpower to expand its R&D capacity. Taiwan has excellent R&D technology and manufacturing capabilities compared to other countries, which can accelerate the country's development of green energy. Undoubtedly, Taiwan's government plays an important role in promoting and supporting green firms by helping them surpass their technology thresholds, conquer production barriers, and catch up with the capacity of global competitors.

Based on history and against a background of groundbreaking high-technology development, Taiwan has the potential to develop as a major producer of green energy products. Taiwan's LED (Light Emitting Diode) industry, which is second only to Japan in terms of size, is representative of its contingent of green energy products. The goal of Taiwan's LED lighting industry is to develop high-quality lighting instruments that are efficient, safe, convenient, and based on a low-pollution design to reduce oil energy consumption and pollution. Because Taiwan's LED industry has immense capacity in technologies related to LED illumination, it is well-suited to develop customized products to meet the various needs of customers.

As a result of the Taiwanese LED industry's capacities, the production of Taiwan's LED elements and backlight model is ranked first in the world – production value was approximately USD 20 billion in 2009, and USD 55 billion in 2010. Taiwan's large listed companies, including Taiwan Semiconductor Manufacturing (TSMC), Formosa Plastics (FPC) and HON HAI have all invested considerable capital in the production of LED illumination. Further, government policies in most countries insist on the use of LED instruments in streetlights and public equipment, which reduces energy consumption by 50%. Additionally, the creation of Original Brand Manufacturing (OBM) for Taiwan's LED firms can reveal more sales channels to further advance the Taiwanese LED industry in the global illumination market.

Because they belong to a highly technological industry, LED firms must continually invest large amounts of capital into production. Meanwhile, in the cost structure of production, corporate investment is primarily focused on R&D investment and the purchase of machines and facilities in addition to setting up factories (i.e., physical investment). Therefore, green energy firms are highly capital-intensive and have high fixed costs and thus require a large amount of capital investment to sustain production and operating performance. In this article, we investigate the Taiwanese LED industry to explore the relationship between oil price and firm investment, and analyze the production cost structure and capital sources of highly capital-intensive industries.

According to the neoclassical investment theory established by Modigliani and Miller (1958) which relates to capital structure, firms can choose two channels to infuse corporate investment capital – external capital markets and internal capital markets. Given the assumption that in perfect capital markets, external funds are perfect substitutes for internal funds, companies are indifferent to using various channels to finance their corporate investment. However, in reality, the capital market is imperfect with asymmetric friction; capital providers from the external markets include equity markets, bond markets, banks, and others. Myers and Majluf (1984) noted that due to market frictions and transaction costs, companies may face various financial constraints. Thus, the choice of financial channels (e.g., internally generated funds, new debt, or new equity) will influence a company's investment strategies and decisions. Capital from internal markets is also important for corporate finance, including the allocation of internal capital to a firm's business units (conglomerate members), which benefit through the redeployment of projects.

Similar to Modigliani and Miller (1958), Reimund (2002) showed that a firm can choose between two competing forms of financing – internal capital markets and bank loans. Through his study of large German corporations, he found that firms that rely on internal capital markets with a lower reliance on bank loans exhibit higher investment-cash flow sensitivity. Therefore, internal capital may help mitigate the costs of external finance such as asymmetric information and agency costs. In addition, Gertner, Scharfstein and Stein (1994) analyzed the costs and benefits of funds generated internally as compared with external capital markets like bank lending. They found that relative to external capital, internal capital leads to increased monitoring incentives. The use of internal capital was also found to reduce a manager's entrepreneurial incentive because the manager cannot control the funds to prevent agency problems in management layers.

Almeida et al. (2004) showed that cash holding indicates corporate liquidity as a relevant factor in the firm's financial structure. Owing to the high cost of raising funds from the external capital market, Acharya, Almeida, and Campello (2007) proposed and developed a financial framework in which cash and debt are jointly determined to handle the firm's intertemporal investment policy. They found that cash holdings play an important and independent role in the optimization of a firm's financial policies.

Some studies have examined the relationship of external funds and corporate investment strategies and found that a firm's cash flow can help to explain its investment levels (Fazzari et al., 1988; Chapman et al., 1996; Samuel, 1998). Bond et al. (2003) employed cross-country comparisons of investment-cash flow sensitivity, and found that the UK displays higher investment-cash flow sensitivity than Belgium, France, and Germany. They discovered that variation in countries' investment-cash flow sensitivities was probably due to the financial systems and financing channels that determined their investment decisions. Therefore, the investment behavior of a firm may be restricted by available external funds. Compared with less developed countries, the financial systems of most developed countries can effectively deploy external finance to a greater degree in investments.

On the relationship of firm investment and liquidity, Petersen and Rajan (1994) noted that a close and continued bank-firm relationship may help the firm to increase the availability of capital and reduce capital costs. A close bank-firm relationship may also infuse capital into firms to help manage a financial crisis. Therefore, it follows that the bank-firm relationship also affects the infusion of capital as investment. Semenov (2006) investigated eleven countries belonging to the Organization for Economic Cooperation and Development (OECD) and found that some of those with close bank-firm relationships exhibit less financial constraints and less financial market friction relative to countries with arm's length bank-firm relationships. This phenomenon suggests that firms with a close bank-firm relationship can more easily obtain investment capital. The authors also found that every country exhibits differences in firm cash flow (internal capital) sensitivity on corporate investment. For firms with close relationships with banks, investment-cash flow sensitivity is less pronounced than that of firms whose relationships with banks are at arm's length. This indicates that under close bank-firm relationships, enterprises can easily obtain bank loans as investments, thus exhibiting lower correlation of cash flow and firm investment.

Bancel and Mittoo (2004) surveyed European countries and found that corporate managers in Europe claim that maintaining financial flexibility is the primary objective of their firms' financial policies. Firms within different countries operate within different financial systems; some use credit from banks whereas others use stock market capitalization; some highlight the entrepreneur as the owner of a firm whereas others emphasize the role of the agent (manager); some obtain capital principally from internally generated funds where others employ new debt or new equity. These crucial differences will often influence a company's investment decisions.

Given these findings, in this paper, we utilize Taiwanese LED green energy firms as a sample to study their investments and propensity for industrial development. In the process, we consider several important factors such as green energy products as a substitute for oil energy, financing strategies, and financial constraints. Because LED green energy is part of the high technology industry, in the research and development (R&D) stage, LED firms need to invest a large amount of capital. As a result, R&D and physical investment, financing strategies, and a firm's growth potential are all vital factors that must be considered. Through this research, we found that when facing high volatility of oil prices, Taiwanese green energy firms are inclined to promptly invest in R&D and physical materials. This suggests that green energy and oil energy can be treated as substitutes for one another. However, because green energy firms offer an efficient operating performance and significant potential for growth, they are likely to attract more investment. Additionally, when analyzing capital source and structure, we found that external capital is the primary source of capital investment for Taiwanese green energy firms; loans from banks were more heavily relied upon than internal funds. In the analysis of a firm's heterogeneity, we revealed that over 70% of Taiwanese LED green energy firms leverage an external financing channel as an investment source, which indicates that the Taiwanese government's policy of offering lower interest rates are vital for the development of the green energy industry and the global green economy.

The remainder of the paper is organized as follows. Section 1 introduces the empirical model. Section 2 discusses the methodology and data. Section 3 presents the empirical results of the analysis; and the final section summarizes and concludes the paper.

1. Empirical model

Recently, global governments have placed a greater emphasis on green energy industry as the most favored for growth. Corporate investment in green energy is chiefly aimed at research and development (R&D), but actual production of renewable energy has yet to be increased. Chen and Yang (2005) argued that investments in R&D are critical for the technology industry. In this vein, the Taiwanese government actively supports industrial R&D investment as a means to improve the technological capabilities of the country's industries. Because investment in R&D in green energy firms is critical, green energy firms require a large amount of capital to dedicate physical resources such as factories, machines, and production equipment. Thus, this paper uses corporate investments to explore the financial structure and the investment trends of firms in Taiwan's green energy industry. The empirical model used in this paper closely parallels that of Semenov (2006), which investigated the influence of cash flow on corporate investment in OECD countries. Because there is a strong connection between the financial decisions of green energy firms and price volatility in the oil market, we add oil price to the investment model to explore the influence of oil price on green energy firms' investments. Given the relevant variables, the investment model used for this paper can be estimated as equation (1).

$$\frac{FI_{i,t}}{K_{i,t}} = \alpha_i + \beta_1 OIL_t + \beta_2 CF_{i,t-1} + \beta_3 Q_{i,t} + \\ + \beta_4 SAL_{i,t-1} + \beta_5 IR_t + \beta_6 S_{i1} + \beta_7 S_{i2} + \\ +_8 S_{i3} + \varepsilon_{i,t}, \quad (1)$$

where $\frac{FI_{i,t}}{K_{i,t}}$ represents the corporate investment of i green firm at t period to be deflated by common stock; OIL_t represents oil price at time t; $CF_{i,t\text{-}1}$ is cash flow lagged by one term and is used to measure the financing constraints and liquidity of green firm; $Q_{i,t}$ is the Tobin's Q, a calculation of market value divided by book value ($\frac{MV}{BV}$) of i firm representing the investment opportunity of a specific firm, and this figure should exceed unity (>1); $SAL_{i,t\text{-}1}$ expresses the influence of one lagged term's firm sales performance on firm investment; IR_t is the bank interest rates; S_{i1}, S_{i2}, S_{i3} are seasonal dummy variables; and $\varepsilon_{i,t}$ is the error term.

2. Methodology and data

In this paper, we employ pooled estimation regression, which combines the cross-sectional and time series data. The methodology includes the fixed effects model (FEM) and the random effects model (REM), and further uses the Hausman test to judge the suitability of the models. To differentiate and gauge individual firm behavior, we use Differential Slope Estimation (Wald test) to investigate the estimation coefficient β_k of the FEM and REM for the specific firm. Pooled estimation has the advantages of providing numerous data observations and blending cross-sectional and time series data to improve the efficiency of econometric estimates (Hsiao, 1985). Further, this methodology yields reliable coefficient estimates when unobservable individual fixed or random effects exist. Two models for fixed and random effects can respectively be written as follows:

Fixed effects model

$$Y_{it} = \alpha_i + \sum_{k=1}^{K} \beta_k X_{kit} + \varepsilon_{it}, \quad (2)$$

Random effects model

$$Y_{it} = (\alpha_0 + \mu_i) + \sum_{k=1}^{K} \beta_k X_{kit} + \varepsilon_{it}, \quad (3)$$

where i = 1, …, N, and t = 1,…, T, and N and T respectively denote the cross-sectional and time dimensions of the panel. Y_{it} and X_{kit} represent the dependent variable and independent variable, respectively. Individual effects are α_i when fixed, and ($\alpha_0 + \mu_i$) when random and normally distributed. ε_{it} is the disturbance term ~$iid(0, \sigma^2)$.

The primary difference between the FEM and REM relates to whether the disturbance term ε_{it} is identical and independent (*iid*). FEM has fixed constants to illustrate data characteristics, so ε_{it} is *iid*. However, the REM constants are random, so it is unnecessary for ε_{it} to be *iid*[1]. Hausman (1978) proposed a method for judging the applicability of the FEM or REM. More specifically, the Hausman test is to be used to examine whether the constant (μ_i) and explanatory variables (X_{kit}) are correlated. If the constant (μ_i) significantly correlates with explanatory variables (X_{kit}), then the estimation results of FEM would be valid, and the FEM provides the best-fitting model. If (μ_i) is not significantly correlated with (X_{kit}), the best-fitting model is provided by REM.

To investigate estimation coefficients of FEM or REM accompanied by diverse cross-sectional objects, we utilize the Wald test (Wald, 1943)[2]. If the null hypothesis of the Wald test cannot be rejected, it indicates that the influences of specific independent variables do not differ across various cross-sectional data event, and thus the traditional pooled estimation can be used. However, if the null hypothesis is rejected, it indicates that specific explanatory variables will differ across cross-sectional data event. In this case, the Differential Slope Estimation can be applied to estimate an individual firm's investment behavior. The null hypothesis H_0 is expressed as follows:

$$\beta_{k_1} = \beta_{k_2} = \ldots = \beta_{k_i} \quad k = 1, 2, \ldots, K \\ i = 1, 2, \ldots, N. \quad (4)$$

[1] See Hsiao (1985).

[2] The Wald test is used to test the joint significance of a subset of coefficients. When some variables are individually non-significant on the basis on *t*-tests, we may test the joint significance of them using Wald test.

We sampled 21 Taiwanese green energy LED firms listed on the Taiwan Security Exchange Corporation (TSEC) as subjects in this research. The research period ranges from 2001Q1 to 2010Q1, providing 606 total quarterly observations. The names of the 21 green energy LED firms are listed in Table A1 (in Appendix), and all data are from the *Taiwan Economic Journal* (TEJ) databank.

In the tradition of Semenov (2006), this paper's empirical model treats firm investment as a function of relative oil price, cash flow (lag one term), the Tobin's *Q* ratio, sales profits, and bank interest rates. Firm investment is determined by the ratio of the firm's long-term investment to capital stock. With respect to the predictor variables: lagged one term cash flow is scaled by capital stock to capture firm cash flow liquidity; Tobin's *Q* ratio is the market value divided by book value and is designed to indicate the firm's growth potential and opportunities for investment; and sales profits are scaled by capital stock to signify the firm's operating performance. In addition to these static, measurable indicator variables, there are other variables that require proxy measures. Bank interest rates, for example, are established by using Taiwan five bank average loan rates. Similarly, we use the price for Dubai light crude as our indicator for oil price to capture the influence of the change of oil price on green energy firm investment. In addition, because this paper uses quarterly data, seasonal dummy variables are included to estimate whether the average investment of the other three quarters significantly differ from the fourth quarter.

Prior to conducting the analyses, it is necessary to first verify that all variables are stationary. Failure to do so can produce invalid empirical results. Therefore, we performed the Augmented Dickey-Fuller (ADF) Unit Root Test on all variables[1]. The ADF test revealed that oil price, Tobin's Q, lagged cash flow, sales, and bank interest rates are level variables $I(0)$ without unit roots. Only firm investment has one unit root $I(1)$[2]. Data source and measurement information are showed in Table 1.

Table 1. Data source and measurement

Notation	Variable	Measurement	Source
$\frac{FI_{i,t}}{K_{i,t}}$	Firm investment	Firm's long-term investment scaled by capital stock	TEJ
OIL_t	Oil price	Dubai light crude oil price	TEJ
$CF_{i,t-1}$	Lagged one term cash flow	Lagged one term cash flow per share	TEJ
$Q_{i,t}$	Tobin's Q ratio	Market value divided by book value	TEJ
$SAL_{i,t-1}$	Sales profits	Sales profits scaled by capital stock	TEJ
IR_t	Bank interest rates	Taiwan five banks average loan rates	TEJ
S_{i1}, S_{i2}, S_{i3}	Seasonal dummy variables	Taking the fourth quarter as the control group to estimate whether or not the average investment of other three quarters significantly different from that of the fourth quarter	Setting dummy variable

[1] Results of the ADF test are based upon an ADF regression with an intercept where the appropriate lag length, *k*, is chosen using the modified Akaike information criterion (MAIC) proposed by Ng and Perron (2001).

[2] Full results of the ADF Unit Root Test are not presented here, but are available upon a request to the author.

3. Empirical results

In this section, we present the empirical findings of the investment regression (see Table 2 for a summary of these findings). Results of the Hausman test show that the random effects model (REM) provides the greatest explanatory power, so we utilize the REM to perform the Differential Slope Estimation. Tables 3 and 4 present the estimation results of the Different Slope Estimation and REM different in cash flow and oil price, respectively.

Table 2. Estimation results of investment equation – green energy firms

	Fixed effects model		Random effects model	
Explanatory variable	Coefficient	*t*-statistic	Coefficient	*t*-statistic
Constant	0.438***	6.14	0.453***	3.27
$SAL_{i,t-1}$	0.430***	6.18	0.446***	6.47
$CF_{i,t-1}$	0.0006	0.99	0.0006	0.92
OIL_t	0.004***	8.25	0.004***	8.26
$Q_{i,t}$	0.024*	2.02	0.023*	1.98
IR_t	-0.027**	-2.78	-0.026**	-2.76
S_{i1}	0.032	0.93	0.033	0.95
S_{i2}	0.032	0.92	0.032	0.94
S_{i3}	-0.030	-0.88	-0.031	-0.89
Observations	606		606	
Adjusted R^2	0.811		0.220	
F-statistic	93.93***(0.000)		22.44***(0.000)	
Hausman test $\chi^2(8)$	2.39(0.9666)			

Notes: Dependent variable is firm investment divided by common stock. The testing results show that REM has the largest explanatory power. Within estimation, quarterly dummies are included in the regression. *Significant at 10% level; **Significant at 5% level; ***Significant at 1% level.

Table 2 shows that the coefficient for sales (lagged by one term) is significantly and positively related to firm investment, indicating that the estimation for lagged sales is an important determinant of green energy firm investment. Specifically, we found that when the sales in the previous term are high, the firm's investment activity increases as well. However, cash flow (which is indicative of a firm's financial liquidity) was not found to be significantly related to firm investment. Reimund (2002) identified a competitive relationship between internal capital markets and banks with respect to their use for financing. Specifically, he studied the investment-cash flow sensitivity of large German firms and found investment-cash flow sensitivities are lower for firms that heavily rely on bank loans instead of internal capital markets. Consistent with Reimund's findings, our results show that for firms with high levels of borrowing from banks and low internal capital funds, internal cash flow is not significantly correlated with investment activity. This is likely due to the fact that the Taiwanese government currently encourages green energy firms to invest a large amount of capital in their R&D processes, which are often financed through bank loans. Concurrently, the government's policy to establish low interest rates further supports the green energy industry. Thus, cash flow does not exhibit a significant correlation to corporate investment. In addition, because investing capital is largely drawn from banks, green firms are under constant pressure to repay their loans. This forces them to concentrate on repaying their bank debts, which can result in low investment-cash flow sensitivities.

Our analysis also revealed a significant positive correlation between oil prices and firm investment. High oil prices are accompanied by higher investment in renewable energy and investment in the firm. Given this investment, the production of renewable energy products is emphasized to replace oil and prevent environmental deterioration.

Q theory, which suggests that in a perfect world, firm investment is determined solely by a firm's investment opportunities measured as a marginal Tobin's *Q* (Chirinko, 1993). Our analysis showed that Tobin's *Q* has a significant, positive relationship with firm investment, indicating a firm's higher prospects for growth and greater capacity to invest in both R&D and physical investments. In addition, interest rates were shown to be significantly and negatively related to investment. This confirms the expectation that when a higher interest rate is established (which increases the cost of borrowing), firms will engage in less investment.

Table 3. Estimation of different slope method – REM-different in $CF_{i,t-1}$

Dependent variable: *FI*					
Common Slope					
Variable	Coefficient	*p*-value	Variable	Coefficient	*p*-value
IR_t	-0.005	0.592	OIL_t	0.005	0.000***
$SAL_{i,t-1}$	1.024	0.000***	$Q_{i,t}$	0.027	0.159*
S_{i1}	0.117	0.045**	S_{i2}	0.084	0.155*
S_{i3}	-0.057	0.345			
Different Slope					
OPTOTECH	-0.023	0.002**	EVERLIGHT	0.010	0.021*
TYNTEK	-0.016	0.029*	GSEO	0.015	0.000***
SHIANYIH	0.022	0.006**	JENTECH	-0.009	0.066*
PTTC	-0.010	0.000***	YTEC	-0.015	0.000***
AOC	-0.017	0.000***			
Adjusted R^2			0.409		
D-W stat.			0.494		

Notes: Dependent variable is firm investments divided by common stock. ***, ** and* denote statistically significant at the 1%, 5% and 10% level, respectively.

Table 4. Estimation of different slope method – REM-different in OIL_t

Dependent variable: *FI*					
Common slope					
Variable	Coefficient	*p*-value	Variable	Coefficient	*p*-value
$CF_{i,t-1}$	0.0005	0.458	$SAL_{i,t-1}$	0.666	0.000***
IR_t	0.008	0.248	$Q_{i,t}$	0.045	0.001***
S_{i1}	0.093	0.015*	S_{i2}	0.091	0.018*
S_{i3}	-0.001	0.972			
Different Slope					
LTC	0.017	0.000***	EVERLIGHT	0.012	0.000***
ICHIUN	0.004	0.000***	UNITY	0.006	0.000***
BRIGHT	0.003	0.001**	TAIWANOASIS	0.005	0.000***
CHIALIN	0.003	0.023*	GSEO	0.028	0.000***
SHIANYIH	0.022	0.000***	SAS	0.006	0.000***
LEDTECH	0.007	0.000***	PTTC	-0.002	0.027*
PARALIGHT	0.005	0.000***	YTEC	-0.003	0.001**
THIEL	0.003	0.010**	LIGITEK	0.006	0.000***
ACME	0.004	0.0005***			
Adjusted R^2			0.741		
D-W stat.			0.372		

Notes: Dependent variable is firm investments divided by common stock. ***, ** and * denote statistically significant at the 1%, 5% and 10% level, respectively.

To further explore the significance of a specific firm's individual behavior on investment activity we used the Differential Slope Estimation. Table 3 shows the estimation results of this method. We discovered mixed results for the influence of lagged cash flow on firm investment activity. Although nine out of 21 companies had significant relationship between the variables, the same relationship for the other 12 companies was non-significant. Among the nine firms for which the relationship was significant, EVERLIGHT (2393), GSED (3406), and SHIANYIH (3531) had a positive relation between cash flow and investment activity. These three large companies prefer to utilize abundant internal capital generated through profits. For the other six companies for which the relationship was significant, it was negative. The latter six companies, coupled with the 12 for which the relationship was non-significant likely use external financing capital (e.g., bank loans) for firm investment. These mixed results likely suggest that cash flow is not a significant predictor.

Due to the fiercely competitive and rapidly changing nature of the green energy LED market, firm investment has primarily focused on R&D. If a firm's cash flow returns decreases, sales revenues cannot keep pace with R&D investment. Therefore, future R&D investments rely primarily on bank loans with low interest rates. Consistent with the findings of Semenov (2006), we found that most Taiwanese green energy firms utilize external financing capital (bank loans) for firm investment instead of internal capital.

Table 4 shows the results of the Different Slope Estimation as a means to reveal differences in oil price. For 15 out of 21 companies, there was a significant and positive relationship between oil price and investment activity, indicating that rises in oil prices can yield more sales of energy-saving products. Large green energy firms, such as LTC (2301), EVERLIGHT (2393), and GSEO (3406), each have larger marginal effects of oil price on firm investment. Further, results show that when oil prices rise, green energy products increase in demand, indicating a substitution effect. As a result, higher oil prices will be accompanied by growing investment in the green energy industry. Because oil prices have risen in recent years, most green firms have aggressively and continuously engaged in firm investment to attain future profits.

Conclusion

With the severe change in global climate, increasing emission of greenhouse gases, and high oil prices, countries across the world collectively require the promotion of energy-conserving measures such as renewable energy to reduce carbon emissions and improve widespread quality of life. Thus, all countries have begun to focus on the development of the green energy industry. Taiwan is a global leader in the development of one technology that promotes a greener world: LED. The development of LED is a vital component of the green energy industry as products generally feature non-polluting, environmentally friendly, energy-saving designs. LED can be used in several types of lighting equipment, including (but not limited to) those used in automobiles, traffic lights, and televisions. Given its economic and environmental benefits, all countries favor green energy as an industry with potential for great market value.

To analyze the production cost structure and capital sources of firms in the green energy industry, this article used representative companies from Taiwan. We modified the investment model proposed by Semenov (2006) by adding crude oil price as a predictor variable to explore the mutual influence of oil energy price and firm investment. Our results revealed that when oil prices are high, green energy firms will promptly invest in both R&D and physical materials. We found that green energy firms increase their investments for companies with high sales and good potential for production.

Our analysis of the capital structure revealed that Taiwanese green energy firms primarily use external capital instead of internal capital as a means to finance their investments. This was indicated by the respective relationships between cash flow and the high sensitivity of bank loan rates on firm investment. Further, in the analysis related to the sample firm's heterogeneity, we found that all sampled companies continue to produce and invest capital in R&D when there is a rise in the price of oil. However, there was a non-significant or negative relationship between liquidity (represented by cash flow) and investment for a number of firms. This indicates that most Taiwanese LED companies tend to leverage external financing channels (e.g., bank loans) as a means to finance their investments. In this vein, the Taiwanese government's incentive policy of establishing low interest rates promotes investment in green energy firms.

New technologies must improve not only in terms of their innovation, but also in terms of cost effectiveness; final price is a crucial factor in the development of renewable energy. Entry into the green energy market requires basic R&D technology, with gradual expansion to higher levels of production. Initial high costs will gradually fall with the widespread technological process, increased production, and the gathering effect of the industry chain. With those falling costs, the development of green energy technologies will be much more universal[1]. Future initiation of green energy development is likely to include making a technological breakthrough, infusing crucial investments, expanding domestic demand for green energy products, encouraging overseas exports of green energy products, and making the LED industry more efficient and less costly. These steps will help to reduce energy costs and minimize carbon emissions, both of which serve to improve the health of the environment.

This paper has used pooled estimation regression to explore current investment trends in Taiwan's green energy industry and the relevant key factors affecting corporate investment. The results presented here can be of informational use for researchers and practitioners engaged in the development of the green technology industry, and can serve as an important reference for governmental decision-making.

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[1] Reduction in production costs and price will be critical for the future development of the LED industry in Taiwan.

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Appendix

Table A1. Random effects of green energy firms

Company name			
	Company code	Name	Random effects
1	2301	LTC	0.725
2	2340	OPTOTECH	-0.455
3	2393	EVERLIGHT	0.419
4	2426	TYNTEK	-0.457
5	2486	ICHIUN	-0.132
6	2499	UNITY	0.046
7	3031	BRIGHT	-0.108
8	3066	TAIWANOASIS	-0.107
9	3310	CHIALIN	-0.204
10	3406	GSEO	1.635
11	3531	SHIANYIH	1.335
12	3653	JENTECH	-0.561
13	5483	SAS	-0.021
14	6164	LEDTECH	0.098
15	6224	PTTC	-0.562
16	6226	PARALIGHT	-0.159
17	6261	YTEC	-0.605
18	6271	THIEL	-0.056
19	6289	AOC	-0.582
20	8111	LIGITEK	-0.062
21	8121	ACME	-0.185

Source: This study.