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Firm Investment in Renewable Energy: An Empirical Evidence from the People's Republic of China

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Abstract— This study investigates the effects of firm characteristics on firms' decisions to invest in renewable energy. Using the unique dataset of annual firm-level data from around 300 firms from the People's Republic of China that invested in renewable energy projects in the People Republic of China during the period 2015-2020 from Bloomberg Terminal, Bloomberg New Energy Finance, and S&P Capital IQ pro, our results demonstrate which firm characteristics affect firm decisions to invest in renewable energy.

Keywords— renewable energy, People' Republic of China, leverage, firm age, green investment, green finance, GHG emission, air pollutant

I. Introduction

Reductions in emissions of carbon dioxide and other greenhouse gases (GHG) must be achieved in the coming decades to avoid catastrophic global temperature rises. Limiting global warming to within 1.5^{o} C will require rapid, far-reaching, and unprecedented changes in all sectors. GHG emissions in Asia and the Pacific now account for over 50% of the world's total.

Renewable energy technologies, considered one of the most effective ways to tackle climate change and global warming, have received increasing attention given their benefits of lower pollution and clean production. According to the 2021 global energy review of the International Energy Agency, renewable energy consumption expanded by 3% in 2020 due to a decrease in the demand for all other fuels. The key driver was attributed to a 7% expansion in renewable electricity generation. In 2021, electricity generation from renewable technologies is set to grow by more than 8% to reach 8300 TWh, which is the rapidest year-on-year expansion since the 1970s.

The energy sector in developing Asia heavily depends on fossil fuels, and energy prices are often subsidized or government controlled. Therefore, huge investments are needed to promote clean and renewable energy. However, public expenditure in the region is tightly constrained, and this has been especially compounded by high COVID-19-related expenditures. Energy demand will continue to accelerate due to increased economic growth, population growth, and energy access, with developing Asia and the Pacific expected to account for two-thirds of global energy demand growth by 2040, according to the International Energy Agency (2019).

The People's Republic of China (referred to as PRC hereinafter), considered one of the world's largest energy consumers, has demonstrated rapid growth in renewable energy investments. According to 2022 energy transition investment trends of Bloomberg New Energy Finance, the PRC's investment in energy transition increased by 60% from 2020 and reached $266 billion in 2021, making them the leading country. Furthermore, renewable energy investment accounts for the largest proportion of nearly $130 billion, again cementing its top position.

Given the rapid growth in the number of new installed renewable energy projects and the diversification of sectors financing renewable technologies in the PRC, this paper contributes to the literature studying investment decisions in renewable energy in developing economies using the case of the PRC.

II. Material and Methods

We use the unique dataset of annual firm-level data from nearly 300 firms from the PRC which invested in renewable energy projects in the PRC during the period 2015-2020 from Bloomberg Terminal, Bloomberg New Energy Finance, and S&P Capital IQ pro database.

Previous studies refer to renewable energy investment (REI) as the capital that renewable energy firms use to purchase different production and operation assets (see, e.g., [2] and [9]). In this study, we calculate this variable as the sum of renewable projects' values that enterprises invest in each year. Our approach allows us to investigate the effects of firm characteristics on firm decisions to finance renewable projects, not only for renewable energy firms but also for other firms working in different industries. The unit is USD. Our dependent variable (REI/K) is then computed as the ratio of renewable energy investment to working capital.

Firm leverage (lev). We employ the commonly used asset-liability ratio as a proxy to measure the financial leverage of the firm. A low asset-liability ratio leaves enterprises with sufficient working capital to finance renewable energy projects.

Table 1. Estimated results for baseline models

Dep.var: REI/K	Pooling	Pooling	Random effect	Random effect	Fixed effect	Fixed effect
rev	-0.059	-0.060	0.057	0.059	0.289	0.371
ln asset	-0.111***	-0.109***	-0.152***	-0.148***	-0.546***	-0.528***
ROA	-0.804	-0.853	-2.488***	-2.615***	-4.854***	-5.156***
lev	0.721**	0.706**	0.968***	0.938***	1.202***	1.223***
firm age	-0.002	-0.001	-0.002	-0.002	0.033**	0.124**
energy cost		0.001		0.001		0.009*
constant	1.601***	1.511***	2.079***	1.916***	7.306***	4.124**
LM test	$Chi^2(1)$=12.18***	$Chi^2(1)$=12.54***				
Hausman test					Chi2(5) = 82.22***	Chi2(6) = 87.86***
Observations	677	677	677	677	677	677
R square	0.167	0.168	0.2383	0.2325	0.2780	0.2848

Firm sales (rev). This article uses the total revenue of the firm as a proxy variable for the business sale variable. The unit is measured in USD. We then compute the ratio of revenue to the total assets.

Return on asset or profitability of firm (ROA). The ratio of net income to total assets is adopted as a measure for firm profitability.

Firm age (firmage). This article employs firm age as a proxy for enterprise growth. The usage of establishing time to measure firm growth has been used in literature (see, e.g., [2] and [6]).

Firm scale (ln asset). The total assets of the firm are used as a proxy for the firm scale in our regression model. The unit is USD. In this study, we take the logarithm value of this variable.

Energy cost (energycost). In this study, we employ the weighted average of the levelized cost of energy (referred to as LCOE hereinafter) of various renewable energies as a proxy for energy cost. The unit is USD/MWh.

A. *Baseline Econometric Models*

We estimate the following reduced form investment equation to investigate the effect of financial variables on firm's renewable energy investment:

$$REI_{i,t}/K_{i,t} = \alpha + \beta_1\, lev_{i,t} + \beta_2\, rev_{i,t} + \beta_3\, ROA_{i,t} + \beta_4\, firmage_{i,t} + \beta_5\, ln\ asset_{i,t} + \beta_6\, energycost_t + \mu_i + e_{i,t}\,, \quad (1)$$

where $REI_{i,t}$ is the total amount of renewable projects' values invested by firm i in year t; $K_{i,t}$ is the working capital of firm i; α is a constant; $lev_{i,t}$ is the financial leverage of firm i; $rev_{i,t}$ denotes the ratio of the total revenue to the total asset; $ROA_{i,t}$ computed as the net income divided by the total asset indicates the return of asset; $firmage_{i,t}$ demonstrates the age of firm i at year t; $ln\ asset_{i,t}$ is the log of total asset which captures the size of the firm; $energycost_t$ measures the cost of renewable energy in the PRC in year t; μ_i captures the individual effect of firm i; β_1, β_2, β_3, β_4, β_5, and β_6 are the coefficients; and finally $e_{i,t}$ denotes the error term.

B. *Models with Interaction Terms*

Since financial leverage plays an important role in renewable energy investment, we consider the heterogenous effect of financial leverage regarding firm size. To take the firm scale into consideration, we present the following econometric model:

$$REI_{i,t}/K_{i,t} = \alpha + \beta_1\, lev_{i,t} + \beta_2\, rev_{i,t} + \beta_3\, ROA_{i,t} + \beta_4\, firmage_{i,t} + \beta_5\, ln\ asset_{i,t} + \beta_6\, energycost_t + \beta_7\, lev_{i,t} \times D_{i,t} + \mu_i + e_{i,t}\,, \quad (2)$$

where $D_{i,t}$ denotes a dummy variable, $lev_{i,t}$ x $D_{i,t}$ is an interaction term. If the logarithm of the total asset of firm is smaller than the mean, $D_{i,t}$ takes the value of zero. The remaining of this economic model is in line with the baseline model. It is also worth noting that the slope of the financial leverage changes once we incorporate the interaction term in our model. To be more specific, when the firm size is smaller than the mean, the effect of leverage is captured by β_1. Otherwise, the effect of financial leverage is captured by $\beta_1 + \beta_7$.

Using the dummy variable might lead to bias estimates. Therefore, we also introduce an interaction term of financial leverage and firm size as follows:

$$REI_{i,t}/K_{i,t} = \alpha + \beta_1\, lev_{i,t} + \beta_2\, rev_{i,t} + \beta_3\, ROA_{i,t} + \beta_4\, firmage_{i,t} + \beta_5\, ln\ asset_{i,t} + \beta_6\, energycost_t + \beta_7\, lev_{i,t} \times ln\ asset_{i,t} + \mu_i + e_{i,t}\,. \quad (3)$$

In this model, the effect of financial leverage is characterized as a linear function of the firm size $\beta_1 + \beta_7\, ln\ asset_{i,t}$.

C. *Semiparametric Fixed Effect Models*

The semiparametric fixed effect model is considered to perform better than the usual fixed effect model (see, e.g., [7]). Therefore, to check the robustness of our results, we further examine the nonlinear effect of leverage and firm age. Accordingly, we consider the following panel data semiparametric fixed effect model of [3].

Nonlinear effect of leverage:

$$REI_{i,t}/K_{i,t} = \alpha + f(lev_{i,t}) + \beta_1\, rev_{i,t} + \beta_2\, ROA_{i,t} + \beta_3\, firmage_{i,t} + \beta_4\, ln\ asset_{i,t} + \beta_5\, energycost_t + \mu_i + e_{i,t}\,. \quad (4)$$

Nonlinear effect of firm age:

$$REI_{i,t}/K_{i,t} = \alpha + \beta_1\, lev_{i,t} + \beta_2\, rev_{i,t} + \beta_3\, ROA_{i,t} + f(firmage_{i,t}) + \beta_4\, ln\ asset_{i,t} + \beta_5\, energycost_t + \mu_i + e_{i,t}\,. \quad (5)$$

D. *Models with ESG Variables*

We investigate the effects of Environmental, Social, and Governance (referred to as ESG hereinafter) variables on the renewable energy investment to working capital ratio. Specifically, we employ the following two types of ESG variables: (1) the external cost of air pollutants as a percent of the company's revenue and (2) the external cost of Greenhouse Gases (referred to as GHG hereinafter) emissions as a percent of the company's revenue. These variables are obtained from the S&P Capital IQ Pro.

Fixed effect model with the external cost of air pollutants:

Table 2. Estimated results for models with interaction terms

Dep.var: REI/K	Fixed effect	Fixed effect	Fixed effect	Fixed effect
rev	0.282	0.316	0.365	0.386
ln asset	-0.562***	-0.322***	-0.547***	-0.3212***
ROA	-4.838***	-4.746***	-5.145***	-5.020***
lev	1.172***	6.089***	1.188***	5.764***
firm age	0.034**	0.026*	0.128**	0.107**
energy cost			0.009**	0.008*
lev x D	0.157		0.184	
lev x ln asset		-0.333**		-0.309**
constant	7.517***	4.222**	4.287**	1.636
Observations	677	677	677	677
R square	0.279	0.289	0.286	0.2942

Table 3. Estimated results for nonlinear fixed effect models of leverage

Dep.var: REI/K	(1)	(2)	(3)	(4)	(5)	(6)
rev	0.995***	0.997***	0.980***	1.121***	1.122***	1.102***
ln asset	-0.537***	-0.546***	-0.359*	-0.500***	-0.508***	-0.356*
ROA	-5.393***	-5.405***	-5.162***	-5.804***	-5.813***	-5.591***
lev						
firm age	0.003	0.003	-0.001	0.152*	0.152*	0.141*
energy cost				0.014**	0.014**	0.013**
lev x D		0.090			0.076	
lev*ln asset			-0.258			-0.212
constant						
Observations	677	677	677	677	677	677
R square	0.3855	0.386	0.389	0.394	0.394	0.396

$$REI_{i,t}/K_{i,t} = \alpha + \beta_1\, lev_{i,t} + \beta_2\, rev_{i,t} + \beta_3\, ROA_{i,t} + \beta_4\, firmage_{i,t} + \beta_5\, ln\ asset_{i,t} + \beta_6\, energycost_t + \beta_7\, aircost_{i,t} + \mu_i + e_{i,t}\ , \quad (6)$$

where $aircost_{i,t}$ denotes the external cost of air pollutants as a percent of the company's revenue and β_7 is the associated parameter. It is also worth noting that in this study, we employ the three alternative ways to measure this cost: (1) the external cost of direct air pollutants; (2) the external cost of indirect air pollutants; and (3) the external cost of direct and indirect air pollutants.

Fixed effect model with the external cost of GHG emissions:

$$REI_{i,t}/K_{i,t} = \alpha + \beta_1\, lev_{i,t} + \beta_2\, rev_{i,t} + \beta_3\, ROA_{i,t} + \beta_4\, firmage_{i,t} + \beta_5\, ln\ asset_{i,t} + \beta_6\, energycost_t + \beta_7\, ghgcost_{i,t} + \mu_i + e_{i,t}\ , \quad (7)$$

where $ghgcost_{i,t}$ denotes the external cost of GHG emissions as a percent of the company's revenue and β_7 is the associated parameter. It is also worth noting that in this study, we employ the three alternative ways to measure this cost: (1) the external cost of direct GHG emissions; (2) the external cost of indirect GHG emissions; and (3) the external cost of direct and indirect GHG emissions.

E. Models Incorporating Covid-19 Stringency Index

The restrictions applied by the government of the PRC in order to combat the Covid-19 pandemic could have negative effects on the installation of renewable energy projects. To incorporate the impacts of these restrictions, we present the following econometric model:

$$REI_{i,t}/K_{i,t} = \alpha + \beta_1\, lev_{i,t} + \beta_2\, rev_{i,t} + \beta_3\, ROA_{i,t} + \beta_4\, firmage_{i,t} + \beta_5\, ln\ asset_{i,t} + \beta_6\, energycost_t + \beta_7\, aircost_{i,t} + \beta_8\, stringency_{p,t} + \mu_i + e_{i,t}\ , \quad (8)$$

where $stringency_{p,t}$ denotes the Covid-19 stringency index at province p and β_8 is the associated parameter. This index is obtained from The Oxford Coronavirus Government Responds Tracker (OxCGRT).

To check robustness of our results, we estimate the following model:

$$REI_{i,t}/K_{i,t} = \alpha + \beta_1\, lev_{i,t} + \beta_2\, rev_{i,t} + \beta_3\, ROA_{i,t} + \beta_4\, firmage_{i,t} + \beta_5\, ln\ asset_{i,t} + \beta_6\, energycost_t + \beta_7\, aircost_{i,t} + \beta_8\, covid_{p,t} + \mu_i + e_{i,t}\ , (9)$$

where $covid_{p,t}$ is a dummy variable which takes the value of 1 when t=2020 and 0 otherwise.

III. Empirical Results

A. Estimated Results for Baseline Models

The estimated results for the baseline econometric models are reported in Table 1. The main findings of our study can be summarized as follows: First, we find that firm size, characterized by the logarithm of total assets, has a negative impact on firm renewable investment ratio, and the impact is statistically significant at 1% level. This is surprising at first; however, it might be possible since big firms can invest a huge amount of money in renewable energy investment despite a smaller investment-capital ratio. Interestingly, we find that leverage plays a crucial role in firm investment in renewable energy. More specifically, a high liability-asset ratio leads to an increase in corporate investment, and the effect is statistically significant at 5% level. The point estimates vary from 0.721 to 1.223, indicating that the renewable energy investment to working capital ratio increases by about 0.0721 to 0.1223 when the financial leverage of the firm increases by 0.1. The potential explanation is that leverage can equip enterprises with more financial budget in order to finance renewable projects. Accordingly, leverage can be indicated the ability of firms to conduct business activities. These findings are indeed in line with previous literature (see e.g., [4]). Third, we indicate that firm age has positive effects on renewable investment to capital ratio once the individual fixed effects are taken into consideration. The regression coefficients on firm age for the two fixed effect models are equal to 0.033 and 0.124 and are statistically significant at the 5% level. This suggests that firms with one more year of experience tend to increase the renewable investment to capital ratio by about 0.033 to 0.124. Lastly, we obtain surprising results that the energy cost also has positive impacts on firm renewable energy investment. One reasonable explanation is that when energy costs fall, less investments in USD are needed to purchase the same amount of GW of power plants.

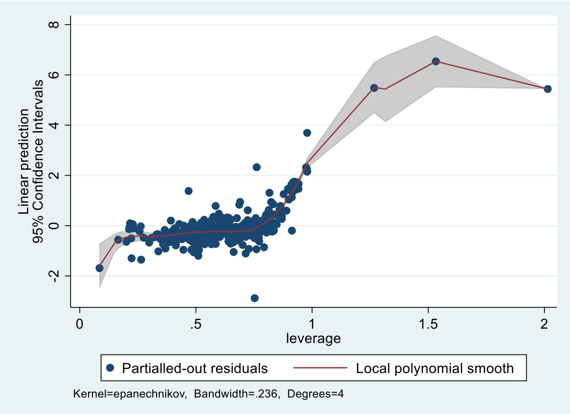

Figure 1. Non-linear effects of leverage on renewable energy investment

Notes: This figure is associated with the estimated results of column (2) in Table 3.

Furthermore, we perform two commonly used statistical tests (Breusch and Pagan Lagrangian Multipliers (LM) test and Hausman specification test) to demonstrate which empirical methodology among pooling, random effect, and fixed effect regression is most favorable. First, we consider the LM test of the random effect model. The chi-square statistic is 12.18 when we do not include energy costs in both pooling and random effect models. Thus, we can reject the null hypothesis of no individual effect at the 1% significance level. In other words, the individual effect is not zero and we should take it into consideration. Second, we perform the Hausman specification test to compare the random effect model with the fixed effect model. The results of Hausman test show that regardless of whether energy cost is introduced or not, the fixed effect model is most suitable in investing the impacts of firm characteristics on firm decisions to invest in renewable energy technologies.

B. *Estimated Results for Models with Interaction Terms*

The estimated results for models with interaction terms are reported in Table 2. The findings can be summarized as follows. First, we consider the model with interaction terms using the dummy variable. The regression coefficients on the interaction term $lev_{i,t}$ x $D_{i,t}$ range from 0.157 to 0.184 depending on whether the energy cost is introduced or not. These results indicate that the finance leverage has a stronger positive impact on renewable investment to capital ratio for enterprises with large firm sizes than for enterprises with small firm sizes. However, the point estimates for this parameter are not statistically significant. It is also worth noting that the point estimates for the two variables *lev* and *lev x D* in this model can be compared with the results from the baseline economic model.

Next, let's consider the model with interaction terms $lev_{i,t}$ x $ln\ asset_{i,t}$. The estimated results for the variables $lev_{i,t}$ and $lev_{i,t}$ x $ln\ asset_{i,t}$ are both statistically significant at 5% level regardless of whether energy cost is incorporated in the model or not. Note also that the impact of leverage on renewable investment to working capital ratio is now characterized by 6.089 – 0.333*ln asset* for the model without energy cost. The descriptive statistics show that the mean of the firm size is 15.796. Thus, on average, the impact of financial leverage on investment to capital ratio is positive at the value of 0.829.

C. *Results for Semiparametric Fixed Effect Models*

We consider the nonlinear effect of leverage on renewable energy investment. The estimated results are reported in Table 3. Overall, our main findings remain virtually the same and the semiparametric fixed model can fit the model better than the linear fixed effect counterpart. Interestingly, we find that the revenue to asset ratio has a positive impact on the renewable investment to capital ratio and the impact is highly significant at 1% level for all six models considered. Analogue to previous results, we also find positive effects of leverage on renewable

Table 4. Estimated results for fixed effect models with air pollutant costs

Dep.var: REI/K	**Direct**	**Direct**	**Indirect**	**Indirect**	**Direct&Indirect**	**Direct&Indirect**
rev	-0.716***	-0.705***	-0.721***	-0.711***	-0.716***	-0.706***
ln asset	-0.254***	-0.253***	-0.254***	-0.253***	-0.254***	-0.253***
ROA	-0.612	-0.629	-0.597	-0.614	-0.612	-0.630
lev	0.358**	0.363**	0.349**	0.354**	0.358**	0.363**
firm age	0.010	0.017	0.011	0.017	0.010	0.017
energy cost		0.001		0.001		0.001
aircost	0.001	0.001				
aircost			0.122	0.126		
aircost					0.001	0.001
Constant	4.105***	3.869***	4.059***	3.820***	4.104***	3.868***
Observations	349	349	349	349	349	349
R square	0.168	0.168	0.169	0.169	0.168	0.168

investment to capital ratio, and the impacts are statistically significant at 5% level since the 95% confidence band excludes zero most of the time (see Figure 1). It is also worth noting that R square substantially increases when the nonlinear effect of financial leverage is taken into consideration. Due to space constraint, we do not report the nonlinear effect of firm age on the renewable energy investment to working capital ratio. Overall, our main findings remained virtually the same. Analogue to previous results, we also find positive effects of firm age on renewable investment to capital ratio, and the impacts are statistically significant at 5% level since the 95% confidence band excludes zero most of the time.

D. Results for Models with ESG Variables

We now investigate the impacts of the external cost of air pollutants on renewable energy investment. The estimated results are displayed in Table 4. We find positive effects of the external cost of air pollutants on the renewable energy investment to working capital ratio regardless of whether they are direct or indirect air pollutants. In other words, firms with higher external costs of air pollutants tend to increase their investments in renewable energy. However, the effects are not significant. Due to the space constraint, we do not report the effect of the external cost of GHG emissions on renewable energy investment. Interestingly, we obtain similar findings that the external cost of GHG emissions has a positive impact on the renewable energy investment to working capital ratio. This demonstrates that firms with higher external costs of GHG emissions tend to increase their renewable energy investments.

E. Results for Models with Covid-19 Stringency Index

Table 5. Estimated results for models with Covid-19 variables

Dep.var: REI/K	**(1)**	**(2)**	**(3)**	**(4)**
rev	-0.710***	-0.710***	-0.707***	-0.707***
ln asset	-0.237***	-0.231***	-0.239***	-0.233***
ROA	-0.699	-0.694	-0.692	-0.687
lev	0.348**	0.350**	0.353**	0.354**
firm age	0.080*	0.078*	0.076*	0.075*
energy cost	0.006	0.006	0.005	0.005
aircost	0.001		0.001	
ghgcost		0.001		0.001
stringency	-0.002*	-0.002*		
covid			-0.089*	-0.086*
constant	1.594	1.531	1.724	1.660
Observations	349	349	349	349
R square	0.183	0.185	0.182	0.183

We first examine the effects of the Covid-19 stringency index on renewable energy investment to working capital ratio. The estimated results are reported in Table 5. Interestingly, we find negative impacts of the Covid-19 stringency index on the renewable energy investment to working capital ratio regardless of whether we employ the external cost of air pollutants or the external cost of GHG emissions as a proxy for the ESG variable, and the impacts are statistically significant. These findings confirm our hypothesis that the restrictions applied by the government to combat the Covid-19 pandemic negatively affect the installation of renewable energy investment. Note also that because of space constraints, we present only the results for the direct costs of ESG variables. Similar findings are obtained when we employ the indirect costs or the direct and indirect costs of ESG variables.

Table 5 also displays the results for the impacts of the Covid dummy on renewable energy investment. Similarly, we obtain the adverse impacts of the Covid-19 pandemic on the renewable energy investment to working capital ratio. Also, the effects are statistically significant.

IV. Conclusions

This study investigates which firm characteristics play important roles in firm decisions to finance renewable energy projects. To this end, we employ a unique dataset from nearly 300 firms in China that invested in renewable energy technologies during the period 2015-2020. Our main results can be summarized as follows. First, we find that both financial leverage and firm age have positive and highly significant impacts on the renewable energy investment to working capital ratio. Second, the firm size and return on assets negatively affect this investment to working capital ratio. Third, the ratio of revenue to total assets has a positive impact on the renewable energy investment to working capital ratio once we control for the nonlinear effect of either financial leverage or firm age. Fourth, we demonstrate that the external costs of both air pollutants and GHG emissions positively affect the renewable energy investment to working capital ratio. Fifth, we find that the restrictions implemented by the government of the PRC to combat the corona pandemic have negative impacts on the renewable energy investment to working capital ratio. Finally, our results are robust to various model specifications.

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