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Determinants of the Development of Green Buildings in China's Provinces:

An Empirical Analysis

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***Abstract*—Green building is one of the important contents of green finance, and also a high-risk industry. Data from 2018 to examine empirically some factors that may affect the number of green buildings are used in this paper. These factors are fiscal expenditure, gross domestic product (GDP), the number of researchers, and the employment rate of recent college graduates at provincial level. The empirical conclusion is that the number of green buildings in China's provinces is related to the fiscal expenditure, gross domestic product (GDP) and the number of researchers, but not to the employment rate of recent college graduates. In addition, some suggestions are also provided for reducing financial risks in relation to the green building development of the real estate sector in China.**

Keywords: green building, regression, China's provinces

I. Introduction

The World Bank has predicted that by 2030, the world will achieve the goal of energy conservation and emission reduction, and 70% of the emission reduction potential lies in energy conservation of buildings. The "China Building Energy Consumption Research Report (2017)" released by the China Building Energy Conservation Association also shows that in 2015 China's total building energy consumption reached 857 million tons of standard coal, accounting for 20% of the country's total energy consumption. It can be seen that promoting building energy conservation and vigorously developing green buildings have become an important part of promoting China's green and low-carbon economy.

The "13th Five-Year Plan" for the construction of housing cities issued by China Bureau of Housing and Urban Construction in 2016 stipulates that by 2020, the energy efficiency level of new urban buildings will be increased by 20% compared with 2015, the proportion of green building area will exceed 50%, and the proportion of green building materials applications more than 40%. Under the guidance of national policies, China's provinces have successively introduced their own unique overall development goals, and fully implemented the green building standards. Many ministries and commissions have also actively promoted and encouraged the use of green financial instruments to conduct pilot projects for financing green real estate projects. For example, in 2016, the "Green Bond Issuance Guidelines" issued by the China Development and Reform Commission explicitly listed green urbanization projects (including green building development, energy saving reconstruction of existing buildings, sponge city construction, smart city construction, and green ecological urban areas) as key support project. With the implementation of the green building policy and the sustainable development image of some leading housing companies, especially Hong Kong-owned housing companies (such as Taikoo, Sun Hung Kai, New World, etc.), green buildings have begun to attract more attention from their peers.

At the same time, in recent years, many countries' sovereign funds or pension funds, insurance companies, etc. have started to provide ESG investment regulations in their internal investment guidelines. For example, when investing in a real estate portfolio of foreign exchange funds, green certification of properties will be one of the key considerations. Therefore, under the continuous drive of a series of policies and investment needs, there is a huge increase in the development of green buildings. In the long run, it is believed that the market will usher in more green and high-quality assets and promote the entry of China's Grade-A office buildings and bulk trading markets.

II. Empirical research

A. Variable selection and data source

The number of green buildings approved in 2018 by China's 23 provinces, 4 municipalities directly under the central government and 3 autonomous regions (excluding Taiwan Province and Tibet and Ningxia Autonomous Regions without green building projects) is used as an explanatory variable, while the GDP of China's provinces, fiscal revenue and per capital disposable revenue as the economic environmental impact factors represent two explanatory variables, as well as the proportion of research and development personnel in China's provinces, the proportion of college graduates as the social environmental impact factors represent the other two variables. We explore the relationship between the explanatory variables and the number of green buildings. We assume that GDP, revenue, college graduation rate and the proportion of researchers in the province's population are positively correlated with the number of green buildings.

TABLE I. VARIABLE SELECTION AND FINISHING TABLE

Variable selection	Variable symbol	Data year
Number of green buildings	Y	2018
Gross Domestic Products	GDP	2018
Provincial fiscal revenue	REVENUE	2018
Proportion of R&D personnel by province	RESEARCH	2018
Proportion of college graduates by province	COLLEGE	2018

a. Source: The China Statistical Yearbook 2019

The data for the explanatory variables are derived from the China Statistical Yearbook 2019, which uses the ratio of the number of research and development personnel in China's provinces and the number of young and middle-aged people in China's provinces (RESEARCH) as an indicator of the ratio of research and development personnel in China's provinces; COLLEGE is a measure of the ratio of university graduates in China's provinces, and the number of green buildings refers to a measure of the number of certified green building projects (Y) in all provinces of China, and is based on data from 23 provinces in China that contain green building projects. The data is sourced from the official websites of the Housing and Urban-Rural Construction Bureau of the four municipalities and three autonomous regions. The collated data is evaluated in a scale unit, and 174 observations are finally retained for empirical analysis. "Table I" summarizes the variable description and abbreviations.

The OLS regression is used in this paper and the Eviews software is the software used for regression analysis, and the counting model Poisson regression model and the multi-linear regression model are selected for robustness check, and the results show that the multi-linear regression model better simulates the actual regression distribution of the data. The general model of linear multiple regression analysis is specified as follows:

$$Y = \beta_0 + \beta_1 GDP + \beta_2 INCOME + \beta_3 RESEARCH + \beta_4 COLLEGE + \hat{u} \quad (1)$$

Where Y is the dependent variable (i.e., the number of green buildings), β0 is the constant term, β1~β4 are the partial regression coefficient of those independent variables, and u is the random error.

B. Statistical description

Data from 23 provinces in China that contain green building projects are used and a summary of their statistical properties is shown below in "Fig. 1". "Fig. 1" shows that the number of the green houses ranges from 50 to 100 houses in most provinces. Only in four provinces, the number of green buildings ranges from 250 to 300350 to 400400 to 450 and from 750 to 800.

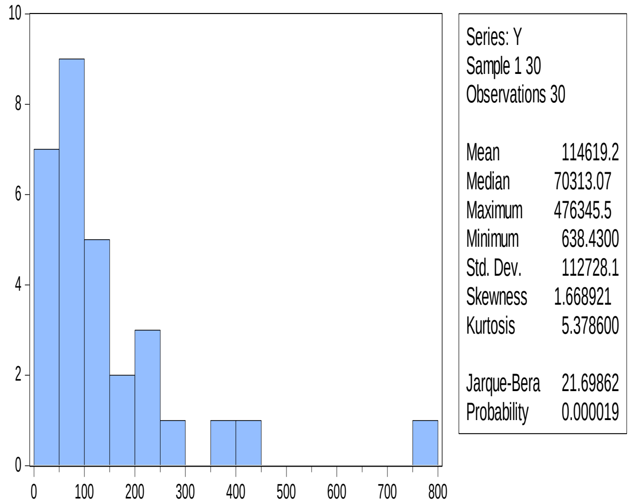

Fig. 1. Descriptive statistics on Y.

a. Source by: Official data of Housing and Urban Construction Bureau of China's provinces

b. The abscissa indicates the number of green buildings each province has passed the audit and the ordinate represents the number of provinces in each section range of green buildings.

The average of the number of green buildings is 114619.2 ten thousand houses but its minimum is only 638.43 ten thousand houses, which illustrates that there are great differences in different territories. There are several reasons accounting for the difference. The eastern coastal region is more likely to absorb and use more "green building" projects than the western and inner regions.

We calculated the correlation matrix of the four independent variables and "Table II" shows the matrix.

It appears that the correlation between COLLEGE and Provincial fiscal REVENUE is the largest, i.e., 0.8721 while the correlation between the GDP and the COLLEGE is the least, 0.6592. The correlation matrix shows that the correlation among all the variables is high and may result in multicollinearity.

We will come back to this issue later after the regression analysis.

TABLE II. THE CORRELATION INDEX MATRIX BETWEEN THE FOUR INDEPENDENT VARIABLES

	GDP	COLLEGE	RESEARCH	REVENUE
GDP	1	0.6592	0.6421	0.7164
COLLEGE	-----	1	0.8151	0.8721
RESEARCH	-----	X	1	0.7597
REVENUE	-----	----	----	1

a. Avoid repeating the same information in this matrix.so delete those correlations from the upper diagonal of the matrix and show only those below the diagonal.

C. *Regression analysis*

To control heterogeneity, we use the robust standard error. As noted in the "Table III", we draw the following three conclusions.

First, the coefficient of COLLEGE and RESEARCH are negative which shows that the Number of green buildings will decrease with the increase of COLLEGE and RESEARCH. Not only the standard error of COLLEGE is much more than 5%, but also the probability of research and university is much more than 5% as well .In this way, we infer that there is multicollinearity. The other coefficients of independent variables are all positive, which fit with the hypotheses we noted.

Second, the Z-value of RESEARCH is larger than 14, which illustrates that RESEARCH is statistically significant at 5% significant level, holding other factors fixed. That is to say, the Number of green buildings is predicted to increase when the R&D personnel increases.

The |t| of other factors except research are all smaller 2, so we can say that the other factors are not statistically significant respectively at 5% significant level, holding other factors fixed.

Third, R^2 is 54.82%, which is the percentage of sample variances in Number of green buildings is explained by independent variables. That illustrates that the fitted model is good to explain the casual relationship or the model includes the main factors influenced Number of green buildings.

Comparing the ordinary standard error with the robust standard error, we can see that there is great differentiation, which illustrates that there may be heteroskedasticity.

$$u^2 = \delta_0 + \delta_1 fixaset + \delta_2 empl + v \qquad (2)$$

$$H_0 : \delta_1 = \delta_2 = 0$$

TABLE III. ROBUST STANDARD ERRORS OF FOUR VARIABLES

Dependent Variable: Y Method: Robust Least Squares Sample: 130 Included observations: 30 Method: M-estimation M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)				
Huber Type I Standard Errors & Covariance				
Variable	Coefficient	Std. Error	Z-Statistic	Prob.
GDP	0.2631	0.2169	1.2133	0.2250
REVENUE	0.3538	0.0249	14.2740	0.0000
RESEARCH	-0.0081	0.0319	-0.2543	0.7992
COLLEGE	-0.0646	0.4891	-0.1321	0.8949
Robust Statistics				
R-squared	0.5482	Adjusted R-squared		0.4980
Rw-squared	0.9670	Adjust Rw-squared		0.9670
Akaike info criterion	52.3580	Schwarz criterion		60.6928
Deviance	2.48E+10	Scale		22985.17
Rn-squared statistic	1441.316	Prob (Rn-squared stat.)		0.0000

a. The results used in the table are obtained by using the rule of retaining the last four digits of the decimal point.

D. *The process of amending*

TABLE IV. THE REGRESSION Y ON X RESPECTIVELY

variable	College	Research	Revenue	GDP
Coefficient	1.98	0.30	0.32	12.55
t-value	8.64	12.47	6.92	4.01
R2	0.7200	0.8413	0.6230	0.3562
$\bar{R}^2$	0.7103	0.8359	0.6100	0.3340

After having a Robust Standard Errors of four variables, we can have a process of amending the regression y on x respectively. From the "Table IV", we can not only see that R-squared of Research is the largest and t-value is also significant, but also the R-square of the model involving Research and College is 0.8413. Namely the biggest and the t-value of these variables are statistically significant. The R-squared becomes significantly larger too. However, the correlation between COLLEGE and RESEARCH is also large. Maybe they have a multicollinearity problem if they are included at the same time in a regression.

E. *The regression result after eliminating multicollinearity*

TABLE V. MULTICOLLINEARITY ESTIMATES

Dependent Variable: Y Method: Least Squares Sample: 130 Included observations: 30				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2487.177	13018.90	-0.191044	0.8499
RESEARCH	0.229040	0.039813	5.752918	0.0000
COLLEGE	0.700889	0.272415	2.572872	0.0157
R-squared	0.871670	Mean dependent var		114619.2
Adjusted R-squared	0.862503	S.D. dependent var		112728.1
S.E. of regression	41800.21	Akaike info criterion		24.21096
Sum squared resid	4.89E+10	Schwarz criterion		24.34973
Log likelihood	-372.2698	Hannan-Quinn criter.		24.25619
F-statistic	95.09351	Durbin-Watson stat		1.912301
Prob(F-statistic)	0.000000			

$\hat{y} = -2487.18 + 0.23research + 0.70college$

(13018.90) (0.040) (0.272)

$N = 30 \quad R^2 = 0.8717 \quad \overline{R^2} = 0.8625$

As noted, In order to test the problem of multicollinearity. I made multicollinearity estimates of the regression results. The data in "Table V" indicate that the coefficient of Research is 0.23, which means that Number of green buildings will increase 2300 houses, and on average when research increase by one thousand houses. The coefficient of Research is 0.70, which means that Number of green buildings will increase 7000 on average when the number of college graduates increase by one. From the regression result, we can see that t-value>2 of Research, which means Research is statistically significant at 5% significance level, holding College fixed. Similarly, t-value>2 of College, which means College is statistically significant at 5% significance level, holding Research constant. R-squared is 0.8717, which illustrates the model is established rationally approximately.

F. BP test and white test

At last, we deal with heteroscedasticity as different provinces exhibit different statistical characteristics. In addition, BP test and White test all illustrate that there is heteroskedasticity. The test result shows that the p-value of F-statistic and Obs*R-squared are all smaller than 0.05, so we reject the null hypothesis, which illustrates that there is still heteroscedasticity even after the standard Weighted Least Squares (WLS) method is used. As such, we further adjust the weight by ordering weight by uhat^2 and the result is shown in "Table VI".

TABLE VI. HETEROSKEDASTICITY TEST

F-statistic	0.551608	Prob. F(1,29)		0.4636
Obs*R-squared	0.578644	Prob. Chi-Square(1)		0.4468
Scaled explained SS	0.421505	Prob. Chi-Square(1)		0.5162
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.122302	0.029578	4.135197	0.0003
WGT^2	-0.000127	0.000172	-0.742703	0.4636
R-squared	0.018666	Mean dependent var		0.118366
Adjusted R-squared	-0.015173	S.D. dependent var		0.160791
S.E. of regression	0.162007	Akaike info criterion		-0.740017
Sum squared resid	0.761139	Schwarz criterion		-0.647502
Log likelihood	13.47026	Hannan-Quinn criter		-0.709859
F-statistic	0.551608	Durbin-Watson stat		2.494968
Prob(F-statistic)	0.463635			

$\hat{y} = -6914.44 + 0.24research + 0.79college$

$(244.98) \quad (.0006) \quad (.003)$

$n = 30 \quad R^2 = 0.9998 \quad \overline{R^2} = 0.9997$

III. CONCLUSIONS AND SUGGESTIONS

A. Conclusions

From the empirical results, it can be seen that the five factors have a more significant impact on green building construction, which confirms that: first, other things being equal, the impact of urban GDP on green construction is significant, and its contribution to the number of green buildings is relatively large among other significant variables, indicating that GDP has a greater impact on the development of green buildings; second, the proportion of people engaged in research and development in China's provinces in China also has a significant impact on green building construction.

B. Suggestions

Based on the development stages of the production cycle of the green building industry in China, and the important influence of local government administrative forces on the development of the green building industry, the future development of the industry mainly depends on government intervention and incentives. By strengthening macro-control capabilities, optimizing industrial layout, and improving industrial policies, we can further exert the positive impact of green buildings.

First, China's government should expand the proportion of green economy expenditure in fiscal revenue. The green building industry has just begun in China and requires government support in particular. Through the government's administrative measures, on the one hand, it is mandatory to require departmental office buildings to take the lead in using green construction technology; on the other hand, by strictly prohibiting the use of large-scale events and important landmark buildings in the city, it may lead to "high energy consumption" building forms. Together with related technical measures, it can have a good demonstration effect. It can show the application process of green building construction methods, as well as the benefits of green buildings in terms of rent, management cost and user experience. Not only can it promote the development of lag-behind areas in the industry, but it can also make the developed areas more competitive.

Second, improve the incentive system for green buildings and refine supporting policies. At present, the beneficiaries of financial subsidies for industrial development are the winners of green building projects, including developers and construction units, and the demand side (from a consumer's perspective) has yet to realize the benefited. How to make consumers choose relatively expensive green projects and expand the demand for green projects are the issues that the government as an industrial planner urgently needs to solve. Only by solving this problem can we guide the industry back to market demand and make the industrial distribution more reasonable.

Finally, it is also an important measure to vigorously introduce outstanding talents to work on the development of green buildings in the region.

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