 doi:10.20944/preprints201804.0274.v1

Article

Empirical Study on Annual Energy-Saving Performance of Energy Performance Contracting in China

Hongquan Ruan [1,2,*], Xin Gao [1,2] and Chaoxuan Mao [3]

[1] School of Economics and Management, Tongji University, Shanghai 200092, China; gaoxin@tongji.edu.cn
[2] Institute for Urban Risk Management, Tongji University, Shanghai 200072, China
[3] School of Statistics and Mathematics, Shanghai Lixin University of Accounting and Finance, Shanghai 201209, China; maocx@lixin.edu.cn
* Correspondence: 1110256@tongji.edu.cn; Tel.: +86-136-3632-5797

Abstract: Currently, the estimation of annual energy-saving performance of Energy Performance Contracting (EPC) projects is still at the operating level of each individual project, lacking a systematic summary. This paper studies the regression relationships of revamping cost in terms of annual energy-saving quantity and annual cost saving of EPC projects. The regression results show that there are statistically significant correlations in the above relationships in the nine subsectors investigated. These results contribute to EPC investment decisions and trust relationships between Energy Service Companies (ESCos) and energy-consuming units (ECUs). Then a multiple linear regression model of revamping cost is set up to analyze its influencing factors. The model indicates that the subsector the sample belongs to, financing, registered capital of the ESCo, and contract period have significant effects on revamping cost. Finally, advice for promoting investment in EPC projects is given.

Keywords: energy performance contracting; trust; annual energy saving quantity; annual cost saving; investment

---

1. Introduction

In 2016, energy consumption of China's GDP of 10,000 CNY fell by 5.0% [1], and it was 0.675 tce/10,000 CNY at 2010 constant prices (tce is the abbreviation of ton of standard coal equivalent). However, China's energy intensity still ranked ninth in the world that year [2]. In fact, the Law of the People's Republic of China on Conserving Energy was enacted as early as 1997, requiring improvements in the exploitation, processing, conversion, transmission, and supply of energy so as to gradually raise the efficiency of energy utilization and promote the development of the national economy in an energy-efficient manner [3]. In addition, from the Eleventh Five-Year Plan for Energy Development in 2007, all previous Five-Year Plans for Energy Development require national goals for energy efficiency (EE) promotion [4–6]. If the latest plan is achieved, by 2020 energy consumption per unit of GDP in 2020 will be 15% lower than in 2015 [6]. The decline in energy intensity needs to be achieved by optimizing the industrial structure and strengthening technological progress. Comparatively, the former is a medium- and long-term process, so greater efforts should be made to improve the efficiency of energy utilization. To achieve universal and potential EE, and also to adapt to the profound social change from a planned economy to a market economy so as to integrate EE projects into the market trading system, learning from the experience of developed countries, China has also gradually popularized the energy performance contracting (EPC) mechanism.

The market for EPC has huge potential in China [7,8]. In 2010, a milestone policy document on opinions of speeding up the implementation of energy performance contracting and promoting the development of the energy-saving service industry was issued [9]. It gives unprecedented policy support to the development of EPC from the aspects of finance, taxation, accounting standards, and financial support. Then, the General Technical Rules for Energy Performance Contracting, the first document on contract specifications for EPC projects, was put out the same year [10]. EPC has achieved rapid development since then: the total output value of the EPC industry increased from 83,629 million CNY in 2010 to 356,742 million CNY in 2016, with an average annual increase of 27.35%; annual energy-saving capacity of EPC projects increased from 10,648,500 tce in 2010 to 35,785,000 tce in 2016, with an annual increase of 22.39%. Despite the rapid development of EPC in China, EPC project investment in the public and private sectors is still facing bottlenecks considering the wide market space for EE promotion and the increasing policy support. The growth rate of EPC project investment has reduced in recent years, as shown in Figure 1. Apart from risk factors [11,12] and financing factors [13,14] that have been widely studied, industry environmental factors such as the market credit environment also hinder the rapid development of EPC. On-site fieldwork has found that a lack of trust in Energy Service Companies (ESCos) is the most critical factor affecting the development of EPC in China compared with other constraints, particularly trust in private ESCos characterized by light assets [15]. In China's current situation, the energy service industry is in its nascent period, the measurement and verification of energy savings are not standardized, and a lack of integrity is a very serious problem [16]. Research has also shown sustainable building energy efficiency retrofits in hotels under the EPC mechanism are largely based on trust, accurate measurement and verification, and team workers' technical skills [17]. At present, ESCos are generally small companies in China, which determines that their company strength and credibility are very common [18]. Under such conditions, energy-consuming units (ECUs) will question whether an ESCo's commitment is true [18]. Other research deems that with the transformation of the market from playing a basic role to playing a decisive role in allocating resources in the new era in China, the long-established government-leading EPC pattern will inhibit development of the EPC market, and there is a relationship between EPC, carbon trading, and energy conservation transactions [19]. The institutional measures and mode integration measures adopted for the above two aspects are the necessary guarantees to face the market integrity [19].

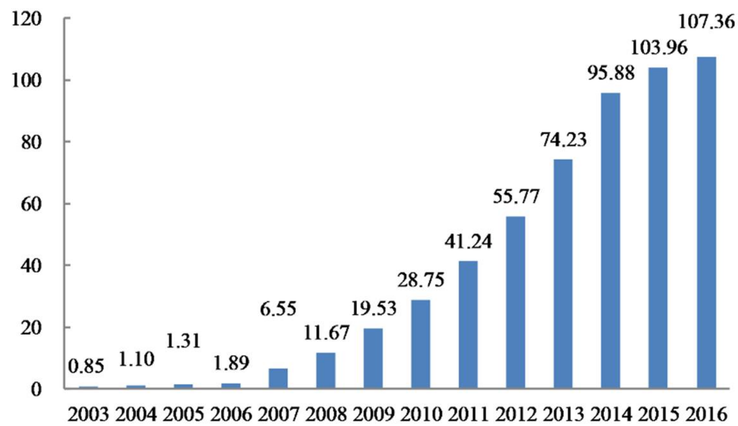

Figure 1. Change of Energy Performance Contract (EPC) investments in China.

Profit expectation is the power source of EPC. In the EPC mechanism, what an ESCo sells is no longer a specific product or technology, but a specific energy-saving service. Its purpose is to sell energy-saving quantity to ECUs [20]. One cannot easily estimate the energy-saving quantity of an EPC project, because it is an amount that does not occur in the project development phase. Under that condition, lack of trust may cause the ECU to suspect the energy-saving quantity promised by the ESCo, thus leaving potentially profitable projects without necessary funding. It might be interpreted that one of the main obstacles to developing EE projects is ECUs' lack of information on energy-saving quantity [21,22]. Energy performance estimation plays an essential role in the success of an EPC project for the owner and the ESCo, and several factors are involved that affect the real energy performance, including the EE investment, the energy-saving amount, and the energy market prices [23].

Before signing an EPC contract, an ESCo first performs EE diagnosis, and then the EE promotion scheme is determined based on the same kind of facilities at the advanced level of energy consumption. Only by these preparations can the ESCo estimate the investment amount corresponding to the scheme and the energy-saving performance (mainly annual energy-saving quantity and annual cost saving in this paper) generated by the project. Because different EPC projects take different risks and adopt different technologies, there are great differences in energy-saving performance. Projects with higher reference standards (usually with higher investment) generally have better energy-saving performance. The study of annual energy-saving quantity and annual cost saving of EPC projects in this paper contributes to EPC investment decisions and trust relationships between ESCos and ECUs. At present, the estimation of annual energy-saving quantity and annual cost saving of EPC projects stays at the operating level of each project, lacking a systematic summary. This paper tries to fill this void. It uses the ESCo Committee of China Energy Conservation Association's (EMCA's) statistical data on 205 EPC projects running from 2011 to 2016 to study the relationships of revamping cost in terms of annual energy-saving quantity and annual cost saving by the linear regression method. The regression results show that revamping the cost of EPC projects in most subsectors has the diseconomy of scale, and there are statistically significant correlations of the above relationships.

Further, the multiple linear regression method is used to analyze the influencing factors of EPC revamping cost. It finds that the sector the sample belongs to, financing, the registered capital of the ESCo, and the contract period have a significant impact on revamping cost, while the impacts of registered capital of the ECU, fiscal incentive, and tax preference on revamping cost are not obvious. Therefore, in order to promote EPC project investment, it is suggested that ESCos should innovate EE promotion technology and push forward transformation contents from single equipment, single project to energy system optimization and regional EE promotion, and should integrate upstream and downstream resources to enhance the competitive ability. Moreover, the government should innovate effective financing mechanisms and create an environment for both sides of EPC projects to sign long-term contracts.

2. Data of Annual Energy-Saving Performance

2.1. Data Sources

Supported by the Chinese government, the World Bank, and the Global Environment Facility, EMCA is an organization of energy-saving service industry associations committed to promoting the EPC mechanism and to fostering and leading the development of an energy-saving service industry in China. Since its establishment in 2003, EMCA, which co-operates with responsible government departments, has participated in various studies and composed the EPC Industry Development Annual Report and energy performance contracting cases.

This paper uses information from 205 EPC projects from energy performance contracting cases (2011–2015) by EMCA and research on typical projects in 2016 by EMCA, including project names, profiles of ESCos and ECUs, transformation contents, annual energy-saving quantities and cost savings, business models, financing channels, and preferential policies. These samples were selected because: (1) EMCA clearly points out that these typical projects are strongly representative and reproducible, with obvious energy-saving effect and reasonable return on investment, suitable for promotion in the related subsectors [24], and (2) other than EMCA, there are few national data sources about EPC projects.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

2.2. Descriptive Statistics

Except for one sample in the electronic information and communication subsector, EMCA classified the samples into industry, building, and public facilities sectors, and subdivided them into nine subsectors: machinery manufacture, chemical, light, coal, building materials, power, metallurgy, building, and public facilities. Among them, the largest number of samples are in the industry sector, with 136 samples, including 42 samples in the metallurgy subsector, 14 samples in the chemical subsector, 14 samples in the coal subsector, 14 samples in the building materials subsector, 25 samples in the power subsector, 15 samples in the machinery manufacture subsector, and 12 samples in the light subsector. There were 47 samples in the building industry. There were the fewest samples in the public facilities industry, with only 21. The subsector distribution of samples is shown in Figure 2.

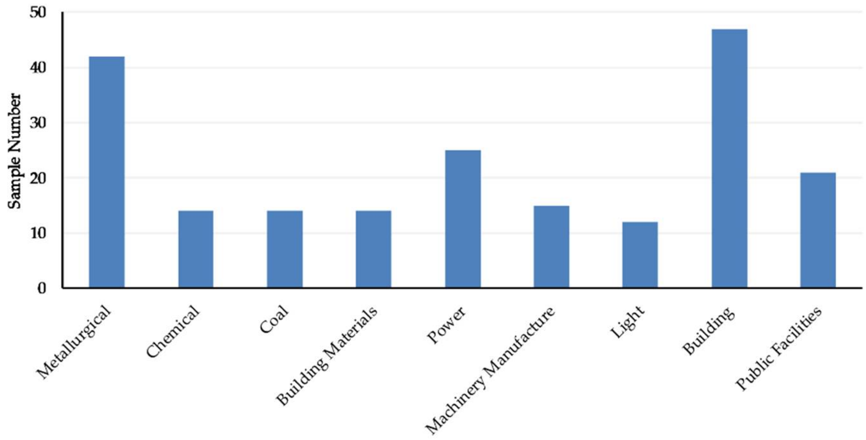

Figure 2. Industrial distribution of the samples.

EE promotion of the samples in the nine subsectors covers 83 technologies, shown in Table 1, including motor modification; heating, ventilation, and air-conditioning (HVAC) reconstruction; lighting system transformation; and launching new energy monitoring and management systems. To get the energy-saving law of each kind of technology, ideally studied samples should be classified based on the EE enhancement technology used. However, this paper studies the estimation of annual energy-saving performance based on the nine subsectors described above. This is because: (1) the number of samples in the classified subsector is too small based on EE promotion technology (an average of 2.5 samples/technology in this paper), and (2) most of the samples use more than one EE promotion technology, so their energy-saving performance is from several technologies simultaneously. It is difficult to distinguish the contribution of each technology.

Table 1. Energy efficiency (EE) promotion technologies of the samples.

Subsector	EE Promotion Technologies
Machinery Manufacture	Lighting system transformation, heating furnace reformation, retrofit of compressed air systems, waste heat utilization of compressors, motor modification, waste heat utilization of circulating water, harmonic control and reactive power compensation, electric feed servo energy saving systems, circulating fluidized beds, biodiesel, steam recovery, steam accumulation, regenerative combustion, ladle baking by gas jet, closed counterflow cooling tower, energy monitoring and management systems
Chemical	Recovery of residual heat of reboiler solvent, heating furnace reformation, recovery of waste heat from high-temperature slag, boiler retrofit, cooling tower hydraulic fans, retrofit of compressed air systems, recovery of waste heat from hydrochloric acid furnaces, motor modification, hydrogen recovery and heat recovery in pure

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

	terephthalic acid projects, reformation of water pump systems, retrofit of circulating water systems, retrofit of airtight electric furnaces
Light	Retrofit of circulating water systems, boiler retrofit, reform of water pump systems, motor modification, transformation of injection molding machines, waste heat recovery from wastewater, waste heat recovery of desiccant, solar photothermal utilization, biogas power generation, mechanical vapor recompression evaporators
Coal	Transformation of static var generator in substations, cooling tower hydraulic fans, recovery of waste heat from flue gas of coke ovens, dry quenching and waste heat generation, motor modification, waste heat utilization of compressors, retrofit of gas blower systems, low-pressure steam pumps, reform of water pump systems, waste heat generation of calciners, energy monitoring and management systems
Building Materials	Waste heat generation of cement production lines, motor modification, waste heat generation of glass production lines, retrofit of ball mills
Power	Lighting system transformation, waste heat utilization of circulating water, motor modification, retrofit of compressed air systems, waste heat generation of coke oven flue gas, optimization of urban heating networks, boiler retrofit, recovery of waste heat from boiler flue gas, compound phase changing heat exchangers, reform of water pump systems, transformation of warm air heaters, transformation of heat exchangers, retrofit of combustion systems, transformation of steam turbines, vacuum-pumping systems of steam ejectors, waste heat utilization of flue gas in photovoltaic glass kilns, retrofit of air preheaters, automatic regulating system for air inlet of cooling towers, photovoltaic tracking systems, energy monitoring and management systems
Metallurgy	Dehumidification transformation of blast furnaces, motor modification, direct reduction of solid waste by rotary hearth furnaces, steam back-pressure power generation byproducts, reform of water pump systems, waste heat generation of electric stove low-temperature flue gas, substitution fuel oil for cold coal gas, retrofit of circulating water systems, recovery of waste heat from slag water, recovery of residual heat from slag steam, heating furnace reformation, power generation with sintering residual heat, sintering waste heat recovery, retrofit of dust removal systems, coal gas recovery, top gas recovery turbine power generation in blast furnaces, waste heat generation of flue gas from submerged arc furnaces, dry quenching waste heat power generation, cooling tower hydraulic fans, flue gas waste heat generation of electric furnaces, retrofit of compressed air systems, recovery of waste heat from dead steam in self-made power plants, lighting system transformation, cooling
Building	Heating, cooling, chilled water storage systems, ventilation, hot water, lighting system transformation, cookers, elevators, building envelopes, power distribution, water supply, use of water, cold chain, swimming pool heating, solar thermal, combined cooling heating and power, energy management systems, battery management systems
Public Facilities	Motor modification, boiler retrofit, lighting system transformation, heat exchange station transformation, reform of cooling and ventilation in stations, optimization of central heating pipe networks, industrial waste heat recovery, energy monitoring and management systems

The EE promotion content of the EPC project corresponds to a certain investment and energy-saving performance, so there is a certain relationship between investment and energy-saving performance. In general, the larger the annual energy-saving quantity of the unit investment, the higher the energy-saving performance of the EPC project. Figures 3–11 show bubble charts of samples in the nine subsectors. The horizontal axis represents revamping cost, the vertical axis represents annual energy-saving quantity, and the size of the bubble represents the annual energy-saving quantity of unit investment in a figure. It can be seen that most of the larger bubbles concentrate in areas with lower revamping costs, indicating a diseconomy of scale in EPC projects.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

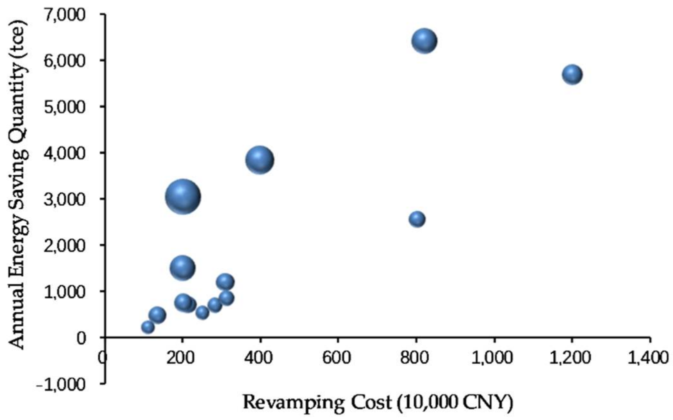

Figure 3. Bubble chart of machinery manufacture subsector samples.

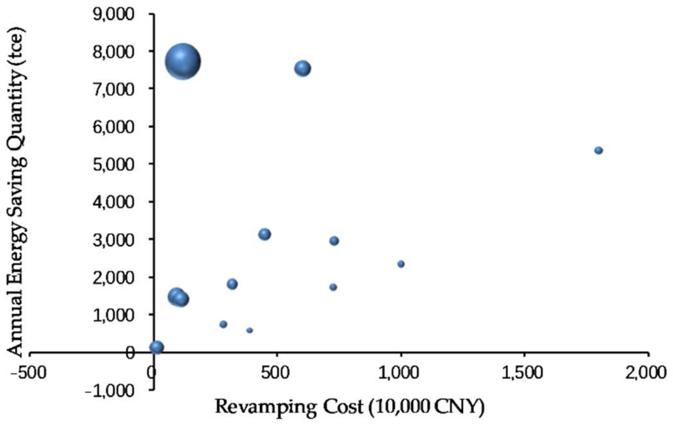

Figure 4. Bubble chart of chemical subsector samples.

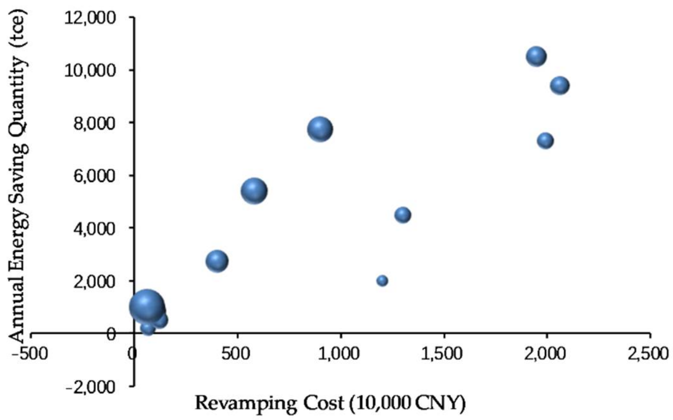

Figure 5. Bubble chart of light subsector samples.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

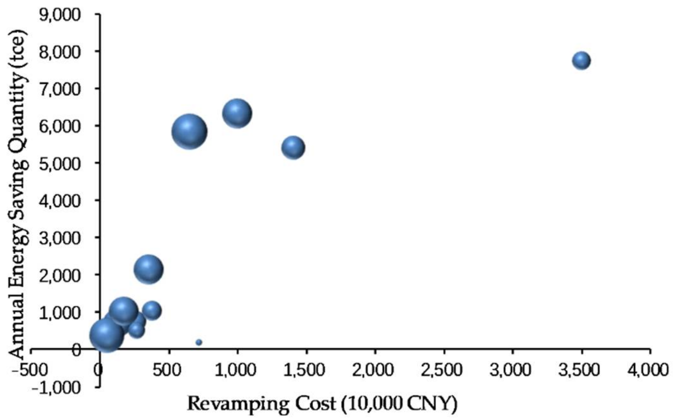

Figure 6. Bubble chart of coal subsector samples.

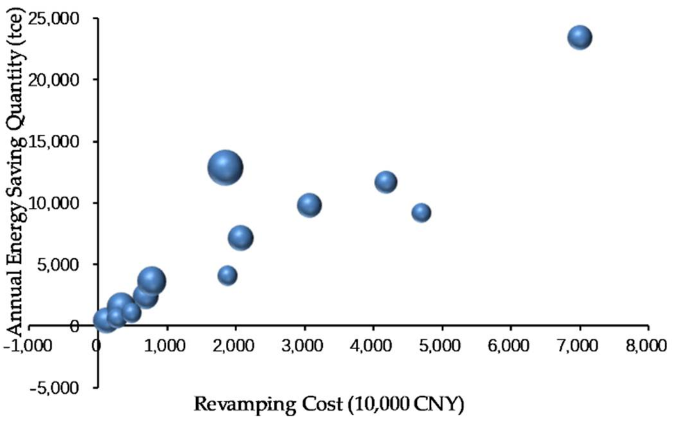

Figure 7. Bubble chart of building materials subsector samples.

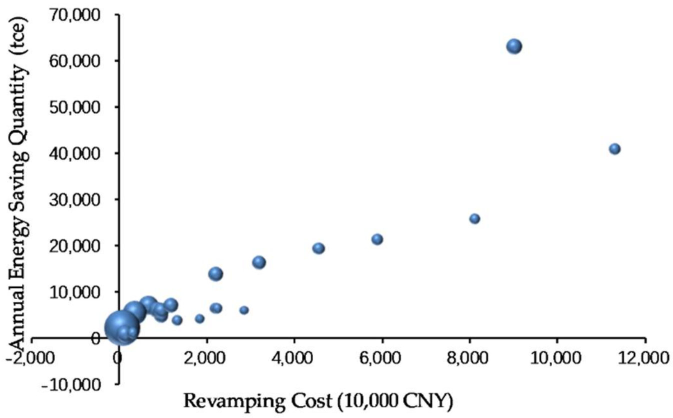

Figure 8. Bubble chart of power subsector samples.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

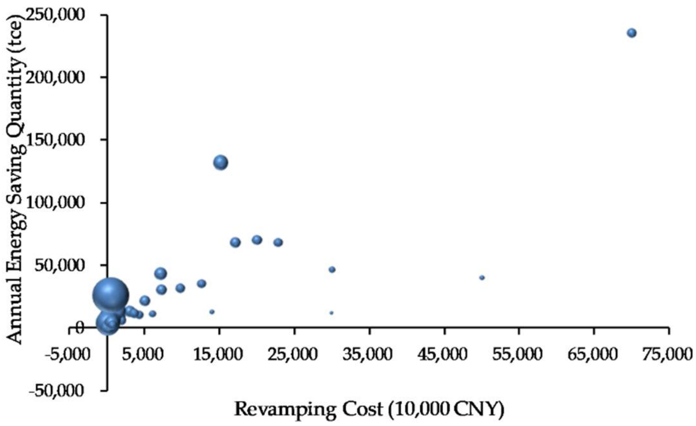

Figure 9. Bubble chart of metallurgy subsector samples.

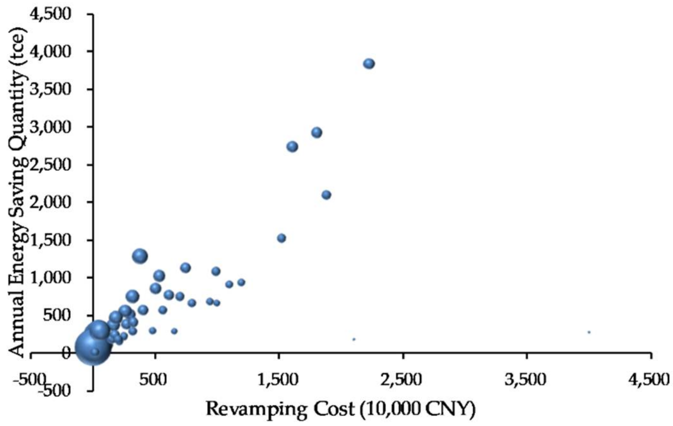

Figure 10. Bubble chart of building subsector samples.

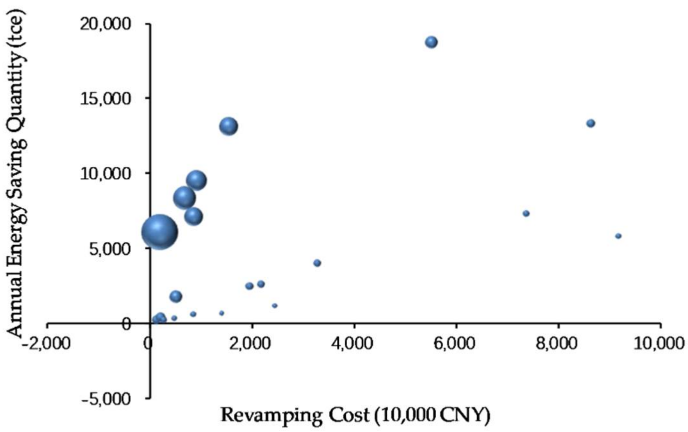

Figure 11. Bubble chart of public facilities subsector samples.

Ten samples were removed from Figures 3–11 for two reasons.

Reason 1: The revamping cost of four samples was too different from the others in the same subsector, far from the average level of the subsector. Considering regression analysis (below), eliminating these extreme values can make the regression results more stable and reliable. These four samples are as follows: (1) EE promotion technology of one sample in the chemical subsector is the retrofit of airtight electric furnaces, with an especially high revamping cost. (2) The same situation occurs in one sample in the coal subsector; its EE promotion technology depends on transformation

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

of the coke-quenching process. (3) Another sample in the coal subsector adopts variable frequency modification of pump motors, and the modification scale is so huge that the revamping cost is very high. (4) One sample in the building subsector uses heat pump technology and chilled water storage technology. Since the building volume is up to 4 million m^2, the revamping cost is also very high.

Reason 2: There are six samples with only revamping cost data, without annual energy-saving quantity information.

Sample numbers in the subsectors after elimination are shown in Table 2. In Chapter 3, the analysis of revamping cost in terms of annual energy-saving quantity and annual cost saving is based on the numbers in Table 2.

Table 2. Number of samples in the nine subsectors after elimination.

Subsector	Number of Samples
Machinery Manufacture	14
Chemical	13
Light	12
Coal	12
Building Materials	13
Power	25
Metallurgy	42
Building	43
Public Facilities	20
Total	194

3. Regression Analysis of Annual Energy-Saving Performance

As pointed out in Chapter 1, the annual energy-saving performance of an EPC project in this paper refers to the annual energy-saving quantity and cost saving. So the relationships of revamping cost in terms of annual energy-saving quantity and annual cost saving are investigated in turn.

3.1. Relationship of Revamping Cost in Terms of Annual Energy-Saving Quantity

We set up a linear regression method of revamping cost in terms of annual energy-saving quantity of each subsector by SPSS22.0 software. The results of curve estimation are shown in Tables 3 and 4. In addition, this paper explores ANOVA of the regression (see Appendix A).

Table 3. Coefficients of revamping cost in terms of annual energy-saving quantity in curve estimation.

Subsector	Variables	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
Machinery Manufacture	Revamping cost	5.159	1.037	0.821	4.977	0.000
	(Constant)	26.455	514.475		0.051	0.960
Chemical	1/Revamping cost	−39.415	11.539	−0.717	−3.416	0.006
	(Constant)	7.872	0.252		31.191	0.000
Light	ln(Revamping cost)	0.829	0.130	0.895	6.358	0.000
	(Constant)	15.227	12.499		1.218	0.251
Coal	Revamping cost	5.911	1.888	2.021	3.131	0.012
	Revamping cost **2 [a]	−0.001	0.001	−1.286	−1.993	0.077
	(Constant)	−265.899	863.878		−0.308	0.765
Building Materials	ln(Revamping cost)	0.965	0.088	0.958	11.015	0.000
	(Constant)	4.113	2.586		1.591	0.140

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

Power	Revamping cost	4.292	0.418	0.906	10.278	0.000
	(Constant)	367.430	1612.215		0.228	0.822
Metallurgy	ln(Revamping cost)	0.746	0.059	0.893	12.547	0.000
	(Constant)	28.861	13.121		2.200	0.034
Building	ln(Revamping cost)	0.562	0.082	0.730	6.838	0.000
	(Constant)	16.765	8.338		2.011	0.051
Public Facilities	ln(Revamping cost)	0.696	0.209	0.618	3.333	0.004
	(Constant)	17.868	26.849		0.665	0.514

Note: [a] **2 represents square of variables.

Table 4. Model summary of revamping cost in terms of annual energy-saving quantity in curve estimation.*

Subsector	R	R^2	R_a^2	**Std. Error of the Estimate**
Machinery Manufacture	0.821	0.674	0.646	1196.193
Chemical	0.717	0.515	0.471	0.822
Light	0.895	0.802	0.782	0.604
Coal	0.855	0.730	0.670	1604.199
Building Materials	0.958	0.917	0.909	0.376
Power	0.906	0.821	0.813	6267.402
Metallurgy	0.893	0.797	0.792	0.760
Building	0.730	0.533	0.521	0.748
Public Facilities	0.618	0.382	0.347	1.174

*Independents: revamping cost of the samples (10,000 CNY).

According to Table 3, there are significant correlations between revamping cost and annual energy-saving quantity in the nine subsectors, but there are big differences between the subsectors. This is mainly due to differences in energy saving-potential of the subsectors; for example, the standard coal consumption rate of power supply in China is 40 gce/kWh more than the international advanced level (gce is the abbreviation of gram of standard coal equivalent); the comparable energy consumption per ton of steel in China is 20 kgce/t more than the international advanced level [25]; the intensity of energy consumption for public buildings should be lowered to less than 24.6 kgce/m^2 and for buildings in heating areas in north to less than 7.02 kgce/m^2 in order to achieve the goal of controlling China's total energy consumption within 1100 million tce in 2020 [26]. Results of the curve estimation of EPC samples in all nine subsectors for revamping cost in terms of energy-saving quantity can be divided into the following four categories.

3.1.1. Light, Building Materials, Metallurgy, Building, and Public Facilities Subsectors

There are power function relationships between revamping cost and annual energy-saving quantity in the light, building materials, metallurgy, building, and public facilities subsectors, i.e., the fitting functions are in accordance with the nature of concave functions. The estimated curves show that the annual energy-saving quantity in these five subsectors increases with increased revamping cost, but the amount of increase decreases. That is to say, the scale between revamping cost and annual energy-saving quantity is diseconomy.

Equation (1) shows the relationship between revamping cost and annual energy-saving quantity of the samples in the light subsector. Average annual energy-saving quantity per unit investment of the 12 samples can be expressed as $(Q/I)_{ave}=\bar{q}=6.4$ ($\bar{q}$ is average annual energy-saving quantity of unit investment; Q is annual energy-saving quantity (tce); I is revamping cost (10,000 CNY)).

$$Q_{li}=15.227\left(I_{li}\right)^{0.829} \quad (I_{li}=0-2500) \tag{1}$$

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

where Q_{li} is annual energy-saving quantity of the samples in the light subsector (tce) and I_{li} is revamping cost of the samples in the light subsector (10,000 CNY).

Equation (2) shows the relationship between revamping cost and annual energy-saving quantity of the samples in the building materials subsector. The average annual energy-saving quantity of unit investment of the 13 samples in the subsector is $\bar{q}=3.4$.

$$Q_{bm}=4.113\left(I_{bm}\right)^{0.965}\ (I_{bm}=0-8000) \tag{2}$$

where Q_{bm} is annual energy-saving quantity of the samples in the building materials subsector (tce) and I_{bm} is revamping cost of the samples in the building materials subsector (10,000 CNY).

The relationship in the metallurgical subsector can be expressed as Equation (3). Its $\bar{q}$ is 6.8, while three samples have $Q/I=q<1.0$ (q is annual energy-saving quantity of unit investment), and other samples have relatively smaller q values, resulting in diminishing marginal annual energy-saving quantity. Direct reduction of solid waste by rotary hearth furnace technology, lithium bromide and screw mechanism cooling technology, and dry quenching waste heat power generation technology, respectively, are used in these three samples, so revamping costs are all high.

$$Q_{me}=28.861\left(I_{me}\right)^{0.746}\ (I_{me}=0-75,000) \tag{3}$$

where Q_{me} is annual energy-saving quantity of the samples in the metallurgy subsector (tce) and I_{me} is revamping cost of the samples in the metallurgy subsector (10,000 CNY).

Equation (4) shows the relationship between revamping cost and annual energy-saving quantity of the samples in the building industry. Its $\bar{q}$ is 2.1, while two samples have $q<1.0$, including one sample with a renovated heating and cooling system, and other samples with renovated building envelopes, cooling systems, lighting systems, and power distribution systems. As the revamping costs are both high, these two samples adopt the energy expenses entrusted contract model and guaranteed savings contract model, respectively, to ensure investment recovery for ESCos. On the contrary, there is one sample with $q=18.5$. Intelligent stable pressure and energy-saving water supply equipment are added to it, with revamping cost of only 42,000 CNY. Its energy performance is remarkably higher relative to revamping cost, so the ESCo's share of the contract is smaller.

$$Q_{bu}=16.765\left(I_{bu}\right)^{0.562}\ (I_{bu}=0-4500) \tag{4}$$

where Q_{bu} is annual energy-saving quantity of the samples in the building subsector (tce) and I_{bu} is the revamping cost of the samples in the building subsector (10,000 CNY).

The relationship in the public facilities subsector can be expressed as Equation (5), with $\bar{q}=4.6$. Among them, there are 11 lighting system transformation samples (apart from advertising lamp box transformation of one sample, the rest are reconstruction of road lighting systems). Average annual energy-saving quantity of unit investment of these samples is $\bar{q}=1.2$, demonstrating that the revamping cost of the lighting system was still high in 2011–2016 relative to annual energy-saving quantity. The other 8 samples among the 20 samples use heating system reconstruction or optimization of heating network, including one sample with $q=31.3$ (its transformation technology is heating according to area, time, and temperature; secondary piping network balance optimization; optimization of heat exchange station and primary piping network). Transformation technology of the remaining one sample are cooling and ventilation transformation, and building new energy monitoring and management systems, with $q=0.6$. The number of samples in the public facilities subsector is not large, but the subsector covers many subclass samples, such as lighting system transformation, heating network optimization, and ventilation and air-conditioning system transformation, thus becoming a "super subsector." So R^2 of this subsector in Table 4 is only 0.382, which is the lowest among the nine subsectors.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

$$Q_{pf} = 17.868\left(I_{pf}\right)^{0.696} \quad (I_{pf} = 0-10{,}000) \tag{5}$$

where Q_{pf} is annual energy-saving quantity of the samples in the public facilities subsector (tce) and I_{pf} is revamping cost of the samples in the public facilities subsector (10,000 CNY).

3.1.2. Chemical Subsector

The relationship in the chemical subsector can be expressed as Equation (6). Its $\bar{q}$ is 11.0, while there is one sample with $q = 64.3$. It adopts waste heat recovery technology of high-temperature slag, so its revamping cost is small and annual energy-saving quantity is large.

$$Q_{ch} = \exp\{7.872 - 39.415 / I_{ch}\} \quad (I_{ch} = 0-2000) \tag{6}$$

where Q_{ch} is annual energy saving quantity of the samples in the chemical subsector (tce) and I_{ch} is revamping cost of the samples in the chemical subsector (10,000 CNY).

3.1.3. Coal Subsector

The relationship in the coal subsector can be expressed as Equation (7) with $\bar{q} = 4.6$. When revamping cost $I \in (0, 2955.5]$ in Equation (7), annual energy-saving quantity increases with increased revamping cost; when $I \in (2955.5, 4000]$, annual energy-saving quantity decreases with increased revamping cost; one sample is a calciner waste heat generation transformation project with a 35 million CNY revamping cost. Therefore, annual energy-saving quantity increases with increased revamping cost in the coal subsector.

$$Q_{co} = -265.899 + 5.911 I_{co} - 0.001\left(I_{co}\right)^2 \quad (I_{co} = 0-4000) \tag{7}$$

where Q_{co} is annual energy-saving quantity of the samples in the coal subsector (tce) and I_{co} is revamping cost of the samples in the coal subsector (10,000 CNY).

3.1.4. Machinery Manufacture and Power Subsectors

Annual energy-saving quantity increases linearly with increased revamping cost in the machinery manufacture and power subsectors.

Equation (8) shows the relationship between revamping cost and annual energy-saving quantity of the samples in the machinery manufacture subsector. It may be that the revamping costs of these samples obtained from EMCA statistics are relatively low, so samples in the subsector do not show diseconomy of scale. Its $\bar{q}$ is 5.1, while there is one sample with $q = 15.0$. Steam heat storage technology used in the sample reduces the influence of steam load fluctuation, saving energy consumption while protecting steam-consuming equipment and steam pipes. The EE promotion effectiveness of the sample is significantly better than that of the other samples.

$$Q_{ma} = 26.455 + 5.159 I_{ma} \quad (I_{ma} = 0-1400) \tag{8}$$

where Q_{ma} is annual energy-saving quantity of the samples (tce) and I_{ma} is revamping cost of the samples in the machinery manufacture subsector (10,000 CNY).

The relationship in the power subsector can be expressed as Equation (9); its $\bar{q}$ is 6.4. The domain of the revamping cost of the samples is 10 times that of the machinery manufacture subsector, and R^2 as shown in Table 4 is larger than that of the machinery manufacture subsector. Therefore, the linear relationship between revamping cost and annual energy-saving quantity is more significant in the power subsector than the machinery manufacture subsector.

$$Q_{el} = 367.430 + 4.292 I_{el} \quad (I_{el} = 0-12{,}000) \tag{9}$$

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

where Q_{el} is annual energy-saving quantity of the samples (tce) and I_{el} is revamping cost of the samples in the power subsector (10,000 CNY).

3.2. Relationship of Revamping Cost in Terms of Annual Cost Saving

As described in Chapter 2.1, data of the samples also include annual cost saving. So it is also possible to estimate annual cost saving by revamping cost. Results of revamping cost in terms of annual cost saving in curve estimation are shown in Tables 5 and 6. There is also a significant correlation between revamping cost and annual energy-saving quantity in each subsector. In addition, this paper explores ANOVA of the regression (see Appendix A). It can be seen that annual cost saving of the samples increases linearly with increased revamping cost in the machinery manufacture, coal, and metallurgy subsectors. The relationships in the other subsectors are consistent with the power function, namely, revamping cost in these subsectors has a diseconomy of scale.

Table 5. Coefficients of revamping cost in terms of annual cost saving in curve estimation.

Subsector	Variables	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
Machinery Manufacture	Revamping cost	0.658	0.080	0.916	8.259	0.000
	(Constant)	18.748	38.346		0.489	0.633
Chemical	ln(Revamping cost)	0.688	0.133	0.842	5.181	0.000
	(Constant)	6.105	4.731		1.291	0.223
Light	ln(Revamping cost)	0.831	0.091	0.945	9.100	0.000
	(Constant)	2.285	1.313		1.741	0.112
Coal	Revamping cost	0.355	0.069	0.851	5.132	0.000
	(Constant)	101.811	81.428		1.250	0.240
Building Materials	ln(Revamping cost)	0.867	0.115	0.909	7.534	0.000
	(Constant)	1.346	1.088		1.238	0.240
Power	ln(Revamping cost)	0.865	0.055	0.957	15.809	0.000
	(Constant)	1.229	0.475		2.588	0.016
Metallurgy	Revamping cost	0.262	0.024	0.866	10.964	0.000
	(Constant)	590.687	392.447		1.505	0.140
Building	ln(Revamping cost)	0.641	0.068	0.817	9.501	0.000
	(Constant)	3.078	1.236		2.491	0.017
Public Facilities	ln(Revamping cost)	0.604	0.143	0.705	4.214	0.001
	(Constant)	6.367	6.589		0.966	0.347

Table 6. Model summary of revamping cost in terms of annual cost saving in curve estimation.*

Subsector	R	R^2	R_a^2	Std. Error of the Estimate
Machinery Manufacture	0.916	0.840	0.828	93.618
Chemical	0.842	0.709	0.683	0.594
Light	0.945	0.892	0.881	0.423
Coal	0.851	0.725	0.697	219.339
Building Materials	0.909	0.825	0.811	0.565
Power	0.957	0.916	0.912	0.420
Metallurgy	0.866	0.750	0.744	2211.686
Building	0.817	0.667	0.660	0.603
Public Facilities	0.705	0.497	0.469	0.778

*Independents: revamping cost of the samples (10,000 CNY).

Equations (10)–(18) show the relationship between revamping cost and annual cost saving.

$$S_{ma} = 18.784 + 0.658 I_{ma} \tag{10}$$

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

$$S_{ch} = 6.105\left(I_{ch}\right)^{0.668} \tag{11}$$

$$S_{li} = 2.285\left(I_{li}\right)^{0.831} \tag{12}$$

$$S_{co} = 101.811 + 0.355 I_{co} \tag{13}$$

$$S_{bm} = 1.346\left(I_{bm}\right)^{0.867} \tag{14}$$

$$S_{el} = 1.229\left(I_{el}\right)^{0.865} \tag{15}$$

$$S_{me} = 590.687 + 0.262 I_{me} \tag{16}$$

$$S_{bu} = 3.078\left(I_{bu}\right)^{0.641} \tag{17}$$

$$S_{pf} = 6.367\left(I_{pf}\right)^{0.604} \tag{18}$$

where S_{ma} is annual cost saving of the samples in the machinery manufacture subsector (tce); and S_{ch}, S_{li}, S_{co}, S_{bm}, S_{el}, S_{me}, and S_{pf} are annual cost savings of the samples in the chemical, light, coal, building materials, power, metallurgy, building, and public facilities subsectors.

Except for a slight decrease of R^2 of the samples in the building materials subsector and basically no change of R^2 of the samples in the coal and metallurgy subsectors, R^2 in Table 6 is larger than that in Table 4. The annual energy cost-saving is energy market price multiplied by amount of energy saved [23,27]. R^2 increases, which indicates that the correlation between revamping cost and annual energy cost saving of the samples is greater than that between revamping cost and annual energy-saving quantity in the same subsector through region adjustment, subsector adjustment, and electricity classification adjustment of energy price. This is because what ESCos and ECUs ultimately seek is annual cost saving of projects, not annual energy-saving quantity. Market forces drive both parties to seek high cost-saving projects, for example, some projects with low annual energy-saving quantity but high energy price. Eventually, it makes the correlation between revamping cost and annual cost saving of the samples in the same subsector more significant.

The adjustment role of energy price is reflected among the different subsectors as mentioned above. Samples in the industry sector account for 67.5% of the 194 effective samples in this paper, roughly in accordance with the proportion of 62% from EMCA's statistics in the Twelfth Five-Year Plan [28]. It can be inferred that EPC projects in China are dominated by the industry sector, contrary to most developed countries. In the United States, roughly 70% of ESCo market revenue comes from municipal, local, and state government facilities; universities/colleges; K–12 schools; and health care facilities customers; 15% of ESCo market revenue comes from federal government customers. The remaining 15% is split between commercial/industrial private customers and public housing [29]. Reasons for ESCos' limited penetration in the American industrial market are the high cost of developing projects, the highly customized nature of process improvements, and the need for industry-specific expertise limiting access to decision-makers within industrial firms and difficulty evaluating project success [30]. Also, mainly for the reasons cited, there are great differences between the regression results of revamping cost in terms of annual cost saving and annual energy-saving quantity among the subsectors in this paper. Coefficient of variation (i.e., $c_v = \sigma / \mu$; c_v is coefficient of variation, σ is standard deviation, μ is average value) is a normalized measure of degree of probability distribution dispersion. Coefficient of variation of average annual energy-saving quantity of unit investment (i.e., $\overline{q}$) among the nine subsectors is $c_v = 2.53 / 5.60 = 0.45$ and of annual cost saving of unit investment (i.e., $\overline{s}$) is $c_v = 0.26 / 0.75 = 0.35$, as shown in Table 7. This shows that there is a

 doi:10.20944/preprints201804.0274.v1

relatively large difference in $\bar{q}$ among the different subsectors, but the difference in $\bar{s}$ among them has become smaller since the adjustment of energy prices.

Table 7. $\bar{q}$, $\bar{s}$, and c_v in the subsectors.

Subsector	$\bar{q}=(Q/I)_{ave}$		$\bar{s}=(S/I)_{ave}$	
Machinery Manufacture	5.1		0.76	
Chemical	11.0		1.31	
Light	6.4		0.89	
Coal	4.6		0.66	
Building Materials	3.4	$\hat{c}_v=0.45$	0.56	$\hat{c}_v=0.35$
Power	6.4		0.53	
Metallurgy	6.8		0.95	
Building	2.1		0.52	
Public Facilities	4.6		0.56	

3.3. Results

In Chapters 3.1 and 3.2, it can be seen that ESCos and ECUs can calculate annual energy-saving quantity by the function of revamping cost in terms of annual energy-saving quantity obtained from regression according to the subsector where the project belongs, and calculate annual cost saving by the function of revamping cost in terms of annual cost saving. For example, applying Equations (9) and (15), annual energy-saving quantity and annual cost saving are about 21,800 tce and 19 million CNY, respectively, if an investment in an EPC project in the power subsector is estimated to be 50 million CNY. The advantage of this approach is that even if the ECU does not understand the expertise of the EPC project, through revamping cost it can estimate the average level of annual energy-saving performance, which contributes to EPC investment decisions and trust relationships between ESCos and ECUs.

4. Research on the Influencing Factors of Revamping Cost

Research in Chapter 3 shows that annual energy-saving performance can be estimated through revamping cost. Nevertheless, what are the main factors that affect revamping cost? This question is studied in this chapter.

4.1. Multiple Linear Regression Method of Revamping Cost

In order to further analyze the 194 samples of Table 2, EViews 7.0 software was used to establish a multiple linear regression method, as shown in Equation (19). For details, see Table A3 in Appendix A. Some samples do not have registered capital of ECU (such as government departments, hospitals, and other institutions), while others have no information on contract period. By deleting the missing data samples, the sample size of Equation (19) is 144, 50 fewer than the samples in Table 2.

$$\begin{aligned}\log(I) = &\underset{(0.001)}{3.021} - \underset{(0.012)}{1.031ma} - \underset{(0.468)}{0.342ch} - \underset{(0.112)}{0.782li} + \underset{(0.746)}{0.171co} + \underset{(0.635)}{0.209bm} - \underset{(0.550)}{0.231el} - \underset{(0.004)}{1.155bu} + \underset{(0.801)}{0.113pf} \\ &+ \underset{(0.000)}{1.423F} - \underset{(0.860)}{0.0632J} + \underset{(0.000)}{0.372\log(REG_E)} + \underset{(0.797)}{0.0127\log(REG_Y)} + \underset{(0.001)}{0.086T}\end{aligned} \quad (19)$$

$$n=144,\ R^2=0.638,\ Prob(F-statistic)=0.000$$

where ma is the machinery manufacture subsector; ch is the chemical subsector; li is the light subsector; co is the coal subsector; bm is the building materials subsector; el is the power subsector; bu is the building sector; pf is the public facilities sector; F indicates whether or not the project is financed; J indicates whether the project enjoys financial incentive or tax preference; REG_E is registered capital of the ESCo; REG_Y is registered capital of the ECU; and T is the contract period.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

The regression model of Equation (19) includes a dependent variable, $\log(I)$; one constant term, 3.021; three numerical variables: $\log(REG_E)$, $\log(REG_Y)$ and T; and 10 categorical variables: nine subsectors, whether or not the sample is financed, whether or not the sample enjoys financial incentive or tax preference. The 0/1 type two-value dummy variable is defined to describe the categorical variables, i.e., 1 is the attribute that conforms to a certain type of characteristic and 0 is the attribute that does not conform to that characteristic. For example, the variable representing whether or not the project is financed is divided into two categories according to whether the revamping cost contains financing funds. When the revamping cost contains financing funds, the variable is defined as 1, otherwise it will be 0.

4.2. Analysis of Factors Influencing Revamping Cost

4.2.1. The Subsectors

The coefficient of the machinery manufacture subsector in Equation (19) is −1.03 if other influencing factors are fixed, which means $(e^{-1.031}-1)\times 100\% = -64.3\%$. This shows that the average revamping cost of the machinery manufacture subsector is 64.3% lower than that of the metallurgy subsector statistically. Similarly, revamping cost of the chemical subsector is 29% lower than that of the metallurgy subsector. Revamping cost in the light, building materials, and power subsectors and building sector is 54.3%, 18.9%, 20.6%, and 68.5% lower, respectively, while revamping cost in the coal subsector and public facilities sector is 18.6% and 12.0% higher, respectively, than that of the metallurgical subsector. Therefore, the average revamping cost of the 144 samples in the statistical sense are as follows, in decreasing order: coal subsector, followed by public facilities, metallurgy, building materials, power, chemical, light, machinery manufacture, and building subsectors. This is partly because samples in the light, machinery manufacture, and building subsectors are mainly small projects.

4.2.2. Financing

Financing has a significant impact on revamping cost statistically if other influencing factors are fixed. Compared to samples that do not adopt financing methods, revamping cost of financed samples is $(e^{1.423}-1)\times 100\% = 315\%$ higher on average. This is because most ESCos presently in China were established in recent years by policy stimulus and have little experience and light assets. They are basically at the initial stage of development. Many of them cannot rely solely on their own funds to undertake projects, and need to be financed by financial institutions. Obviously, it will be more conducive to expanding the scale of investment if ESCos are able to get financing. However, we also found that only 34 of the 144 samples have financing (revamping cost comes partly from financing for 28 samples, and entirely from financing for 6 samples), and the other 110 samples are almost exclusively invested by ESCos. The difficulty in financing is another bottleneck for the development of EPC in China [13,14]. The characteristics of EPC project financing used to guarantee repayment of the loan are the future cash flow of the project and the asset value of the project itself, rather than the credit of the investors. The future income of projects has great uncertainty, which brings great risks to banks and other financial institutions. This characteristic also indirectly validates that this research has important practical value.

4.2.3. Financial Incentive or Tax Preference

Financial incentive or tax preference has no significant impact on revamping cost statistically if other influencing factors are fixed. China has incorporated EPC projects into the policy support system, which provides either financial incentive or tax preference. However, in terms of quantity, only 15 samples get financial incentive, 10 samples enjoy tax preference, and only 4 samples receive both financial incentive and tax preference among the 144 samples. Financial incentive or tax preference should have an energizing effect on EPC projects. However, Equation (19) shows that the coefficient of financial incentive or tax preference is negative, and the corresponding probability

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

value of the coefficient is 0.860. There are some reasons. (1) There may be multiple collinearity between financial incentive or tax preference and other factors. Upon testing, what is found is that the correlation coefficient between financial incentive or tax preference and the light subsector is relatively large. In addition, five samples get financial incentive or tax preference in the 10 effective samples of the light subsector, which is the highest proportion in all the subsectors. (2) Financial incentive or tax preference often happens in the phase of project implementation, that is, it is not clear whether the project will get such incentives in the future while determining revamping cost. (3) The amount of financial incentive or tax preference is not large. Specifically, EPC projects received 760 million CNY from the central financial award in total in Twelfth Five-Year, while the total investment in EPC projects was 371,100 million CNY in the same period. (4) In addition to asset incentives, there are a number of complex relationships between ESCos and the Chinese government, for example, some incentives are gratuitous, but there are additional conditions. The above four reasons make the impact of financial incentive or tax preference on revamping cost more complex, vague, and difficult to show.

4.2.4. Registered Capital

Registered capital of ESCos has a significant impact on revamping cost statistically if other influencing factors are fixed. If the registered capital of an ESCo increases 1%, the revamping cost will increase 0.37% on average. In the 144 samples, seven samples use a guaranteed savings contract model, five samples (all in the building subsector) use an expense entrusted contract model, one sample uses a hybrid guaranteed savings and shared savings contract model, and the remaining 131 samples use a shared savings contract model. The distribution of contract models also explains why ESCos invested in most of the samples. In the shared savings contract model, the EPC project is financed and serviced by an ESCo, the energy cost saving is shared by the ESCo and the ECU within the contract period according to negotiated rate, and ownership of the transformed facilities will be transferred to the ECU after the contract expires. Therefore, ESCos usually negotiate with ECUs on the shared rate of cost savings by improving the revamping cost ratio in this contract model. The funds that the ESCo can use are positively related to the ESCo's registered capital, hence registered capital of the ESCo influences revamping cost.

The ECU's registered capital has no significant impact on revamping cost statistically if other influencing factors are fixed. This is because investments of most samples come from the ESCo or the ESCo is responsible for part of the financing, even though the ECU invests in the EPC project, because coming from various subsectors, their registered capital is quite different.

4.2.5. Contract Period

Contract period has a significant impact on revamping cost statistically if other influencing factors are fixed. If the contract period increases 1%, the revamping cost will increase $(e^{0.086}-1)\times 100\% = 9\%$ on average. In shared savings contracts, in order to obtain the maximum benefit, ESCos tend to negotiate longer contract periods, while ECUs love shorter contract periods. The result of the game is that a longer contract period often requires that the economic lifespan of the project is relatively longer, so that the revamping cost is pushed up.

5. Discussion and Conclusions

Because the typical projects from EMCA's statistics may not be fully representative, people will find that the annual energy-saving quantity and annual cost saving of some EPC projects are quite different in practice from the results calculated by Equations (1)–(18). The reasons the samples in this paper are not fully representative are as follows: (1) Ninety percent of the 204 samples adopted shared savings contract models, quite different from the 63% in Twelfth Five-Year from EMCA's statistics [28], due to small projects usually having low investment and a short payback period, and tending to adopt a guaranteed savings contract model. (2) The typical projects from EMCA's statistics do not

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

contain projects with poor performance. (3) Other reasons, such as reporting biases, etc. In a word, it can be judged that the above samples as a whole may not wholly represent the EPC industry in China.

Therefore, the results of the curve estimation as shown in Tables 3–5 are conditional, and the details are as follows: (1) The EE promotion technology used by the assessed EPC project should be within the scope of the technology used in the 204 samples, i.e., the technology should be found in Table 1. If the EE promotion technology adopted by the project is relatively new, it is necessary to carry out a professional assessment to determine investment and benefit, rather than mechanically apply the results in this paper. (2) The revamping cost of the assessed EPC project should also be within the scope of the sample investment. If the investment is beyond the scope, the calculated annual energy-saving performance may deviate. (3) The time of project evaluation should be close to 2016. If it is a project takes place many years later, it will lead to a deviation due to the progress of technology, the increase of marginal cost of EE investment year by year, and the change of energy price.

In addition, it is important to note that the difference of outlier elimination will lead to a difference of research conclusions. For example, if the sample with 35 million CNY revamping cost in the coal subsector in Chapter 3.1.3 is removed as an exception, the relationship of revamping cost in terms of annual energy-saving performance will change correspondingly. A variety of factors affect whether a sample is an exception or not, such as the classification method of samples. This paper is based on the classification of the nine subsectors according to EMCA. If the sample number is large enough, the research will be more meaningful based on the classification of EE promotion technology.

Diseconomy of scale in EPC projects of most subsectors is shown in Chapters 2 and 3. Moreover, high-investment projects of a similar nature, compared to their small counterparts, usually require longer average investment returns and bring more risks [13]. Therefore, small ESCos can compete for projects with small investment intensity to make limited funds turn around faster and improve their viability. Nevertheless, it is quite plausible that the most cost-effective projects have already been completed, leaving less “low-hanging fruit” for ESCos to target [31]. This has contributed to the intensifying competition in low-revamping-cost EPC projects. Moreover, it is necessary to expand revamping costs of EPC projects from the perspective of further improving energy utilization efficiency by the whole society. As can be seen in Figure 1, investment in China’s EPC projects in 2016 totaled 107,355 million CNY, 126 times the 851 million CNY in 2003, but the growth rate of investment in 2015 and 2016 slowed obviously. The Thirteenth Five-Year Plan for the energy conservation and environmental protection industry [32] clearly puts forward expanding and strengthening the energy-saving service industry, and sets a target of total output value of the industry at 600 billion CNY in 2020 (the total output value in 2016 was 356,742 million CNY). It can be seen that there is a large gap in the investment of EPC projects at the national level.

The subsector of the project has a significant impact on revamping cost. On the one hand, this is due to the difference of energy-saving potential in the different subsectors, as discussed in Chapter 3.1, and on the other hand, it may also be related to the lower level of EE promotion technology in some subsectors. For example, the intensity of energy consumption for public buildings (not including buildings in heating areas in the north) was 22.5 kgce/m^2 [26] in 2015, lower than most developed countries. Meanwhile, ESCos generally obtain energy saving by using a single technology. So the EE promotion space is relatively limited, which leads to the low average investment in EPC projects in the building subsector. Therefore, only by ESCOs’ innovating EE promotion technologies and promoting EE service content from single equipment, single project to expanding to energy system optimization and regional EE promotion can the EPC investment gap be alleviated at a deeper level.

Registered capital of ESCos has a significant impact on revamping cost. EPC is really a market-oriented mechanism, but in China, the government has taken a top-down approach to promoting it after its introduction. This led to the total number of enterprises engaged in energy-saving service reaching 5426 in 2015 [28]. Therefore, after China entered the new development stage of letting the

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

market decide the allocation of resources, it is necessary for ESCos to integrate upstream and downstream resources, and ESCos with less competitive strength will have to be eliminated.

Financing and contract period have significant impacts on revamping cost. In 2015, China officially abolished five management measures on financial incentives, including interim measures for the management of financial incentive funds for energy performance contract projects. The way to stimulate EPC industrial development with subsidies is no longer the main means, and the government, in its support for the industry, has begun to focus on providing a good institutional environment and policy guidance. Financing is the key to ensure adequate investments in EPC projects, therefore an effective financing mechanism for EPC projects should be developed. For the term of the contract period, a good institutional environment helps to build a market credit environment, which will help ESCos and ECUs carry out designs for longer contract periods.

In a word, this empirical study on annual energy-saving performance contributes to EPC investment decisions and trust relationships between ESCos and ECUs. To promote investment in EPC projects by public and private sectors, it is suggested that ESCos should innovate EE promotion technology in the various subsectors and promote EE service content from single equipment, single project to expanding to energy system optimization, regional EE promotion, and integration of upstream and downstream resources to enhance competitive ability, while the government should innovate an effective financing mechanism and provide a good institutional environment.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1.

Acknowledgments: We thank Zhonghan Liu from University of Houston for providing language help.

Author Contributions: Hongquan Ruan, Xin Gao, and Chaoxuan Mao analyzed the data; Hongquan Ruan and Chaoxuan Mao wrote the paper.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. ANOVA of revamping cost in terms of annual energy-saving quantity in curve estimation.*

Subsector	Sum of Squares		df	Mean Square	F	Sig.
Machinery Manufacture	Regression	35,436,882.655	1	35,436,882.655	24.766	0.000
	Residual	17,170,546.550	12	1,430,878.879		
	Total	52,607,429.206	13			
Chemical	Regression	7.878	1	7.878	11.668	0.006
	Residual	7.427	11	0.675		
	Total	15.304	12			
Light	Regression	14.754	1	14.754	40.424	0.000
	Residual	3.650	10	0.365		
	Total	18.403	11			
Coal	Regression	62,747,324.159	2	31,373,662.079	12.191	0.003
	Residual	23,161,090.616	9	2,573,454.513		
	Total	85,908,414.774	11			
Building Materials	Regression	17.148	1	17.148	121.341	0.000
	Residual	1.555	11	0.141		
	Total	18.703	12			
Power	Regression	4,149,422,721.139	1	4,149,422,721.139	105.636	0.000
	Residual	903,447,660.773	23	39,280,333.077		
	Total	5,052,870,381.912	24			
Metallurgy	Regression	90.841	1	90.841	157.424	0.000
	Residual	23.082	40	0.577		
	Total	113.923	41			
Building	Regression	26.185	1	26.185	46.761	0.000
	Residual	22.959	41	0.560		
	Total	49.144	42			

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

Public Facilities	Regression	15.296	1	15.296	11.107	0.004
	Residual	24.790	18	1.377		
	Total	40.086	19			

*Independents: revamping cost of the samples (10,000 CNY); dependents: annual energy-saving quantity (tce).

Table A2. ANOVA of revamping cost in terms of annual cost saving in curve estimation.*

Subsector	Sum of Squares		df	Mean Square	F	Sig.
Machinery Manufacture	Regression	597,789.255	1	597,789.255	68.207	0.000
	Residual	113,937.200	13	8764.400		
	Total	711,726.454	14			
Chemical	Regression	9.458	1	9.458	26.843	0.000
	Residual	3.876	11	0.352		
	Total	13.334	12			
Light	Regression	14.801	1	14.801	82.811	0.000
	Residual	1.787	10	0.179		
	Total	16.589	11			
Coal	Regression	1,266,923.556	1	1,266,923.556	26.334	0.000
	Residual	481,096.179	10	48,109.618		
	Total	1,748,019.735	11			
Building Materials	Regression	18.098	1	18.098	56.760	0.000
	Residual	3.826	12	0.319		
	Total	21.924	13			
Power	Regression	44.090	1	44.090	249.928	0.000
	Residual	4.057	23	0.176		
	Total	48.148	24			
Metallurgy	Regression	66.636	1	66.636	111.143	0.000
	Residual	23.982	40	0.600		
	Total	90.619	41			
Building	Regression	32.833	1	32.833	90.270	0.000
	Residual	16.368	45	0.364		
	Total	49.201	46			
Public Facilities	Regression	10.739	1	10.739	17.756	0.001
	Residual	10.886	18	0.605		
	Total	21.625	19			

*Independents: revamping cost of the samples (10,000 CNY); dependents: annual cost saving (10,000 CNY).

Table A3. Multiple regression results.*

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
Constant	3.020673	0.892696	3.383764	0.0009
Machinery manufacture subsector	−1.030871	0.404814	−2.546531	0.0120
Chemical subsector	−0.341498	0.469324	−0.727639	0.4681
Light subsector	−0.781959	0.488855	−1.599572	0.1121
Coal subsector	0.170786	0.525832	0.324792	0.7459
Building materials subsector	−0.209356	0.440275	−0.475511	0.6352
Power subsector	−0.230760	0.385362	−0.598814	0.5503
Building subsector	−1.155329	0.391073	−2.954256	0.0037
Public Facilities subsector	0.112704	0.446362	0.252495	0.8011
Financing	1.423285	0.283553	5.019462	0.0000
Financial incentive or tax preference	−0.063197	0.357215	−0.176916	0.8598
Log(REG_E)	0.372210	0.076802	4.846377	0.0000
Log(REG_Y)	0.012741	0.049293	0.258464	0.7965
T	0.086389	0.023537	3.670422	0.0004
R-squared	0.473740	Mean dependent var		6.656395
Adjusted R-squared	0.421114	SD dependent var		1.678460

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 April 2018 doi:10.20944/preprints201804.0274.v1

S.E. of regression	1.277049	Akaike info criterion	3.419146
Sum squared resid	212.0109	Schwarz criterion	3.707878
Log likelihood	−232.1785	Hannan–Quinn criter	3.536470
F-statistic	9.002013	Durbin–Watson stat	2.214652
Prob(F-statistic)	0.000000		

*Dependent variable: log (*I*).

References

1. Statistical Communiqué of the People's Republic of China on the 2016 National Economic and Social Development. Available online: http://www.stats.gov.cn/tjsj/zxfb/201702/t20170228_1467424.html (accessed on 6 August 2017).
2. Global Energy Statistical Yearbook 2017. Available online: https://yearbook.enerdata.net/total-energy/world-energy-intensity-gdp-data.html (accessed on 18 September 2017).
3. Law of the People's Republic of China on Conserving Energy. Available online: http://www.gov.cn/flfg/2007-10/28/content_788493.htm (accessed on 1 August 2017).
4. Energy Development Plan for Eleventh Five-Year. Available online: http://ghs.ndrc.gov.cn/ghwb/gjjgh/200709/P020070925542065049508.pdf (accessed on 12 July 2017).
5. Energy Development Plan for Twelfth Five-Year. Available online: http://www.gov.cn/zwgk/2013-01/23/content_2318554.htm (accessed on 12 July 2017).
6. Energy Development Plan for Thirteenth Five-Year. Available online: http://www.ndrc.gov.cn/zcfb/zcfbtz/201701/W020170117335278192779.pdf (accessed on 12 July 2017).
7. China Energy Service Company (ESCO) Market Study. Available online: http://www.ifc.org/wps/wcm/connect/742aad00401df888898aff23ff966f85/IFC+final+ESCO+report-EN+.pdf?MOD=AJPERES (accessed on 6 November 2018).
8. White Paper: Unleashing Energy Efficiency Retrofits through Energy Performance Contracts in China and the United States. Available online: http://www.globalchange.umd.edu/data/epc/EPC_Market_Opportunity_Paper_final0429.pdf (accessed on 24 December 2018).
9. The Opinion of Speeding up the Implementation of Energy Performance Contracting and Promoting the Development of Energy-saving Service Industry. Available online: http://www.gov.cn/zwgk/2010-04/06/content_1573706.htm (accessed on 13 May 2017).
10. General Technical Rules for Energy Performance Contracting. Available online: http://hzs.ndrc.gov.cn/newjn/201010/W020101025315177548454.pdf (accessed on 28 April 2017).
11. Hu, J.R.; Zhou, E.Y. Engineering Risk Management Planning in Energy Performance Contracting in China. In *Systems Engineering Procedia, Proceedings of the 4th International Conference on Engineering and Risk Management (ERM), Fields Inst, Toronto, ON, Canada, 28–30 October 2011*; Wu, D.D., Ed.; Elsevier Science BV: Amsterdam, The Netherlands, 2011.
12. Wu, Z.J.; Dong, X.C.; Pi, G.L. Risk Evaluation of China's Petrochemical Energy Performance Contracting (EPC) Projects: Taking the Ningxia Petrochemical Company as an Example. *Nat. Gas Ind.* **2017**, *37*, 112–119.
13. Li, Y. AHP-Fuzzy Evaluation on Financing Bottleneck in Energy Performance Contracting in China. In *Energy Procedia, Proceedings of the 2011 2nd International Conference on Advances in Energy Engineering (ICAEE), Bangkok, Thailand, 27–28 December 2011*; Elsevier Science BV: Amsterdam, The Netherlands, 2012.
14. Li, Y.; Qiu, Y.M.; Wang Y.D. Explaining the contract terms of energy performance contracting in China: The importance of effective financing. *Energy Econ.* **2014**, *45*, 401–411, doi:10.1016/j.eneco.2014.08.009.
15. Kostka, G.; Shin, K. Energy conservation through energy service companies: Empirical analysis from China. *Energy Policy* **2013**, *52*, 748–759, doi:10.1016/j.enpol.2012.10.034.
16. Qian, D.; Guo, J.E. Research on the energy-saving and revenue sharing strategy of ESCOs under the uncertainty of the value of Energy Performance Contracting Projects. *Energy Policy* **2014**, *73*, 710–721, doi:10.1016/j.enpol.2014.05.013.
17. Xu, P.P.; Chan, E.H.W.; Visscher, H.J.; Zhang, X.L.; Wu, Z.Z. Sustainable building energy efficiency retrofit for hotel buildings using EPC mechanism in China: Analytic Network Process (ANP) approach. *J. Clean. Prod.* **2014**, *107*, 378–388, doi:10.1016/j.jclepro.2014.12.101.
18. Energy Performance Contracting Needs Continuous Promotion by Government. Available online: http://www.yicai.com/news/5247068.html (accessed on 22 December 2017).

19. Wei, D. The Thought and Solution of Energy Management Contracting Development. *J. Shandong Univ. (Philos. Soc. Sci.)* **2016**, *6*, 118–126.
20. Sun, H. *EPC Practice*; China Economic Publishing House: Beijing, China, 2012; p. 15, ISBN 978-7-5136-1334-7.
21. Walter, T.; Sohn, M.D. A regression-based approach to estimating retrofit savings using the Building Performance Database. *Appl. Energy* **2016**, *179*, 996–1005, doi:10.1016/j.apenergy.2016.07.087.
22. Backlund, S.; Eidenskog, M. Energy service collaborations–it is a question of trust. *Energy Effic.* **2013**, *6*, 511–521, doi:10.1007/s12053-012-9189-z.
23. Deng, Q.L.; Zhang, L.M.; Cui, Q.B.; Jiang, X.L. A simulation-based decision model for designing contract period in building energy performance contracting. *Build. Environ.* **2014**, *71*, 71–80, doi:10.1016/j.buildenv.2013.09.010.
24. EMCA. *Energy Performance Contracting Cases (2011–2015)*; China Economic Publishing House: Beijing, China, 2017; pp. 3–625, ISBN 978-7-5136-4577-5.
25. State Grid Energy Research Institute. *2016 Analysis Report of Energy Saving and Electricity Saving in China*; China Electric Power Press: Beijing, China, 2017; pp. 8–10, ISBN 978-7-5198-0179-3.
26. Building Energy Conservation Research Center, Tsinghua University. *2017 Annual Report on China Building Energy Efficiency*; China Architecture and Building Press: Beijing, China, 2017; pp. 15–18, ISBN 978-7-112-20573-8.
27. Deng, Q.L.; Jiang, X.L.; Cui, Q.B.; Zhang, L.M. Strategic design of cost savings guarantee in energy performance contracting under uncertainty. *Appl. Energy* **2015**, *139*, 68–80, doi:10.1016/j.apenergy.2014.11.027.
28. EMCA. *EPC Industry Development Report (2011–2015)*; China Architecture and Building Press: Beijing, China, 2017; p. 59, ISBN 978-7-5136-4648-2.
29. Larsen, P.H.; Goldman, C.; Satchwell, A. Evolution of the U.S. energy service company industry: Market size and project performance from 1990–2008. *Energy Policy* **2012**, *50*, 802–820, doi:10.1016/j.enpol.2012.08.035.
30. Vendors as Industrial Energy Service Providers. Available online: http://aceee.org/sites/default/files/pdf/white-paper/vendors.pdf (accessed on 1 January 2018).
31. Goldman, C.; Hopper, N.; Osbom, J.G. Review of US ESCO industry market trends: An empirical analysis of project data. *Energy Policy* **2005**, *33*, 387–405, doi:10.1016/j.enpol.2003.08.008.
32. Thirteenth Five-Year Plan for Energy Conservation and Environmental Protection Industry. Available online: http://hzs.ndrc.gov.cn/newzwxx/201612/t20161226_832641.html (accessed on 19 December 2017).