Analyzing Principal-Agent Problem on Energy Use and Energy Efficiency Retrofit from selected Governmental Buildings in Beijing

Zhijun Liu

University of California, Davis

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1. Introduction

Energy efficiency issues have been highlighted by the Chinese government since 2004 due to concerns on national energy security and the responsibility of global climate change mitigation. Based on the China 2004 energy statistic data, building consumed 25.5% of the total national energy, and it was estimated that building has the greatest potential for energy conservation. Though the average building energy consumption (J/m^2) in China is much lower than that in developed countries, some preliminary field investigations have shown the energy usage in large public governmental buildings was much higher than the average level, or even exceeds three to five times. In order to obtain a clear "picture" of energy consumption in these buildings, as well as to provide available building energy consumption data for energy policy makers, from 2005 to 2008, a comprehensive survey was conducted under the guidance of the Chinese Government of Development and Reform Committee to investigate the energy usage in large public governmental buildings in Beijing. After the data survey, several retrofit projects were executed to reduce energy consumption level.

The author was involved in this survey project as an engineer from the China Academy of Building Research. The investigated data is far beyond the author's expectation: the density of energy consumption is much higher than the average level compared to other similar buildings. Besides the technique aspects, including mismatching design, inefficient equipments and unreasonable operation, other measures should be applied to analyze this phenomenon for different perspectives. One of the perspectives is to utilize "Principal-Agent" (PA) theory to study this phenomenon, and to identify PA problems in energy use and energy efficient retrofit. In this report, the author attempts to investigate this phenomenon from "Principal -Agent" perspective and analyze its effect.

The purpose of this paper is to characterize the PA problems involving in energy use, energy efficiency retrofit in these surveyed governmental buildings so as to evaluate the effect of PA problems. The data used for this analysis is from part of that survey data.

2. Methodology and Data

2.1 Principal-Agent problems in Energy Efficiency

Agency theory addresses that when the principal and the agent in a contract have split incentives, goals, or different levels of information, principal-Agent (PA) problems arise. In general, the principal is the party who pays the agent, the other party, for good and service. Correspondingly, the agent acts on the principal's behalf or provide some service.

Agency theory can be applied to energy efficiency field, and the PA problem does exist in energy efficiency area. Based on the fact that whether end users can choose technology or they pay energy bills, four types of PA problems in energy efficiency are summarize in table 1.

Table 1 The four cases of Principal-Agent problem

	End user can choose technology	**End user cannot choose technology**
End user pay energy bills	Case 1 (no PA problem)	Case 2 (efficiency problem)
End user does not pay energy bills	Case 3 (use problem and efficiency problem)	Case 4 (use problem)

The methodology of this study is to use Agent theory to identify PA problems in energy end-use and energy efficiency retrofit for large governmental buildings. To be specific, this paper firstly describes the relationship between principal and agent to identify the PA problems, and then analyze their incentives for energy efficiency and the impact of asymmetrical information. At last, the effect of PA problems is estimated.

2.2 Basic information for the surveyed governmental buildings

Surveyed energy usage data from ten governmental buildings in Beijing were chosen for this study.

Basic information of these ten buildings is summarized in table 2, and the sum-up energy consumption is shown in table 3.

Table 2 Basic Information of the Ten Governmental Buildings

Building Names	Number of Buildings	Construction and Retrofit Time	Area (m^2)	Number of Occupants
A	1	1998	14818	462
B	6	1903～2001	55785	1986
C	3	1955～2000	43700	650
D	4	1984～1993	12800	400
E	1	1987～1992	37050	548
F	1	1999	45000	890
G	1	1990	13403	1198
H	6	1904～1952	11400	374
I	8	1983～2001	51637	1334
J	4	1980～2003	27956	810
Total	35	/	313549	8352

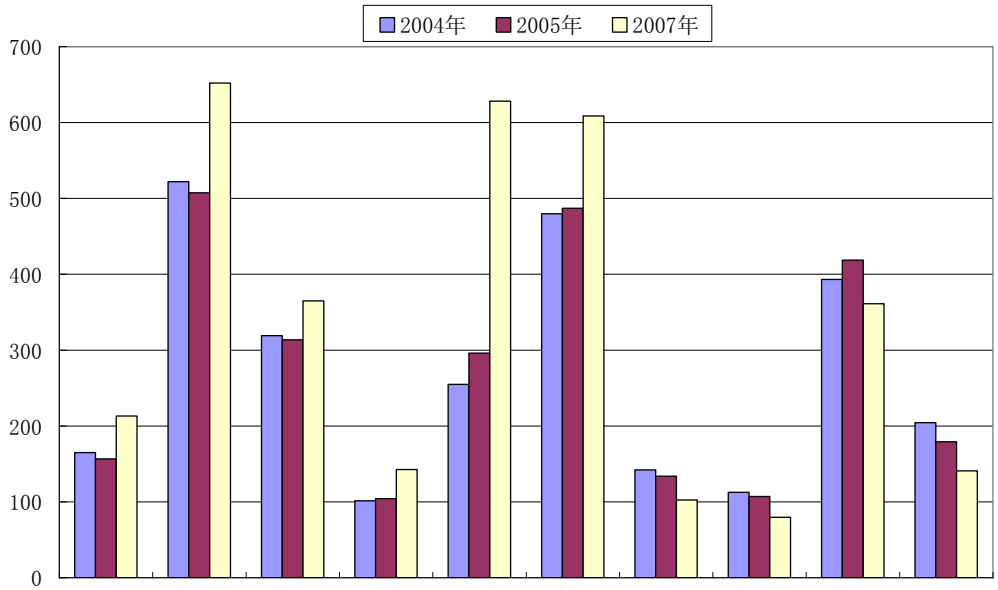
Table 3 Summary of Total Energy Consumption in Ten Governmental Buildings

Energy / Year	Electricity （M kWh）	Natural gas (m^3)	Fuel (t)	Thermal (GJ)	Total (tce)
2004	26.943	198419	586	Heating Area 187674m^2	4408
2005	27.026	235162	338.03	Heating Area 187674m^2	4101

2007	32.928	225983	440.89	Heating Area 63936.9	4965

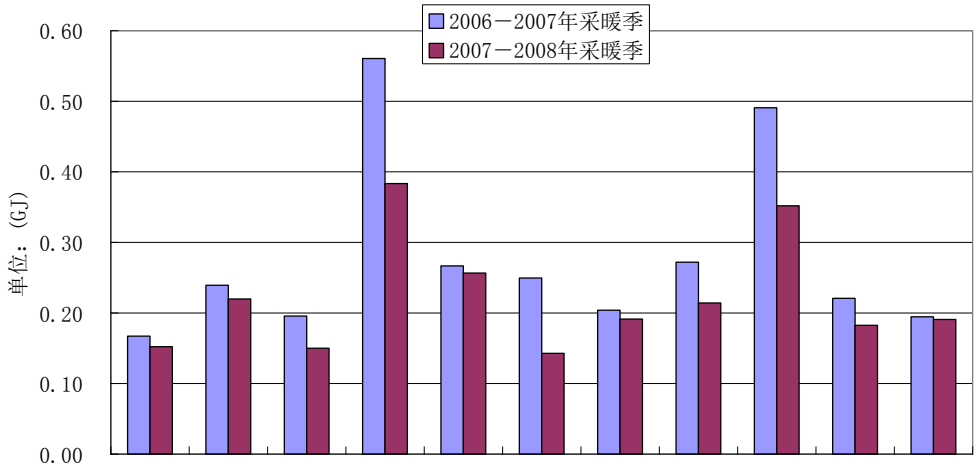
The energy efficiency retrofit of these ten buildings was done at begin of 2007. Electricity and thermal consumption data was collected before and after retrofit. The data in figure 1 and figure 2 dose not illustrate a significant reduction for energy consumption before and after retrofit. Some buildings even consumed more electricity after the retrofit. A variety of causes contribute to this phenomenon, one of which is the increase of new appliance, equipments for the preparation of 2008 Beijing Olympic Games. The thermal energy consumption for heating decreased after retrofit, but not significant in all these buildings.

Figure 1 Electricity usage data in the ten buildings before and after retrofit



Note: the y axis unit is 10^4 kw, data in 2007 is from after retrofit

Figure 2 Thermal energy consumption in the ten buildings before and after retrofit



All the governmental buildings are state-owned. Governmental officers and staff are the user of these buildings and the cost of building construction, retrofit and maintenance, as well as energy bills are paid by the funds of financial allocation.

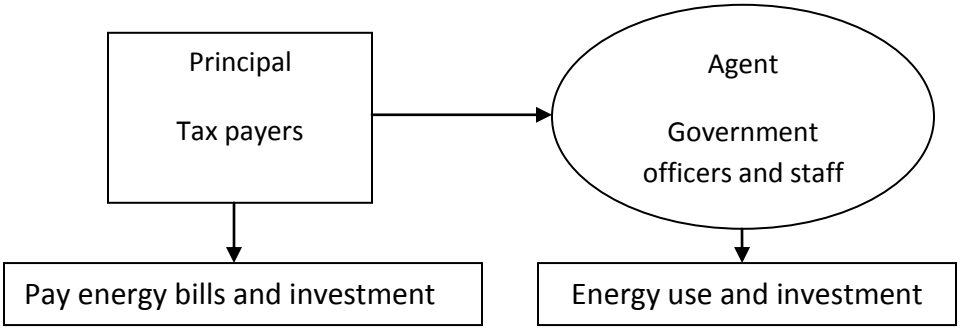
The retrofit data indicates that it might be inadequate to solve the energy efficiency problem in governmental buildings merely rely on engineering retrofit or replace for inefficient equipments. More studies are required to investigate this problem from other perspectives, and identification of PA problems in the end-energy use and retrofit would be useful to solve this problem.

3. PA Problems identification and analysis

3.1 Identification of PA problems in energy end-use

Since the governmental buildings are state-owned, the cost of construction, retrofit and maintenance, as well energy bills are paid by governmental financial allocation. The energy end-users are the governmental officers and staff. It is easy to identify the PA problem in this case. The principal is the tax payers or financial allocation; the agent is the governmental officers and staff. In addition, in this case, the energy users have the right to choose energy technologies and to make decision for the energy investment under the guidance of financial allocation. The relationship between the principal and the agent is illustrated in figure 3.

Figure 3 PA problem in energy end-use

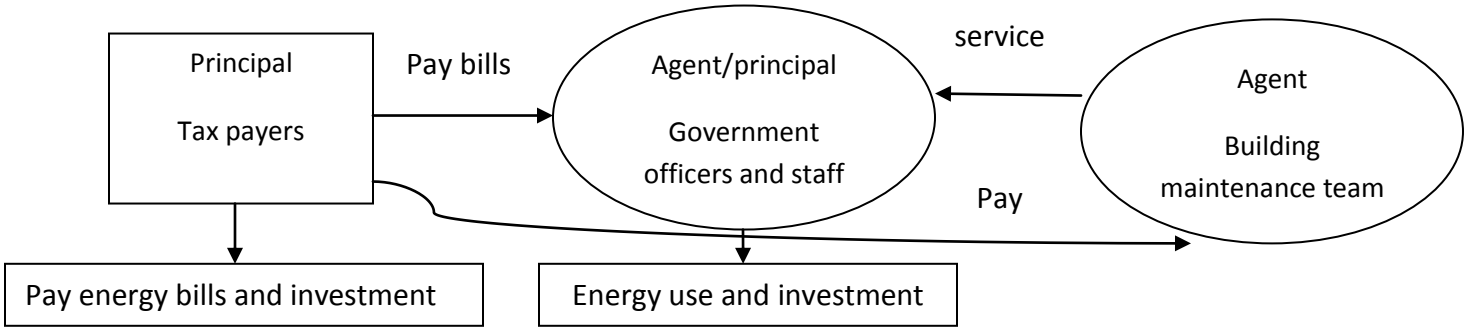


Use problem and efficiency problem will occur in this case since the agent is the energy user and also has right to choose technology, while they don't need to pay the bills and investment.

This is the simplest case for energy end-use in governmental buildings. In order to get insight into this phenomenon, another party needs to be identified: the building maintenance team (BMT). The BMT is responsible for the operation of whole building and monthly or yearly energy data collection. In most cases, the BMT is a part of the governmental staff, that is, they get paid from governmental financial allocation based on their service provided for building maintenance. In general, the BMT is the executor, has little right for energy investment decision-making--- the government officers are responsible for the investment.

There is another case that the BMT is not a part of governmental staff, they are temperately hired workers from the society. In this situation, the principal is government officer and the agent is the BMT. The BMT mainly concerns the safety operation of the buildings, not the energy bill payment and energy investment. Safety and easy to operation are their considerations when they make suggestions to the government officers about the energy investment. Also, sometimes they will cater to the officer for luxury investment to obtain high level comfortable indoor environment other than the economical of the investment. This relationship is shown in figure 4.

Figure 4 PA problems in energy use



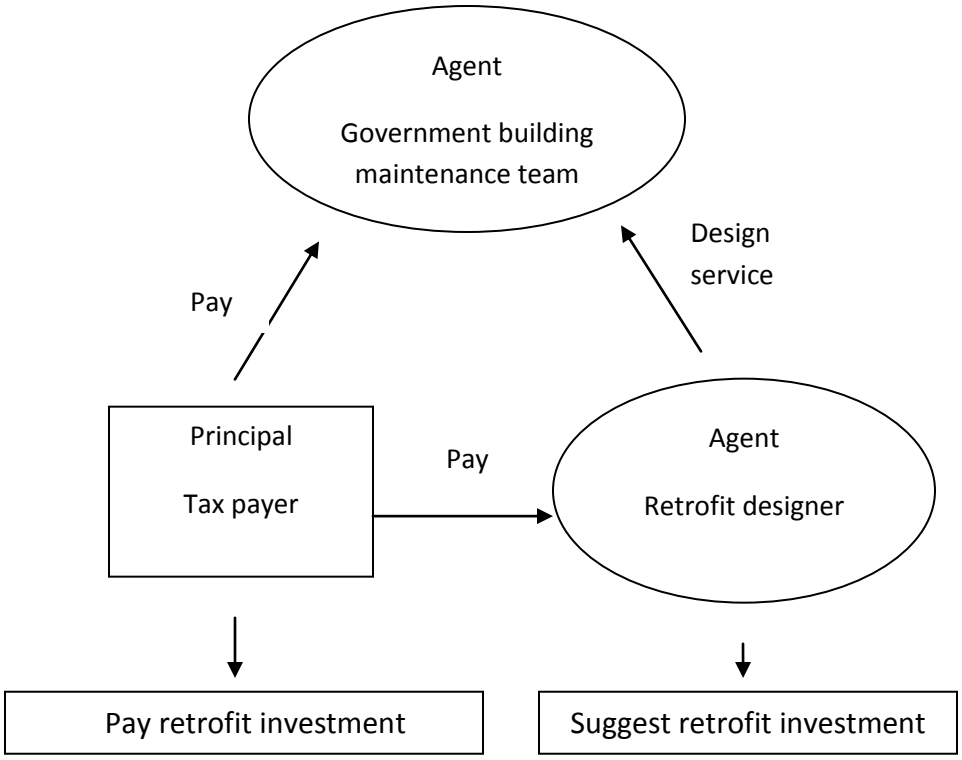
3.2 Identification of PA problems in the retrofit of governmental buildings

The energy efficiency retrofit was conducted after the energy data survey to energy consumption in these governmental buildings. The PA problem in retrofit process is more complicated since several parties are involved in.

In general, efficient problem occurs in the retrofit process. In order to investigate this PA problem, the parties involved in energy efficiency retrofit are identified first. These parties include the government officers and staff occupied in the buildings who use energy and make decision for energy investment; the tax payers who pay energy bills and investment /retrofit cost; the building maintenance team who are responsible for the retrofit execution and management; the retrofit designers who offer retrofit blueprints and design techniques; the equipments providers who provide “energy efficient” products as well as the installation of their equipments. The relationship between the retrofit designer and the building maintenance team is present in figure 5.

The retrofit designer gets paid from the government officer by providing retrofit blueprints and technique support. Usually, the design fee is calculated based on a rate of the total investment of retrofit, saying 5% or 10%. The total investment of retrofit is largely depended on the cost of retrofit equipments.

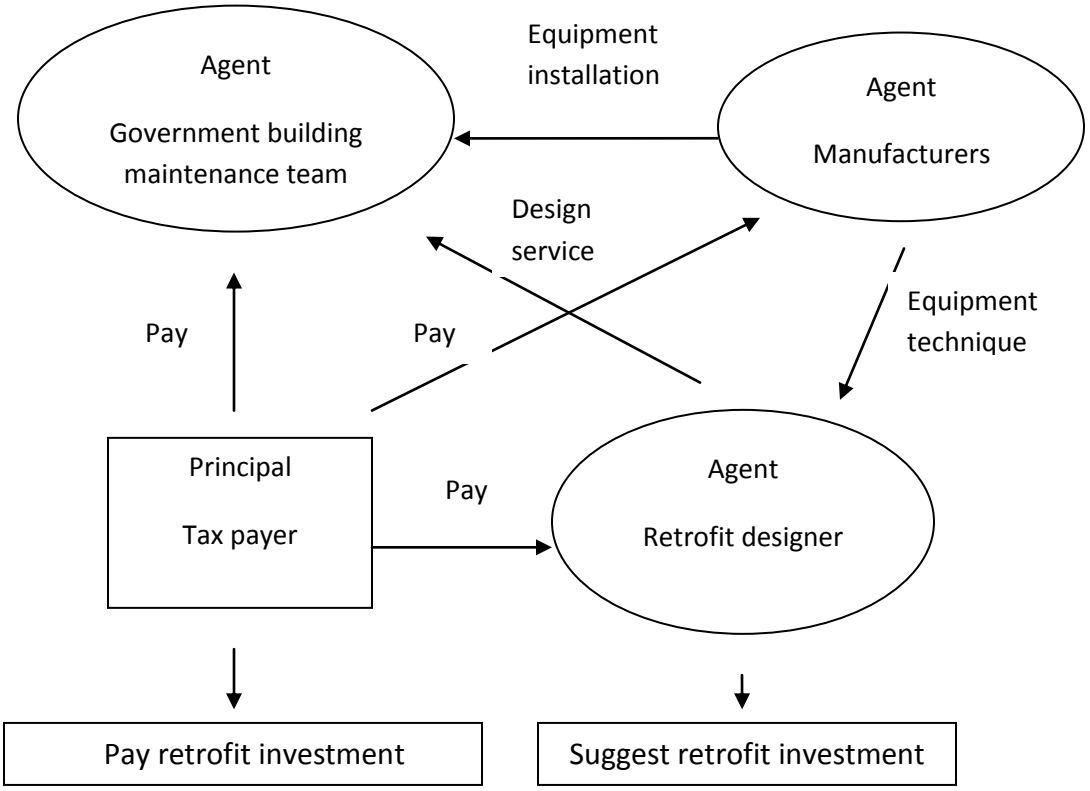
Figure 5 PA problems in retrofit design



The manufactures provide equipments and installation for the energy efficient retrofit, and at the same time provide equipment techniques to the retrofit designers.

When considerations are involved in retrofit activities, the transaction process becomes much complicated. As illustrating in figure 6, the principal is the tax payer, all others are agents, but these agents have different roles and authorities to make decision. The governmental officers are the decision maker for the retrofit objectives, and pay the other agents by financial allocation. These are both use problem and efficiency problem.

Figure 6 PA problems in retrofit



3.3 Incentives and information asymmetry

Due to all the agents, including governmental officers and staff, building maintenance team, retrofit designer, and retrofit equipments provider, get paid from the only principal, tax payer, who is an "imaginary" figure, the PA problems exist in the whole energy use and efficient retrofit. This can be manifested by incentives analysis and discussion on information asymmetry.

The governmental officers and staff are the energy users and energy efficiency decision makers, but they do not need to pay energy bills and investment, thus, they usually have little incentive for energy conservation. Also, they know little information about the energy efficient equipments for retrofit. What they concerns are the comfortable office environment provided by the building energy consumption system.

So far as the incentive of governmental building maintenance team, though they are responsible for the retrofit projects, they may not concern too much on the energy

efficiency issues, since they do not pay the energy bills. Their incentives are to ensure the safety operation of energy systems and easy to operate equipments. Cost and energy efficiency are not their concerns.

The retrofit designer is more likely to focus the revenue of design. If the design fee is based on a fixed rate of the total retrofit cost, the designer tends to choose more expensive or larger size equipments to gain more design fee. In addition, they tend to design "big size" system or choose "big size" equipments to reduce the risk of design failure and to increase their design fee.

The manufacturers provide equipments for retrofit and are responsible for the installation. They claim their equipments are energy efficient, which true information is hardly informed to the governmental officers and designers. The manufactures get paid directly from the governmental officers but actually indirectly from the tax payer since all the energy bills and investment are paid by tax payers. The manufacturers aim to sell their products, and the energy efficiency is not critical if the purchaser (the government officers) concern more on safety, comfortable other than energy efficiency.

The information asymmetry is manifested on the delivery of energy efficient equipments. The manufacturers have more energy efficient information on their products, and they always claim their products are energy efficient, but the other parties like designers, building maintenance team, and governmental officers know little about the true information for these equipments. Even it is required to choose energy efficient equipments for retrofit, the final selected equipments cannot guarantee to be energy efficient due to information asymmetry and split incentives.

3.4 Quantify PA problems for energy use and efficient retrofit

It would be easy to qualify the PA problem for energy use and efficient retrofit if the data for energy consumption and retrofit cost are available. This is because the PA problem exists in the whole process of energy use and efficient retrofit. The underlying cause is the absence of principal: tax payer is an "imaginary" person whose rights and authority

for decision-making are replaced by the agent: governmental officer. In this paper, due to a lack of adequate data, the PA problem quantifying process is not conducted.

4. Conclusion and Recommendation

In this paper, the relationships between principal and agent are analyzed to identify the PA problems by "following the money "in transactions, and the incentives and information asymmetry involved in the PA problems were discussed and concluded.

In sum, PA problems are prevalent in governmental buildings for energy end-use and energy efficient retrofit. All the agents, including governmental officers and staff, building maintenance team, retrofit designers and retrofit equipment manufacturers have little incentive for energy efficiency. The information on energy efficient equipments and system design are asymmetrical distributed between these agents.

The underlying cause for the prevalence of PA problems in governmental buildings is due to the absence of principal. Tax payer is the principal but it is an "imaginary" person whose rights and authority for decision-making are replaced by the agent: governmental officers.

In order to solve PA problems for energy use and energy efficient retrofit in governmental buildings, a variety of recommendations can be addressed. However, the most important is to let the principal—the tax payer has more rights and power to supervise the decision-making agent—the government officers to ensure they have responsibilities for their energy usage and investment.

5. References

[1] Mind the gap- quantifying Principal-Agent Problems in Energy Efficiency

[2] Energy consumption data survey for ten governmental buildings in Beijing

[3] Lecture notes from Dr. Alan Meier's energy efficiency class.