UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Energy Performance Contracts in Imperfect Markets: A Study on Energy Efficiency Retrofits of Commercial Buildings in China

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Certificate of Authorship/Originality

I, Shiyu Wan, certify that the work in this thesis has not been previously submitted for a degree nor has it been submitted as a part of the requirements for any other degree except as fully acknowledged within the text. This research is supported by the Australian Government Research Training Program.

I also certify that this thesis has been written by me. Any help that I have received in my research and in the preparation of the thesis itself has been fully acknowledged. In addition, I certify that all information sources and literature used are quoted in the thesis.

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Publications

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Journal Papers:

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Wan, S., Liu, Y. Ding, G., Runeson, G. & Er M. 2022, 'Risk Allocation for Energy Performance Contract from the Perspective of Incomplete Contract: A Study of Commercial Buildings in China'. *International Journal of Climate Change Strategies and Management*. Vol. ahead-of-print No. ahead-of-print.

Presentations in International Conferences:

Wan, S., Ding, G., Runeson, G. Er M. & Liu, Y. 2020, 'Develop a system dynamic model of the risk allocation of commercial building energy efficiency retrofit under energy performance contract in China'. *Pacific Rim Real Estate Society (PRRES) Conference 2020*.

Wan, S., Ding, G., Runeson, G. Er M. & Liu, Y. 2019, 'A Dynamic Model of Risk Allocation of Energy Efficiency Retrofits under Energy Performance Contract for Office Buildings in China', *Abstract Proceedings of 2019 International Conference on Resource Sustainability - Cities (icRS Cities)*.

Abstract

Energy consumption in buildings has become an important issue in China. As major energy consumers, commercial buildings have become the target for energy efficiency retrofit. An energy performance contract (EPC) is a new mechanism which offers a series of retrofit strategies by energy service companies. EPCs are a tested and effective mechanism to improve energy efficiency, however they have not been widely used in the current building energy efficiency market. To establish why the market has not reacted as expected, this research examines the nature and characteristics of the EPC market, and then proposes an incentive mechanism to encourage the uptake of EPCs in the market of commercial building energy efficiency retrofit in China.

The research had three research questions: i) What are the market barriers to the uptake of EPCs in the commercial building energy efficiency retrofit market, ii) What are the reasons contributing to these market barriers and iii) How can the uptake of EPCs in the commercial building energy efficiency retrofit market be incentivised. The research followed a quantitative paradigm to test the existence of market imperfections as defined in microeconomic theory. Multiple research methods including qualitative and quantitative practices were applied to collect data. A questionnaire survey and interviews were used to test the existence of market imperfections in the EPC market. The argument that the EPC market suffers from different kinds of imperfections is supported by empirical findings and the policy implications are discussed. Lastly, based on potential strategies identified through interviews, a detailed incentive mechanism for the EPC market is developed from the conceptual framework of transaction costs defined in institutional economic theory. Two case studies selected from demonstration cities of pilot EPC projects in China demonstrate the successful application of such incentives and identify shortcomings. The analysis of case studies provides support for implementing the incentive mechanism proposed in this research to boost EPC uptake and help the market become more competitive.

The barriers to the EPC market have been fully investigated using formal models in economic theory. The research formalises the economic characteristics of the imperfect EPC market from three perspectives: incomplete information, market power and externalities. These three perspectives reveal the nature of the EPC market in a theoretical and holistic way. Adapting the theory of transaction costs as a tool to deal with the imperfections, these market imperfections are addressed by policy design. In the long term, policies of energy price and carbon tax are theoretically suitable. Strategies of information disclosure, particularly energy performance benchmarking, and reforming the existing financing system are identified as necessary for the market. Subsidies and energy consumption limits are identified as useful in the short term. The research outcome shows the nature of energy efficiency market under EPCs and provides policymakers with a framework for generating market incentives in the EPC market and offers information to stakeholders on the current market situation. The findings have the potential to boost the uptake of EPCs and improve the energy efficiency of commercial buildings in China.

Key words

Energy performance contract (EPC), energy efficiency market, building energy efficiency retrofit, commercial buildings, market barriers, market imperfections, transaction cost, policy design

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List of Abbreviations

ANOVA	Analysis of variance
BEER	Building energy efficiency retrofit
BEPBD	Building energy performance benchmarking and disclosure
BO	Building owner
CABEE	China Association of Building Energy Efficiency
CBEER	Commercial building energy efficiency retrofit
CHURDCQ	Commission of Housing and Urban-Rural Development of Chongqing, China
CNY	Chinese Yuan
CSTID	Centre of Science & Technology and Industrialisation Development, China
ECMP	Energy consumption monitoring platform
EITC	Economic and Information Technology Commission, Shanghai
EMC	Energy management contract
EMCA	ESCO Committee of China Energy Conservation Association
EPC	Energy performance contract
ESCO	Energy service company

FYP	Five-Year Plan
Gov	Government
HREC	Human Research Ethics Committee
HVAC	Heating, ventilation, and air conditioning
IE	Independent expert
LEED	Leadership in Energy and Environmental Design
LSD	Least significant difference
MOF	Ministry of Finance, China
MOHURD	Ministry of Housing and Urban-Rural Development of the People's Republic of China
MSB	Mean square between
MSE	Mean square error
M&V	Measurement and verification
PCA	Principal component analysis
R&D	Research and development
SCD-URLCMC	Shanghai Changning District Urban Renewal and Low Carbon Project Management Centre
TCs	Transaction costs
tce	tonne coal equivalency
USD	USA dollar