2019

Essays on Environmental, Energy and Land Economics in China

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Dissertation submitted

to the Davis College of Agriculture, Natural Resources and Design

at West Virginia University

in partial fulfillment of the requirements for the degree of

Doctor of Philosophy in

Natural Resource Economics

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2019

Keywords: Environment Pollution, Emission Regulation, Housing Values, Institutional Experiment, Electricity Consumption, Metropolitan Growth, Information structure, Contractual Choice, Propensity Score Matching, China.

ABSTRACT

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This dissertation consists of three essays involving environmental pollution, electricity consumption, and farmland leasing in China. These economic analyses are linked by their inclusion of institutional changes which have occurred in China over the past half-century. The first essay examines the effects of environmental pollution and institutional abatement targets on real average housing prices in China. The Spatial Difference-In-Difference model shows that the overall effect of 2006 SO_2 institutional abatement targets is to increase real average housing prices across provinces. The changes in both emissions of sulfur dioxide and industrial wastewater discharges have negative impacts on the change of real average housing prices.

Essay two considers one of the most important issues in electricity consumption research, namely, the electricity consumption function. This research demonstrates that metropolitan electricity consumption is a function of economic output and electricity consumption habits along with the electricity demand management reform.

Finally, the third essay develops a theoretical model to identify optimal farmland contracts. Under complete information, a fixed-rent contract is the optimal institutional arrangement from land lessor’s perspective. Conversely, a share contract is the best choice for land lessor under incomplete information. The empirical results show that the farmer who leases farmland to external individuals has a lower probability of choosing a fixed-rent

contract. However, the farmer who leases farmland to internal individuals is less likely to choose a share contract.

Acknowledgments

I would like to thank my major advisor, Alan Collins, for his guidance and support throughout my years at Morgantown. I also want to thank other members of my dissertation committee: Xiaoli Etienne, Mark Sperow, and Bryan McCannon. Dr. Etienne provided me very valuable comments on my dissertation. She taught me econometric method by which I applied to my dissertation. Her suggestions help to greatly improve the quality of my paper. Dr. Sperow hosted my qualifying exam. I'm grateful for his encouragement and advice not only on my qualifying exam preparation but also writing the dissertation. At the same time, my sincere appreciation goes to Dr. McCannon, who was my professor of microeconomic theory. From his comments and insights, this dissertation becomes richer in scope and more rigorous in analysis.

I also want to thank to my parents, friends, and classmates, from whom I gain help and encouragements. Finally, I want to thank my wife and son. This dissertation is dedicated to you.

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Chapter 1: Introduction

This dissertation combines research on three essay topics involving institutional economic analyses within China. The first essay examines the impacts of province level pollution and institutional abatement targets for SO_2 on housing prices throughout the country of China. The second one determines how economic output and electricity demand management reform affect metropolitan electricity consumption in Guangzhou, China. Finally, the third essay emphasizes on the effect of information structure on farmland contractual choice in Canton of China.

The objective of the first essay in Chapter 2 is to examine the effects of pollution and institutional abatement targets on housing prices in China. Three econometric models are examined: Fixed Effects, Spatial Fixed Effects and Spatial Difference-In-Difference. So, I ask three questions: (1) How do water pollution discharges and air pollution emissions impact real average housing prices in China? (2) Do institutional abatement targets for air pollution increase real average housing prices? (3) How consistent and robust are the different econometric approaches in assessing the impacts from questions (1) and (2)?

To answer these questions, I provide a theoretical demand-supply framework and empirical evidence to show how environmental pollution and regulatory targets in SO_2 emission abatement affect real average housing prices on a province level. The theoretical framework reveals that environment pollution has a negative impact on real average housing prices, and the empirical results show that emission regulation targets have a positive impact on housing prices. The empirical results are consistent and robust across the three models. In terms of the empirical results, theoretical expectations for SO_2 emissions and discharges of industrial wastewater are both confirmed in Fixed Effects Models and

Spatial Fixed Effects Models, which are consistent with theoretical implication above. Moreover, the empirical results from an institutional experiment of different regulatory targets by province demonstrate that the institutional abatement targets drive up real average housing prices in China.

In Chapter 3, the purpose is to investigate the effect of economic output on electricity consumption. This effect is examined under electricity demand management reform by setting up a dynamic optimal control model in order to derive a basic electricity consumption function. So, I ask three questions: (1) What is the relationship between electricity consumption and economic output? (2) If economic output increases, will that cause more electricity usage? (3) How does reform of electricity demand management impact electricity consumption?

To answer these questions, I set up a theoretical model showing that electricity consumption is a function of economic output and electricity consumption habits. Based on this model, I design an institutional experiment using the kink regression discontinuity approach to investigate the effect on electricity consumption from the 1985 electricity demand management reform that occurred in Guangzhou. The empirical results demonstrate three findings: (1) a unidirectional Granger causality running from economic output to electricity consumption; (2) previous electricity consumption habits have a "path dependent" effect on current electricity consumption; and (3) given electricity demand management reform, economic output drives up the electricity consumption.

The objective of the final essay in Chapter 4 is to examine the effect of information structure on the farmland contractual choice behavior. Based on this idea, I ask five questions: (1) What is the relationship between information structure and farmland contractual choice? (2) Under what kind of information environment would fixed-rent contract be preferred as the optimal leasing arrangement? (3) Under what kind of condition would land lessor choose a share contract rather than a fixed-rent contract? (4) How does the information structure affect farmland contractual choice? (5) What methods can be used to examine the effect of information structure on farmland contractual choice?

To answer the questions above, I first build a theoretical model to identify the optimal farmland contract. I show that under complete information, land lessor chooses fixed-rent contract as the optimal institutional arrangement. The share contract is the best choice for land lessor under incomplete information. Second, I test the theoretical hypothesis using a data set of farmland contracts in Canton, China. If an internal individual (inside their village) represents a tenant who is under complete information and an external individual (outside their village) represents a tenant who is under incomplete information, then the empirical results by Logit Model and Propensity Score Matching Model both show that the farmer who leases the farmland to tenants outside the village has a lower probability of choosing a fixed-rent contract compared to the farmer who leases to external tenants and is more likely to choose a share contract. In addition, the farmer with higher agricultural income ratio is more likely to choose a fixed-rent contract, while the farmer with lower agricultural income ratio is more likely to choose a share contract. The results support the theoretical model’s hypothesis that information structure affects farmland contractual choice.

Chapter 2: The Impacts of Environmental Pollution and Institutional Abatement Targets on Housing Prices in China

2.1 Introduction

Across the world, housing assets are a critical source of wealth for many households and an important determinant of consumption within economies. This means that home values, and therefore housing prices, are important to both households and economic policymakers. Housing prices are affected by numerous factors (Rogers 2006; Cho et al. 2009; Ahmed et al. 2010; Sanjuán et al. 2015). In recent literature, the relationships between influential factors and housing prices have been found to vary substantially across countries and regions (Bjørnland and Jacobsen 2010; Gupta et al. 2010; Teng et al. 2013; Lai et al. 2014; Lee and Song 2015). Econometric research indicates that the impact on housing prices frequently yields notably different results. For instance, Du et al. (2018) have found that energy consumption drives up real average housing price, while Sun and Tsang (2018) argue that regulation and monetary policy impact housing prices. So, the key question is: which factors influence housing prices most significantly? In terms of the general model on housing, the literature recently emphasizes assessing the housing policy effect on the housing markets (Aoki et al. 2004; Del Negro and Otrok 2007; Kajuth 2010; Bofinger et al. 2013).

On the other hand, the empirical research focuses on the applying the spatial econometric approach to housing markets (Anselin and Lozano-Gracia 2008). They find that spatial variations in house prices are considerable. It is demonstrated that regional house price spatial variations can indeed largely be explained by characteristics of the residential environment (Visser et al. 2008). In addition, Cho et al. (2009) show that the value of proximity to greenways, parks, and water bodies increases over time, while the value of lot size and proximity to golf courses falls. Du et al. (2018) suggest that energy consumption has increased housing sales in China from 2004 to 2015, utilizing an optimal dynamic general equilibrium theoretical framework combined with a spatial economic model.

Additionally, the research on the nexus between environmental regulation and housing market has been conducted (Kiel 2005; Kuethe and Keeney 2012; Currie et al. 2015; Tian et al. 2017). For instance, Jim and Chen (2006) find that views of green spaces and proximity to water bodies raise housing prices. The outdoor environmental quality influences house-buyers' preferences and purchase decision (Jim and Chen 2007). Other scholars have observed consumer housing purchase behavior in China through choice experiment method (Wang and Li 2006). Wang et al. (2015) have found that the environmental characteristics have obvious positive impacts on housing prices of cottages and villas. Wu et al. (2015) have found sulfur dioxide emissions are negatively associated with average housing prices in China from 1993 to 2011. But they do not examine the effect of water pollution on housing prices. So, I will assess the effects of air pollution and water pollution on real average housing prices in China.

In terms of the research on environmental regulation in China, Xu (2011) utilizes the goal of a 10% reduction of sulfur dioxide emissions in China's 11th Five-Year Plan (2006–2010). Based on Xu's (2011) study, Shi and Xu (2018) find that in more pollution-intensive industries, stricter environmental regulation reduces both the probability that a firm will export and the volume of exports.

However, there has been limited attention in economic literature devoted to investigating the effects of institutional abatement targets and environment pollution on real average housing prices in developing countries. Moreover, there is no literature regarding estimating the effects of air pollution and water pollution on housing prices. So, the objective of this essay is to examine the effects of both air pollution and water pollution integrating institutional abatement targets, based on different kinds of econometric models, such as Fixed Effects Model, Spatial Fixed Effects Model, and Spatial Difference-In-Difference model. In this essay, I focus on the impacts of environmental pollution and institutional abatement targets on housing values in the theoretical model, using panel data in China. I ask the following questions: (1) How do water pollution discharges and air pollution emissions impact real average housing prices across provinces in China?(2) Do institutional abatement targets for air pollution increase real average housing prices? (3) How consistent and robust are different econometric approaches in assessing the impacts from questions (1) and (2)?

Furthermore, most of literature evaluating the effect of pollution on housing prices mainly uses hedonic model, and the current studies do not consider the spatial effects. But in this essay, the impacts of institutional abatement targets and environmental pollution on real average housing prices in China will be examined by a demand and supply framework integrating spatial effects. Combining with this framework, I introduce an econometric modeling strategy to derive empirical implication regarding the relationship among real average housing prices, pollution, and emission regulation targets. In order to test the implication, I utilize Fixed Effects and Spatial Fixed Effects Models, combining with institutional experiment to analyze the impacts of the environmental pollution and institutional abatement targets on real average housing price in China. Province level data are used from 1998 to 2015. Hence, this essay contributes to the existing literature by examining the effects of institutional abatement targets and environment pollution on the real average housing prices in China. So, my contributions are following: (1) providing a new econometrical framework on the effects of environmental pollution and institutional abatement targets on real average housing prices, (2) designing an institutional experiment integrated spatial factors to access the impact of institutional abatement targets on real average housing prices, and (3) distinguishing and examining both water and air pollution impacts on real average housing prices.

This introduction section provides a brief overview of prior research analyzing the housing prices. These previous studies cover various sample periods and geographical regions, and employ somewhat different theoretic models and empirical methodologies. The structure of sections 2.2 and 2.3 covers theory development and subsequent methods following the pathways shown in Figure 2.1. In section 2.2, I outline the framework applying the econometric model of demand and supply with the environmental variable in the determination of the real average housing prices. In Section 2.3, I present the data utilized in the analysis. The impacts on real average housing prices are examined at the end of this section. Section 2.4 presents conclusions and further discussion.

2.2 Theoretic Framework and Empirical Models

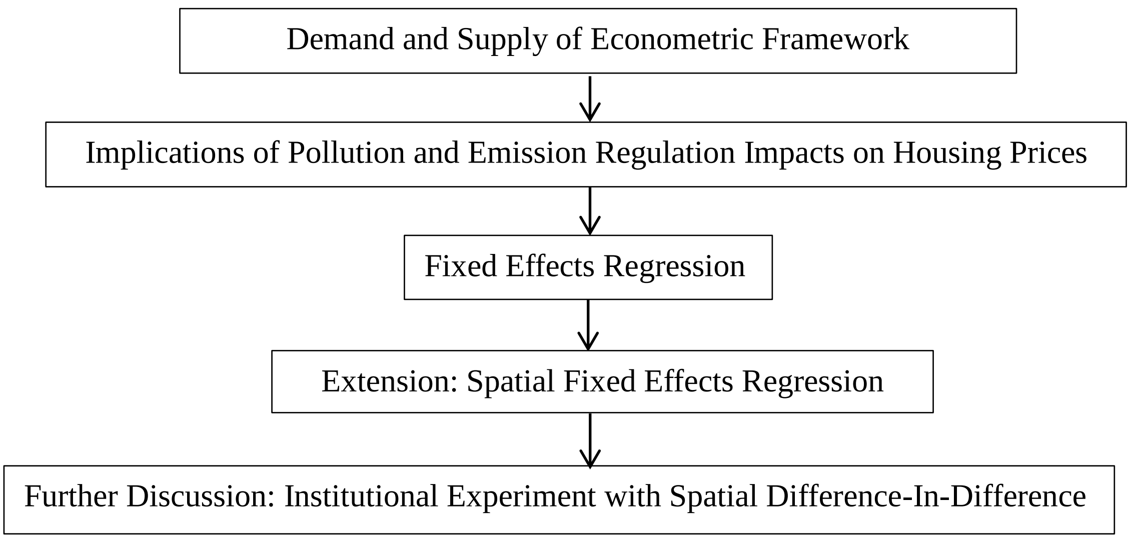

Figure 2. 1: Structural Flow Chart of the Theory and Econometric Methods Utilized in Chapter 2

Following the theoretical framework of Chow and Niu (2015), I utilize a multiplicative equations model based on the demand and supply of Chinese housing markets. I let *i* denote the province and *t* the time-period. The multiplicative inverse demand and supply equations can be written as:

Multiplicative Inverse Demand:

$$RAHP_{it} = e^{a}(Q_{it}^{D})^{-b}(POLLUTION_{it}')^{-h}(I_{it})^{f}(UR_{it})^{g}e^{u_{it}^{D}} \quad (2.1)$$

Multiplicative Inverse Supply:

$$RAHP_{it} = e^{m}(Q_{it}^{S})^{d}(BC_{it})^{j}e^{u_{it}^{S}} \quad (2.2)$$

where Q_{it} denotes housing space per capita and $RAHP_{it}$ denotes real average housing prices by province and year. u_{it}^{D} and u_{it}^{S} are error terms.

After taking the natural log of both sides for (2.1) and (2.2), I transfer multiplicative inverse demand function and supply function into linear inverse demand function and supply function as below:

Linear Inverse Demand:

$$\ln RAHP_{it} = \mathrm{a} - \mathrm{b}\ln Q_{it}^{D} - \mathrm{h}\ln POLLUTION_{it}' + f lnI_{it} + g lnUR_{it} + u_{it}^{D} \quad (2.3)$$

Linear Inverse Supply:

$$\ln RAHP_{it} = \mathrm{m} + \mathrm{d}\ln Q_{it}^{S} + \mathrm{j}\ln BC_{it} + u_{it}^{S} \quad (2.4)$$

In this research, I assume $lnPOLLUTION_{it}' = (lnpollution_{it}^{air}, lnpollution_{it}^{water})^{T}$ as a two-dimensional vector that contains the potential damage for human exposure to pollution–air and water (Gupta et al. 2008; Greenstone and Hanna 2014), which indicates the types of environmental pollution. As we know, a less desirable environment and poor quality of life attributes decrease the housing price per square meter (Visser et al. 2008; Wu et al. 2015). The other variables I_{it} denotes real disposable income per capita and

BC_{it} denotes the real average costs for real estate construction (Zahirovich-Herbert and Gibler 2014). As the extent of urbanization impacts demand for housing (Wang et al. 2017), UR_{it} denotes urbanization. Actually, rural migrants could obtain the urban Hukou (permanent urban resident license) through purchasing housing in urban area, so that rural migrants can acquire the social welfare including education and medical services in that area. So, in order to obtain relatively higher quality social services in urban area, rural migrants purchase housing and own a limited period (70 years) set of property rights to housing.

Both demand and supply equations are assumed to be approximated by linear relationships and in equations (2.3) and (2.4), the parameters *a, b, h, m, d, j, f and g* are positive. Using these assumptions, the equilibrium real average housing prices can be solved as:

$$lnRAHP_{it}^{*} = \frac{\mathrm{ad+mb}}{\mathrm{b+d}} - \frac{\mathrm{hd}}{\mathrm{b+d}} lnPOLLUTION_{it}' + \frac{\mathrm{fd}}{\mathrm{b+d}} lnI_{it} + \frac{\mathrm{gd}}{\mathrm{b+d}} lnUR_{it} + \frac{bj}{\mathrm{b+d}} lnBC_{it} + \frac{\mathrm{d}u_{it}^{D} + bu_{it}^{S}}{\mathrm{b+d}}$$

$$= A_0 + \beta lnPOLLUTION_{it}' + A_1 lnI_{it} + A_2 lnUR_{it} + A_3 lnBC_{it} + u_{it} \quad (2.5)$$

where $A_0 = \frac{\mathrm{ad+mb}}{\mathrm{b+d}}$, $\beta = -\frac{\mathrm{hd}}{\mathrm{b+d}}$, $A_1 = \frac{\mathrm{fd}}{\mathrm{b+d}}$, $A_2 = \frac{\mathrm{gd}}{\mathrm{b+d}}$, $A_3 = \frac{bj}{\mathrm{b+d}}$, and $u_{it} = \frac{\mathrm{d}u_{it}^{D}+bu_{it}^{S}}{\mathrm{b+d}}$

In order to estimate the effect of environmental pollution in equation (2.5) on housing prices and capture the fixed effects on province and time, I extend equation (2.5) and get:

$$lnRAHP_{it}^{*} = A_0 + \alpha_i + \mu_t + \beta lnPOLLUTION_{it}' + A_1 lnI_{it} + A_2 lnUR_{it} + A_3 lnBC_{it} + \varepsilon_{it} \quad (2.6)$$

where $\varepsilon_{it} + \alpha_i + \mu_t = u_{it}$. α_i captures all unobserved, time-constant factors that affect $RAHP_{it}$, which is individual fixed effect. The year effect, μ_t, is also treated as a parameter to be estimated. $\varepsilon_{\mathrm{it}}$ is the perturbation term varying with the province and time.

So, from equation (2.6), the effect mechanism of variable of interest ($\ln POLLUTION'_{it}$) on equilibrium real average housing prices ($lnRAHP^*_{it}$) is derived:

$$\frac{\partial lnRAHP^*_{it}}{\partial lnPOLLUTION'_{it}} = \frac{\frac{\partial RAHP^*_{it}}{RAHP^*_{it}}}{\frac{\partial POLLUTION'_{it}}{POLLUTION'_{it}}} = \frac{\partial RAHP^*_{it}}{\partial POLLUTION'_{it}} \frac{POLLUTION'_{it}}{RAHP^*_{it}} = \beta = -\frac{\mathrm{hd}}{\mathrm{b}+\mathrm{d}} < 0$$

The theoretical implication related to the equilibrium real average housing prices stems from the result shown above:

Implication The change of Environmental pollution has negative impact on the change of equilibrium real average housing prices.

According to the First Law of Geography, everything is related to everything else, but near things are more related than distant things (Tobler 1979). Based on this, housing prices will be spatially autocorrelated if there is relative locational dependency between housing prices, and location characteristics are important determinants of housing prices (Osland 2010). So, if I measure the spatial spillover effect from housing prices, the equation (2.6) can be extended into the Spatial Fixed Effects Model. In general, the basic spatial econometrics model that has been labeled SAR (Spatial Autoregression Model) is popularized by a great deal of the literature on statistical testing of alternative model specifications (LeSage 2014). Based on (2.6), the Spatial Fixed Effects Model can be expressed as:

$$lnRAHP^*_{it} = A_0 + \alpha_i + \mu_t + \beta lnPOLLUTION'_{it} + A_1 lnI_{it} + A_2 lnUR_{it} + A_3 lnBC_{it} + \rho w'_i lnRAHP_t + e_{it} \quad (2.7)$$

where $\rho w'_i lnRAHP_t + e_{it} = \varepsilon_{it}$, e_{it} is the residual for (2.7) and w'_{i} is the ith row of the spatial weight matrix $W = \begin{bmatrix} w_{11} & \cdots & w_{1n} \\ \vdots & & \vdots \\ w_{n1} & \cdots & w_{nn} \end{bmatrix}$. The coefficient of spatial autoregressive $\rho \neq 0$ is an unknown parameter which specifies the strength of correlation between co-located provinces. Error term e_{it} represents unobservable factors excluding spatial spillover effects. $w'_i lnRAHP_t = \sum_{j=1}^{n} w'_{ij} lnRAHP_{jt}$, w_{ij} represents the (i, j) element of the spatial weight matrix W; $\rho w'_i lnRAHP_t$ is the spatial lag item representing spatial autocorrelation. In terms of W, if province i and province j have a common border, then $w_{ij} = 1$, otherwise $w_{ij} = 0$. And the diagonal elements are 0, that is, $w_{11} = \cdots = w_{nn} = 0$, which means that the distance between the same province is 0.

Furthermore, as robustness test, in terms of the effect of institutional abatement targets on real average housing prices, the institutional abatement targets in province i and year t (PL_{it}), such as central government setting an abatement targets to reduce national emission by 10% on average, encourage the local governments to make efforts to regulate emission. Following Chay and Greenstone (2005), Wu et al. (2015) and Shi and Xu (2018), I specify the estimation of effect of institutional abatement targets on equilibrium real average housing prices altered from (2.7) as below (let $h = (h_1, h_2)$ and $\beta = (\beta_1, \beta_2)$):

$$lnRAHP_{it}^{*} = A_0 + \alpha_i + \mu_t + \beta_1 lnpollution_{it}^{water} + \beta_2 lnpollution_{it}^{air} + A_1 lnI_{it} + A_2 lnUR_{it} + A_3 lnBC_{it} + \rho w'_i lnRAHP_t + e_{it}$$

$$= A_0 + \vartheta_2 province_i + \vartheta_3 time_t + \beta_1 lnpollution_{it}^{water} + \beta_2 lnpollution_{it}^{air} + \vartheta_0 lnpollution_{it}^{air} PL_{it} + \vartheta_1 PL_{it} + A_1 lnI_{it} + A_2 lnUR_{it} + A_3 lnBC_{it} + \rho w'_i lnRAHP_t + \theta_{it} \quad (2.8)$$

where $PL_{it} = province_i * time_t$, $province_i$ is a group dummy variable equal to 0 for the province in which sulfur dioxide reduction target is below 10% and 1 for the province in which sulfur dioxide reduction target is at or above 10%, and $time_t$ is a stage dummy variable equal to 0 for 2001-2005 and 1 for 2006-2010. And $\vartheta_2 province_i + \vartheta_3 time_t + \vartheta_0 lnpollution_{it}^{air} PL_{it} + \vartheta_1 PL_{it} + \theta_{it} = \alpha_i + \mu_t + e_{it}$. θ_{it} is the residual for (2.8).

2.3 Empirical Analyses

2.3.1 Background and Data

Actually, China's residential real estate sector plays a substantial role in the economy and has been a key driver of the nation's economic growth (Yao et al. 2014). But there is a great deal of research which has explored the existence of housing price bubble problems inside mainland China (Shih et al. 2014; Bian and Gete 2015; Du and Peiser 2014; Du and Zhang 2015; Feng and Wu 2015; Huang et al. 2015; Ng 2015; Wen and Tao 2015; Wu et al. 2015).

On the other hand, in terms of regulations for air emissions in China, the Eleventh Five-Year Plan (2006-2010) was implemented by the China State Council, which only regards the regulation of sulfur dioxide emission but does not refer to water pollution problem (Xu 2011). In order to achieve this regulation goal, the Chinese central government set a national sulfur dioxide reduction target of 10% at the provincial level (Shi and Xu 2018).

In order to test the relationship between pollution, air regulation, and housing prices in China, I conduct an empirical analysis at the province level. Annual data from 1998 to 2015 were extracted from the China statistical yearbook from 1999 to 2016 and Economy Prediction System (EPS) database. However, I exclude the data from Tibet province, because of missing data. Hence, there are 30 provinces in the sample. According to implication in theoretic section, I follow the measurement for housing prices in China from Feng and Lu (2013) and Huang et al.(2015), so I let the dependent variable be annual real average housing prices (2015 as the base year). Tables 2.1 and 2.2 present the variables, their respective definitions, and summary statistics.

Table 2. 1: Variable Definitions

Variable	Abbreviation	Definition
Real Average Housing Prices	*lnRAHP*	natural logarithmic of (Average Housing Prices*(CPI2015 /CPI_t))
Water Pollution Discharges	*lnWW*	natural logarithmic of (Amount of Discharge for Industrial Wastewater/Total Population)
Air Pollution Emissions	*lnSO2*	natural logarithmic of (Sulfur Dioxide Emission/Total Population)
Real Estate Construction Cost	*lnBC*	natural logarithmic of (Cost of Real Estate Construction *CPI2015/CPI_t)
Real Income	*lnI*	natural logarithmic of (Disposable Income *(CPI2015 /CPI_t)/Total Population)
Urbanization	*lnUR*	natural logarithmic of (100*Urban Population/Total Population)

Table 2. 2: Descriptive Statistics

Variable	*lnRAHP*	*lnWW*	*lnSO2*	*lnBC*	*lnI*	*lnUR*
Mean	7.9865	2.6666	5.0255	7.3311	9.7806	3.7602
Min	6.6172	1.1793	3.2244	6.4447	7.7850	2.6418
Max	10.0271	4.1188	6.4688	8.6344	11.5895	4.4953
Standard Deviation	0.6461	0.5140	0.6296	0.4708	0.8582	0.3670
Observations	540	540	540	540	540	540

Figure A1 in Appendix A1shows that the time trend of natural log of real average housing prices of China in the sample provinces from 1998 to 2015. It demonstrates that the natural log of real average housing prices in China among the sample provinces have an increasing trend, especially for Beijing and Yunnan.

According to Liu et al. (2018), I utilize two environmental pollution indicators: (1) natural logarithmic of discharges of industrial wastewater per capita (*lnWW*), and (2) natural logarithmic of the annual quantities of sulfur dioxide emissions per capita (*lnSO2*). On one hand, the total population in each province is different. On the other hand, purchasing a house is the individual's own decision, so I measure pollution per person to precisely reflect how much pollutant for each individual has to suffer within a province, which will affect the individual’s consumption decision and the real average housing prices that the consumer is willing to pay. Meanwhile, pollutant per capita is consistent with other covariates such as real income per capita and urbanization.

Figure A2 in Appendix A2 and Figure A3 in Appendix A3 show the time trend of natural log of discharges of industrial wastewater per capita of China and the time trend of natural log of sulfur dioxide emissions per capita of China in the sample provinces from 1998 to 2015, respectively. Figure A2 demonstrates that ln*WW* decreases after the peak in most of provinces, but increase still occurs in some provinces, such as Qinhai and Shandong. Figure A3 illustrates that ln*SO2* decreases after the peak in most of provinces, except for Xinjiang and Yunnan.

As shown in Table 2.3, provincial governments set different sulfur dioxide reduction targets. Because according to the bargaining power based on the previous provincial sulfur dioxide emissions, each provincial government negotiated with the central government on the specific sulfur dioxide reduction burden. The emission regulation contracts for the provincial pollution reduction targets were signed by the provincial vice presidents (Xu 2011). Table 2.3 demonstrates the sulfur dioxide reduction targets for all provinces in China from 2006 to 2010. Therefore, institutional abatement targets denoting the Eleventh Five-Year Plan for sulfur dioxide emission regulation, are represented by a dummy variable coded as one each year from 2006 to 2010.

Table 2. 3: Sulfur Dioxide Emission Reduction Targets in China (unit: 10,000 tons)

Province	SO_2 emissions in 2005	SO_2 emission targets in 2010		Reduction Percentage (%)
		Total	In which: Electricity sector	
Beijing	19.1	15.2	5	20.4
Tianjin	26.5	24	13.1	9.4
Hebei	149.6	127.1	48.1	15
Shanxi	151.6	130.4	59.3	14
Neimenggu	145.6	140	68.7	3.8
Liaoning	119.7	105.3	37.2	12
Jilin	38.2	36.4	18.2	4.7
Heilongjiang	50.8	49.8	33.3	2
Shanghai	51.3	38	13.4	25.9
Jiangsu	137.3	112.6	55	18
Zhejiang	86	73.1	41.9	15
Anhui	57.1	54.8	35.7	4
Fujian	46.1	42.4	17.3	8
Jiangxi	61.3	57	19.9	7
Shandong	200.3	160.2	75.7	20
Henan	162.5	139.7	73.8	14
Hubei	71.7	66.1	31	7.8
Hunan	91.9	83.6	19.6	9
Guangdong	129.4	110	55.4	15
Guangxi	102.3	92.2	21	9.9
Hainan	2.2	2.2	1.6	0
Chongqing	83.7	73.7	17.6	11.9
Sichuan	129.9	114.4	39.5	11.9
Guizhou	135.8	115.4	35.8	15
Yunan	52.2	50.1	25.3	4
Shaanxi	92.2	81.1	31.2	12
Gansu	56.3	56.3	19	0
Qinghai	12.4	12.4	6.2	0
Ningxia	34.3	31.1	16.2	9.3
Xinjiang	51.9	51.9	16.6	0

Source: "Reply to *Pollution Control Plan During the Eleventh Five-Year Plan,*" issued by the China State Council in 2006.

Here, in order to evaluate the impact of institutional abatement targets on real average housing prices in China, I design an institutional experiment five years before and five years after 2006 between the treated that is setting sulfur dioxide reduction target at or above 10% and the controlled that is setting sulfur dioxide reduction target below 10% (details in Table 2.3).

Figure 2. 2: Map of Treated Group and Controlled Group in China at 2006

In Figure 2.2, the treated Group involves Beijing, Hebei, Shanxi, Liaoning, Shanghai, Jiangsu, Zhejiang, Shandong, Henan, Guangdong, Chongqing, Sichuan, Guizhou, Shaanxi, Ningxia. And the controlled includes Tianjin, Neimenggu, Jilin, Heilongjiang, Anhui, Fujian, Jiangxi, Hubei, Hunan, Guangxi, Hainan, Yunnan, Gansu, Qinghai, Xinjiang.

2.3.2 Empirical Results

The key to causal inference is control for observed confounding factors. If important confounders are unobserved, I might try to get the causal effects using Fixed Effects Models involving two-way Fixed Effects Models, Spatial Fixed Effects Models and Spatial Difference-In-Difference Model. This essay considers a variation on the control theme: strategies that use data with a time or cohort dimension to control for unobserved but fixed omitted variables (Angrist and Pischke 2008).

(1) Regression Results

Here, I proceed to estimate the external effect of sulfur dioxide emission for equation (2.6), following empirical strategy of Chen et al. (2018). The regression results for individual Fixed Effects Models (FE) are reported in Table 2.4. According to Hausman test, the p-value of accept the null hypothesis of random effects is 0.1839, so I decide to utilize Fixed Effects Models. Since the variance inflation factor is 3, which is less than 10 so means that multicollinearity is not a problem for estimation (Wooldridge 2012). In, Table A1, the panel unit root test shows that the variables involving ln*RAHP*, ln*WW*, ln*SO2*, ln*UR*, ln*BC* and ln*I* are stationary (Appendix A4), so I can continue to run the Fixed Effects Models, Spatial Fixed Effects Models, and Spatial Difference-In-Difference Regression.

Table 2. 4: Results of Fixed Effects Models (Dependent Variable: lnRAHP)

Variable	FE (P)	FE (T)	FE (PT)
lnWW	-0.0439*	0.0024	0.0027
	(0.0255)	(0.0232)	(0.0235)
lnSO2	-0.1412 ***	-0.1396 ***	-0.1036 ***
	(0.0239)	(0.0228)	(0.0245)
lnBC	0.3152 ***	0.2719 ***	0.2619 ***
	(0.0455)	(0.0439)	(0.0427)
lnI	0.4967 ***	0.1924 ***	-0.0052
	(.0277)	(0.0412)	(0.0475)
lnUR	0.1439 ***	0.0917 ***	0.0483
	(0.0274)	(0.0273)	(0.0267)
Constant	1.1018 ***	4.1296 **	5.9055 ***
	(0.1629)	(0.3603)	(0.4058)
Fixed Effects			
Province	YES	NO	YES
Year	NO	YES	YES
Adj-R^2	0.9091	0.8573	0.7406
N	540	540	540

Notes: 1) *** p<0.01, ** p<0.05, * p<0.1;2) Robust standard errors in parentheses.

Table 2.4 shows that model FE (P) has statistically significant negative coefficient for *lnWW*, which means that *lnWW* variable has a statistically significant negative impact on *lnRAHP*. This result confirms the theoretical implication that the change of environmental pollution lowers the change of real average housing prices. Specifically, if the discharge level of industrial wastewater increases by 1 %, the real average housing prices drop by 0.0439% (162.42 Yuan RMB per square meter or 23.88 U.S Dollar per square meter).

The significance of *lnWW* conflicts with the empirical results of Jim and Chen (2006). They demonstrate that environmental pollution does not influence housing willingness-to-pay, implying a tolerance of this chronic environmental nuisance in the urbanized metropolitan area of China.

In terms of sulfur dioxide emissions, the consistently negative, statistically significant coefficients for the variable *lnSO2* are reported in FE (P), FE (T) and FE (PT).

So, increases in the sulfur dioxide emissions results in decreases in the real average housing prices in China. This result confirms the theoretical implication and is consistent with the findings by Yusuf and Resosudarmo (2009) about the impact of air pollution on housing prices. They argue that, in the cases of total hydro carbon and sulfur dioxide, pollutants have a negative association with housing prices at 5% level of significance.

Therefore, I can conclude that the impact of sulfur dioxide emissions is greater than the impact of discharges of industrial wastewater, because the absolute value of coefficient of *lnSO2* is much greater than the absolute value of coefficient of *lnWW*. Specifically, if the emission level of sulfur dioxide increases by 1%, then the real average housing prices drop by 0.1412% (522.40 Yuan RMB per square meter or 76.82 U.S Dollar per square meter) in FE (P), 0.1396% (516.48 Yuan RMB per square meter or 75.95 U.S Dollar per square meter) in FE (T) and 0.1036% (383.29 Yuan RMB per square meter or 56.36 U.S Dollar per square meter) in FE (PT). However, given an 1 % increase in discharges of industrial wastewater, the real average housing prices decline by 0.0439% (162.42 Yuan RMB per square meter or 23.88 U.S Dollar per square meter). It means that the impact of sulfur dioxide emissions is different from the impact of discharges of industrial wastewater.

Table 2.4 also reports the results with the *lnBC*, *lnI* and *lnUR* as the control variables. In terms of all models in Table 2.4, the coefficients of the *lnBC* , *lnI* and *lnUR* are consistently positive and statistically significant in FE (P) and FE (T). It means that the changes of real cost of real estate construction, real disposable income per capita and urbanization also drive up the change of real average housing prices in China.

(2) FE Extension from Spatial Fixed Effects Regression

In order to investigate the spillover effect of housing prices between neighbor provinces, I utilize Table 2.5 to test the equation (2.7). Table 2.5 illustrates that the empirical results of the Spatial Fixed Effects (SFE) regression are consistent with the results from Table 2.4.

Table 2. 5: Results of Spatial Fixed Effects Models (Dependent Variable: lnRAHP)

Variable	SFE (P)	SFE (T)	SFE (PT)
lnWW	-0.0233	-0.0661***	-0.0004
	(0.0206)	(0.0184)	(0.0216)
lnSO2	-0.0648***	-0.0996 ***	-0.0846 ***
	(0.0200)	(0.0152)	(0.0228)
lnBC	0.2198 ***	0.5589 ***	0.2395 ***
	(0.0372)	(0.0448)	(0.0395)
lnI	0.2095 ***	0.3709 ***	0.0253 ***
	(0.0299)	(0.0303)	(0.0441)
lnUR	0.0585**	0.1390 ***	0.0318
	(0.0228)	(0.0352)	(0.0247)
Spatial	0.5111 ***	0.1490***	0.2824***
rho	(0.0354)	(0.0393)	(0.0537)
Fixed Effects			
Province	YES	NO	YES
Year	NO	YES	YES
Adj-R^2	0.8720	0.9093	0.8494
N	540	540	540

Note: 1) *** p<0.01, ** p<0.05, * p<0.1; 2) Standard errors are presented below in parentheses.

Table 2.5 illustrates that the natural log of discharges of industrial wastewater are negatively associated with the natural log of real average housing prices in SFE (T). It means that *lnWW* negatively impacts *lnRAHP* and confirms the theoretical implication above. Moreover, the coefficients of *lnSO2* are significant and negative in each model-SFE (P), SFE (T) and SFE (PT). The effect of *lnSO2* on *lnRAHP* is negative, which supports the implication from the theoretical model. Comparing with the results from Table 2.4, I find that the impact of *lnSO2* is also greater than the impact of *lnWW*, which is consistent with the findings without spatial spillover effects. Compare coefficient size with non-spatial model–it seems the bias from not including spatial dependence is a more negative impact of *lnWW* on *lnRAHP* but is a less negative impact of *lnSO2*. Specifically, if the emission level of sulfur dioxide increases by 1 %, then the real average housing prices drop by 0.0648%

(239.74 Yuan RMB per square meter or 35.25 U.S Dollar per square meter) in SFE (P), 0.0996% (368.49 Yuan RMB per square meter or 54.19 U.S Dollar per square meter) in SFE (T) and 0.0846% (312.99 Yuan RMB per square meter or 46.02 U.S Dollar per square meter) in SFE (PT). And if the discharge level of industrial wastewater increases by 1 %, the real average housing prices drop by 0.0661% (244.55 Yuan RMB per square meter or 35.96 U.S Dollar per square meter) in SFE (T). Furthermore, I need to estimate the effect of institutional abatement targets on real average housing prices.

(3) Further Discussion: Evaluation of Emission Regulation using SDID

The fixed effects strategy above requires panel data of repeated observations on the same individuals (or time). However, the institutional abatement targets vary only at a group level. The source of omitted-variable bias when evaluating these institutional targets must therefore be unobserved variables at the province and year level. To conduct the robustness check, group-level omitted variables can be captured by group-level fixed effects, so I design a sulfur dioxide emission regulation institutional experiment occurred at 2006 across nation to investigate the causal effect of institutional abatement targets on real average housing prices.

Again, in order to deal with the spillover issue, I change equation (2.7) by introducing the institutional abatement targets into the Spatial Difference-In-Difference (SDID) Model (Dubé et al. 2014; Heckert 2015; Dubé et al. 2017) in equation (2.8), which combines the Spatial Fixed Effects Model and Difference-In-Difference Method.

According to the experimental design of sulfur dioxide emission regulation institutional targets from Shi and Xu (2018), I examine the effect of sulfur dioxide emission regulation institutional targets since 2006 on real average housing prices in China, so I design an institutional experiment using SDID.

A similar experiment (effect of sulfur emission regulation on export) has been conducted using Difference-In-Difference-In-Difference (Shi and Xu 2018; Cai et al. 2016). In order to investigate the causal effect of institutional abatement targets between neighbor provinces, I utilize the dataset from 2001 to 2010, which includes observations prior to and after the 2006 the Eleventh Five-Year Plan referring to the Central Government Target of sulfur dioxide reduction. Table 2.6 illustrates that the empirical results of the Spatial Difference-In-Difference regression that is corresponding to (2.8).

Table 2. 6: Results of Spatial Difference-In-Difference (Dependent Variable: lnRAHP)

Variable	Coefficient	Standard errors
PL	0.8500***	0.1634
lnWW	-0.0652**	0.0313
lnSO2	-0.0691**	0.0298
PL*lnSO2	-0.1744***	0.0306
lnBC	0.2181***	0.0506
lnI	0.2563***	0.0421
lnUR	0.0997***	0.0320
Spatial rho	0.4351***	0.0538
Province	0.1727**	0.0713
Year	0.0489**	0.0227
Constant	0.4758*	0.2750
Adj-R^2	0.8337	
Observations	300	

Note: 1) *** p<0.01, ** p<0.05, * p<0.1

As further extension, I show the estimates of SDID in Table 2.6. The change of *PL* from 0 to 1 is significantly positive ($(e^{0.85} - 1) - 0.1774 * 5.162422 + (e^{0.1727} - 1) + (e^{0.0489} - 1) = 1.339647 - 0.1774 * 5.162422 + 0.188509 + 0.50115 = 1.113492337$), which measures the differential between the treated provinces and the controlled provinces during the Eleventh Five-Year Plan when mean of *lnSO2* of the treated is 5.162422. This empirical result illustrates that institutional abatement targets for sulfur dioxide emission reduction are positively associated with the natural log of real average housing prices in China. It shows that for those provinces whose SO_2 emission reduction institutional targets were set at 10% or above starting after 2006 (thus, *PL* changes from 0 to 1), the real average housing prices within those provinces increased on a one-time basis by 1.1135% (4119.64 Yuan RMB per square meter or 605.83 U.S Dollar per square meter). Thus, these results are interpreted to mean that during the Eleventh Five-Year Plan, institutional abatement reduction targets for SO_2 were effective in reducing emissions such that these emission reductions were incorporated into increased natural log of real average housing prices due to environmental improvements. As a result, the institutional abatement targets of the treated provinces increase the natural log of real average housing prices.

Similarly, the total effects of *lnSO2* are significantly negative both for prior to the treatment (-0.0691) and after the treatment (-0.2435=-0.0691-0.1744), the coefficient of *lnWW* is also significantly negative (-0.0652), and the coefficients of lnBC, lnI and lnUR are significantly positive. So, these empirical results are consistent with the results from Table 2.5 and Table 2.6.

2.4 Conclusions

This essay provides a framework to conduct empirical research demonstrating how environmental pollution (water and air) along with institutional targets for reductions in air emissions affects real average housing prices in China. This framework reveals that the changes of both types of environment pollution have negative impacts on the change of real average housing prices. In terms of the empirical results, theoretical expectations for sulfur dioxide emissions and discharges of industrial wastewater are confirmed by both Fixed Effects Models and Spatial Fixed Effects Models. Moreover, the empirical results from institutional experiment demonstrate that emission reduction targets of 10% or larger result in higher real average housing prices across provinces during the Eleventh Five-Year Plan in China. Furthermore, the impact of sulfur dioxide emissions is greater than the impact of discharges of industrial wastewater on real average housing prices.

Environmental pollution represents a typical negative externality problem related to market failure (Bajari et al. 2012). From the perspective of the Chinese inter-province housing market, discharges of industrial wastewater and sulfur dioxide emissions are relevant market failures. The negative impact of these emissions on real average housing prices confirms numerous previous studies of air pollution emission impacting housing prices. As noted above, abatement targets about declining emissions for SO_2 since 2006 have increased real average housing prices. Lo et al. (2017) find that environmental enforcement in the Environmental Protection Bureau showed steady improvement between 2000 and 2013. They observe that a "widely publicized environmental quality administrative leadership responsibility system since 2000 to enhance accountability may account for the positive development of stronger local government support for pollution control". In addition, central supervision significantly reduces industrial emissions (Zhang et al 2018).

Examining the empirical results from both the Fixed Effects and Spatial Fixed Effects Models, a conclusion can be reached that the impact of air pollution on real average housing prices is greater than the impact of water pollution on real average housing prices based on the absolute value of coefficient for air pollution versus water pollution. Furthermore, empirical results of Spatial Difference-In-Difference Model tell me that the absolute value of coefficient of institutional abatement targets is much greater than the absolute value of coefficient of air pollution. It means that even though air pollution reduces the real average housing prices, but institutional abatement targets for air pollution drive up the real average housing prices. In a word, the impacts of environmental policies on housing market are significant. In developing countries like China, governments are investing large amounts of resources to reduce the increasingly severe air pollution. While such investment has many benefits, my study shows that it can also bring extra impacts to housing market. Policymakers therefore need to take the difference of strength of impacts of different environmental policies into account in future policymaking.

Finally, this study has limitations that include: (1) the theoretical model assumes linearity and equilibrium, (2) the specification of econometric model does not consider macroeconomic factors such as interest rates and educational expenditure, (3) the use of real average housing prices without site specific information, thereby assuming that housing attributes remain constant over time, (4) only air pollution and water pollution are assessed as environmental pollutants – other environmental aspects potentially impacting housing prices, such as noise and green space, are not included in our models, and (5) important uncertainties within the housing market concerning central government regulations, real estate market structures, and home ownership (Ho and Kwong 2002) are not included in the empirical models. (6) Based on the framework, I do not investigate the other impacts from pollution on society that are not reflected in real average housing prices and thus not in my model. For instance, the impact of pollution on health is other serious problem in China. So, I will extend the empirical research to examine the effect of pollution on medical expenditure or Mortality.

Chapter 3: Metropolitan Electricity Consumption Function: The Institutional Experimental Evidence from Guangzhou, China

3.1 Introduction

One of the surprising discoveries in electricity economics over the past twenty years has been the relationship between electricity consumption and economic output. In the literature, the evidence so far is contradictory for different regions and countries around the world. Actually, the nature of nexus between electricity consumption and economic output can be expressed as an electricity consumption function, according to the economic theory. The reason why there are different empirical results on this topic is that such an electricity consumption function has not been developed before in the literature. So, this study derives the optimal electricity consumption function by the solving for the optimal inter-temporal income problem, but it is different from the traditional optimal inter-temporal utility model (He and Gao 2017). The concept of a consumption function dates back to the origin of Keynesian macroeconomics where The General Theory of Employment, Interest, and Money emphasized the central importance of consumption (Carroll and Kimball 1996). A consumption function reflects the relationship between consumption and economic output (Gao and He 2017). As summarized in section 3.2, there is an extensive literature which estimates the nexus between electricity consumption and national income as measured by gross domestic production (GDP). Little attention, however, has been paid to developing a theoretical basis for connecting electricity consumption with GDP using an optimal inter-temporal model.

In addition to a limited exploration of theory concerning electricity consumption function, electricity demand management reform is another seldom researched aspect of electricity markets. In terms of the metropolitans in China, they always face electricity power shortages. One response to these shortages is to implement reform of electricity markets. For instance, the electricity consumption changes as the rule of electricity demand management changes. So, institutional reform matters in the electricity consumption function.

The example of interest in this research is Guangzhou where a prolonged process of electricity market reform has occurred since 1985 (Pollitt et al. 2017). Up until 1984, consumption of electricity was measured on a community basis (not individual household), so that household payments for electricity reflected average usage all households in the community. However, in 1985, individual household metering of consumption began in order for electricity payments to reflect household level consumption. This electricity demand management reform has the electricity use transit from community (public) usage to individual (private) usage for the residential customers (households), which produces an incentive for households to save electricity. This change required that electric grids be adjusted to the “ammeter sole use system” to help alleviate shortages of electricity. In addition, a schedule of peak rates for commercial and industrial customers was designed to save the electricity consumption and alleviate electricity shortages. Specifically, during the peak demand period, a charge from 1.3 to 1.5 times the basic electricity rate is levied. So, the electricity demand reform can alleviate electricity shortages efficiently.

The three objectives of this essay are to: (1) establish a theoretical basis for an electricity consumption function using optimal control theory, (2) empirically examine the relationship between electricity consumption and economic output in Guangzhou of China, and (3) introduce electricity demand management reform into both the theoretical and empirical models, because electricity demand management reform could be a key driver of affordable and efficient electricity services consumption through economic growth. This research is based upon the perspective that with rising income, consumers are more likely to afford electronic appliances, such as televisions, refrigerators, washing machines, computers, and air conditioners, thus increasing the demand for electricity (Huang et al. 2018). This perspective leads to three questions:

(1) What is a theoretically appropriate relationship between electricity consumption and economic output?
(2) If economic output increases, will that cause more electricity consumption?
(3) How does reform of electricity demand management impact electricity consumption?

The contributions of this essay include: (1) development of an inter-temporal optimization model that connects electricity consumption to economic output based upon electricity consumption habits, which has not been discussed in the literature, (2) design of a natural experiment using kink regression discontinuity approach to investigate the effect of the 1985 electricity demand management reform that occurred in Guangzhou on electricity consumption.

This section provides a brief introduction of the background and motivation of this research. Sections 3.3 and 3.4 present the theoretical model and subsequent methods following the pathways shown in Figure 3.1. In section 3.2, I discuss the literature on general consumption function and the nexus between electricity consumption and economic output. In section 3.3, I outline the theoretical framework applying the optimal control theory to derive the metropolitan electricity consumption function. Section 3.4 introduces the time series econometric methods to test the unit root and cointegration for the data utilized in the analysis. Empirical results will be addressed in section 3.5. Finally, section 3.6 presents conclusions and further discussion.

3.2 Literature Review

3.2.1 Literature on General Consumption Function

The nature of the relationship between electricity consumption and economic output in economic theory can be expressed as the electricity consumption function which is the function of income or wealth. In the economic literature, since Friedman (1957), many economists have conducted theoretic and empirical research to the consumption function (Gorman, 1964). Spiro (1962) finds that if income is to remain permanently constant, the desired stock of wealth will ultimately be accumulated and therefore consumption would equal net income. The Zellner consumption function (Zellner 1957) fits well but gives rather low estimate of the long run marginal propensity to consume and a rather high and hard to interpret coefficient for the liquid assets variable (Griliches et al. 1962).

In terms of consumption function theory development (Zellner and Geisel 1970), Thompson (1967) asserts and demonstrates an equivalence that exists between the utility function and standard aggregate consumption function.

Baxter and Moosa (1996) propose to split consumption expenditure on non-durable items into 'basic needs' and other expenditure. Foldes (1996) considers a neo-classical model of optimal economic growth with population growth, technological progress. Gong et al. (2012) broadens the conclusion of Carroll et al. (1996) for the case of the HARA utility function.

However, recently, the economists gradually transfer into the empirical research on consumption function from the theoretical modeling. Hence, I would derive an electricity consumption function.

3.2.2 Literature on the Relationship between Electricity Consumption and GDP

In this section, I start to review the main literature on the relationship between electricity consumption and GDP. Table 3.1 lists the summary of recent literature review for those four hypotheses on the nexus between electricity consumption and economic output for different regions and countries around the world. The first of these is the conservation hypothesis implying unidirectional Granger causality running from economic output to electricity consumption. In contrast, the growth hypothesis postulates unidirectional Granger causality running from electricity consumption to economic output. The feedback hypothesis contemplates bidirectional Granger causality such that electricity consumption and economic output mutually influence each other. The fourth view is the neutrality hypothesis of no direct Granger causal links between electricity consumption and economic output (He et al. 2017).

Table 3. 1: Summary of Recent Literature Review for Electricity Consumption and Economic Output

Study	Methodology	Time Period	Region/ Country	Hypothesis
Ghosh (2002)	Granger causality test	1950 -1997	India	conservation
Jumbe (2004)	Granger causality test	1970-1999	Malawi	conservation
Chen et al. (2007)	Pairwise Granger causality test	1971- 2001	10 Asian countries	conservation
Jamil and Ahmad (2010)	Granger causality test	1960–2008	Pakistan	conservation
Shahbaz et al.(2011)	Granger causality test	1971- 2009	Portugal	conservation
Ikegami and Wang (2016)	Granger causality test	1996Q4–2015Q2	Japan and Germany	conservation
Shiu and Lam (2004)	Granger causality test	1971–2000	China	growth
Altinay and Karagol (2005)	Granger causality test	1950–2000	Turkey	growth
Yuan et al. (2007)	Granger causality test	1978–2004	China	growth
Ho and Siu (2007)	Granger causality test	1966 -2002	Hong Kong	growth
Narayan and Singh (2007)	Granger causality test	1979- 2000	Fiji	growth
Akinlo (2009)	Granger causality test	1980–2006	Nigeria	growth
Ciarreta and Zarraga (2010)	Granger causality test	1970–2007	12 European countries	growth
Bildirici and Kayikçi (2012)	Granger causality test	1990–2009	Soviet Republics	growth
Al-Mulali et al. (2014)	Granger causality test	1980–2010	18 Latin American countries	growth
He et al.(2017)	VECM Granger causality test	1950-2013	Guangzhou of China	growth
Yoo (2005)	Granger causality test	1970–2002	Korea	feedback
Yoo (2006)	Granger causality test	1971–2002	Malaysia and Singapore	feedback
Tang (2008)	Granger causality test	1972 quarter 1 to 2003 quarter 4	Malaysia	feedback
Odhiambo (2009)	Granger causality test	1971-2006	South Africa	feedback
Narayan and Prasad (2008)	Panel Granger causality	1974–2002	Middle Eastern countries	feedback
Yang et al. (2010)	Granger causality test	1982-2008	Taiwan	feedback
Acaravci (2010)	Granger causality test	1977- 2006	Turkey	feedback
Shahbaz and Lean (2012)	Granger causality test	1972-2009	Pakistan	feedback
Ouédraogo (2010)	Granger causality test	1968–2003	Burkina Faso	feedback
Hamdi et al. (2014)	VECM Granger causality test	1980 quarter 1–2010 quarter 4	Bahrain	feedback
Ozturk and Acaravci (2011)	Granger causality test	1971- 2006	Middle East and North Africa countries	neutrality

According the literature above, the nexus between electricity consumption and economic output has been extensively studied but the evidence so far is contradictory and inconclusive (Stern et al. 2018). Most of the scholars above just make good use of the national level data without any institutional factors, and there has been limited attention in economic literature devoted to investigating the effect of total income combining electricity demand management reform on electricity consumption in metropolitan area. Comparing to the current studies, I try to set up a theoretical model to investigate the relationship between electricity consumption and gross products (total income), and concentrate on using the data from the metropolitan level in Guangzhou, China and consider the policy implication.

3.3 Theoretic Model

My first objective is to derive a metropolitan electricity consumption function that rests upon a theoretical basis of an optimally allocating government expenditures on electricity infrastructure in order to maximize a metropolitan's inter-temporal total income (Y). This objective is based on an assumption that competition between regions motivates subnational metropolitan's officials to maximize a metropolitan's inter-temporal total income. Chinese metropolitans compete against each other for performance rankings and metropolitan officials' careers are linked to their performance in the tournaments (Xu 2011). The most popular performance indicator used in metropolitan rankings is GDP (Xu 2011). By linking metropolitan performance to officials' promotion, tournament-like metropolitan competition provides high-powered incentives to subnational officials to maximize total income in the whole metropolitan society (Xu 2011). In addition, according to Wagner's Law, an increase in total income in the society has a positive effect on government spending (Kónya and Abdullaev 2018). Hence, in order to increase their share of the economy, officials consider maximizing total income in their metropolitan as an incentive (Narayan et al. 2008).

Based on that assumption, the inter-temporal metropolitan total income function (M) can be expressed as below:

$$\mathrm{M} = \sum_{t=0}^{T} \mathrm{Y}_t \left(\frac{1}{1+\theta}\right)^t \quad (3.1)$$

where θ represents a social discount rate and T represents metropolitan government's planning period. With a constrained optimization, I turn my attention to the constraints. First, there is a constraint based on an income accounting identity:

$$\mathrm{Y}_t = \mathrm{C}_t + \mathrm{I}_t + G_t \quad (3.2)$$

where consumption is C_t, I_t denotes all investment (private and public) that is outside the electricity generation industry, and G_t denotes government investment on electricity infrastructure, all in year t. Investment is the change in the economy's stock of capital:

$$\mathrm{I}_t = \mathrm{K}_{t+1} - (1-\delta)\mathrm{K}_t \quad (3.3)$$

where δ denotes depreciation rate of capital. Hence, plug (3.3) into (3.2), I obtain:

$$\mathrm{Y}_t = \mathrm{C}_t + G_t + \mathrm{K}_{t+1} - \mathrm{K}_t + \delta\mathrm{K}_t \quad (3.4)$$

Writing this identity in discrete-time form, I have:

$$\mathrm{K}_{t+1} - \mathrm{K}_t = \mathrm{Y}_t - \mathrm{C}_t - G_t - \delta\mathrm{K}_t \quad (3.5)$$

where δ represents the capital depreciation rate.

The production function for Y_t is assumed to be represented in Cobb-Douglas (C-D) form:

$$Y_t = Q(\mathrm{K}_t, \mathrm{E}_t, \mathrm{L}_t) = \mathrm{A}_t \mathrm{K}_t^a \mathrm{E}_t^b \mathrm{L}_t^d \quad (3.6)$$

where A_t denotes technology level, K_t is capital, E_t is electricity utilized in production, and L_t is labor. The parameters of equation (3.6) are restricted as: $0 < a < 1, 0 < b < 1, and\ 0 < d < 1$. An aggregate C-D production function is assumed here to help ensure well behaved solutions. Here, production represents the total supply of metropolitan goods and services. A change of capital stock can be derived from (3.5) and (3.6) as:

$$K_{t+1} - K_t = Q(K_t, E_t, L_t) - C_t - G_t - \delta K_t \quad (3.7)$$

The second constraint comes from the capacity of electricity production due to available infrastructure. To express this constraint, I use F_t to represent value of electricity infrastructure at year t and G_t to represent annual investment on electricity infrastructure. So, the value of electricity infrastructure at year t+1 (F_{t+1}) is composed of annual investment on electricity infrastructure (G_t) and the value of remaining electricity infrastructure. A convenient way of modeling the latter is to assume that the value of remaining electricity infrastructure at the end of year t is ($F_t - \pi F_t$), where the electricity infrastructure depreciation rate is π. Therefore, I define changes in the value of electricity infrastructure as

$$F_{t+1} = G_t + (F_t - \pi F_t) \quad (3.8)$$

Finally, the amount of electricity consumption, E_t, is treated as the functional of the capacity of electricity infrastructure and other factors ($\varepsilon_t = \varepsilon_t(D_t)$) involving electricity demand management reform (D_t), so that $E_t(F_t, \varepsilon_t(D_t)) = fF_t\,\varepsilon_t(D_t)$, where f is the transfer coefficient representing what percentage of stock of electricity generated from electricity infrastructure can be effectively used, and ε_t will be transferred as the form of the error term in the econometric model.

Therefore, I have the following set-up for an optimal control problem:

$$\underset{G_t}{Max} \sum_{t=0}^{T} Y_t \left(\frac{1}{1+\theta}\right)^t \qquad (3.9)$$

$$\text{s.t. } K_{t+1} - K_t = A_t K_t^a (f\,\varepsilon_t(D_t)\,F_t)^b L_t^d - C_t - G_t - \delta K_t$$

$$F_{t+1} - F_t = G_t - \pi F_t$$

$$K_0 = K^* \text{ and } K_T \text{ is free}$$

$$F_0 = F^* \text{ and } F_T \text{ is free}$$

$$G_t \geq 0,\ F_t \geq 0, \text{and } K_t \geq 0$$

where A_t, L_t, and C_t are supposed to be exogenous variables, G_t is control variable, K_t and F_t are state variables. Finally, the electricity consumption function is derived as below with more details about this derivation provided in Appendix B1:

$$lnE_t = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln E_{t-1} + \beta_3 D_t + v_t \quad (3.10)$$

3.4 Econometric Methods and Data

To estimate an electricity consumption function, the first step is to conduct the unit root tests without and with break data (Figure 3.1). If the variables are stationary at level, I can run the OLS regression directly, since there is no spurious issue in that case. However, if the variables are found to be non-stationary at level, the process is to continue to conduct the unit root tests for all variables at first difference. When variables are stationary at first difference, I can further conduct cointegration tests by Johansen and ARDL approaches. If there is cointegration relationship among variables, the spurious problem will be solved and then the Granger Causality tests and Kink Discontinuity Regression method can be conducted. According to Chow and Niu (2015), I do not involve any time dummy variables, interaction terms containing time dummy variable and lagged variables in the unit-root and cointegration tests.

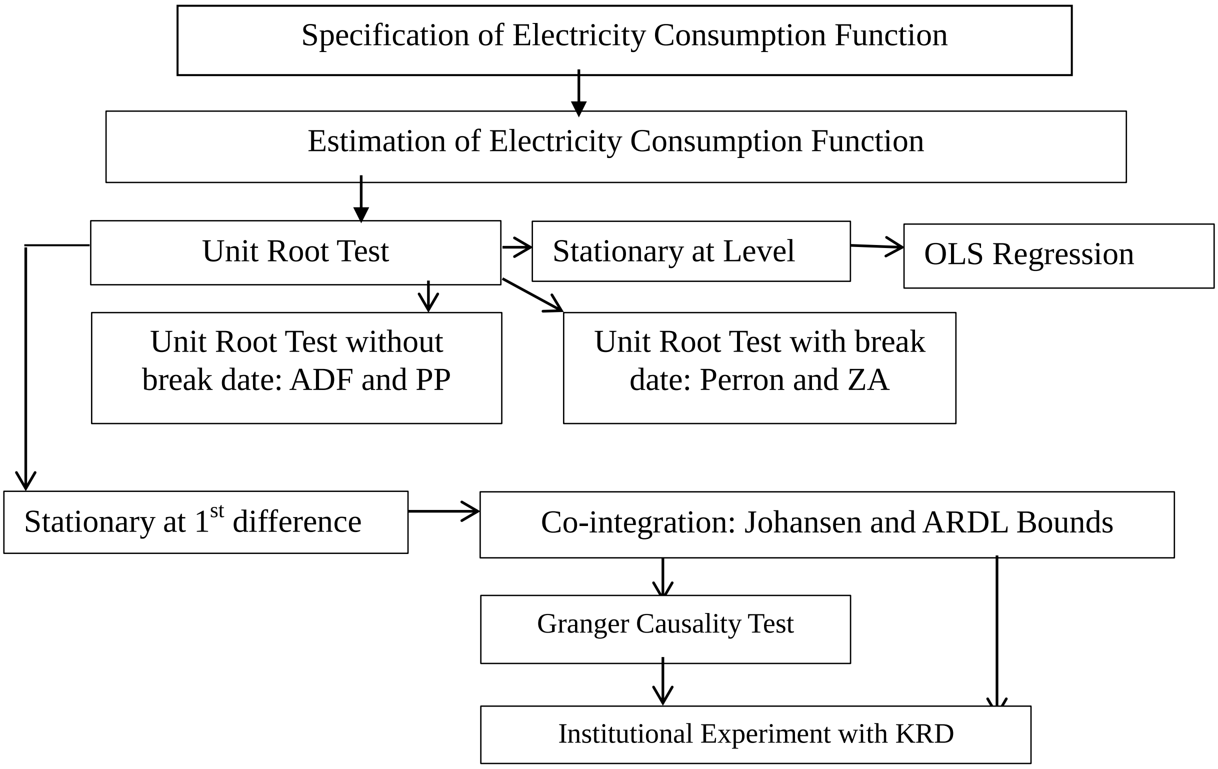

Figure 3. 1: Structural Flow Chart of the Theory and Econometric Methods Utilized in Chapter 3

3.4.1 Unit Root and Cointegration Tests

Because standard Granger causality tests should be conducted on stationary time series or cointegration with unit root process, I first test the unit roots of X_t to confirm the stationary properties of each variable. This is achieved by using the Augmented Dickey-Fuller test (Dickey and Fuller 1979; Mackinnon 1996). For the time series X_t representing $\ln E_t$ and $\ln Y_t$, the Augmented Dickey-Fuller (ADF) relationship is expressed as:

$$X_t = \alpha_0 + \alpha_1 X_{t-1} + \alpha_2 \mathrm{t} + \sum_{i=1}^{l} \beta_i \, \Delta X_{t-i} + u_t \quad (3.11)$$

where Δ is the difference operator, l is the auto-regressive lag length that must be large enough to eliminate possible serial correlation in β_i, α_0 is a constant, α_1 is the coefficient of interest, α_2 is the coefficient on a time trend, and u_t is the error term.

In addition, Phillips and Perron (1988) propose an alternative (nonparametric) method of controlling for serial correlation when testing for a unit root. The PP test is as below:

$$X_t = \alpha_0 + \alpha_1 \mathrm{t} + \alpha_2 X_{t-1} + u_t \quad (3.12)$$

However, when there are any structural breaks in the data, the ADF test is biased towards a spurious acceptance of non-stationarity because of misspecification bias and size distortions. The Perron's test allows for a one-time change in structure occurring at time T_B ($1 < T_B < T$, T is the number of observations). The model is considered in this test: one that allows for an exogenous change in the level of the series：

$$X_t = \alpha_0 + \alpha_1 DT_t^* + \alpha_2 t + \alpha_3 X_{t-1} + \sum_{i=1}^{l} \beta_i \Delta X_{t-i} + u_t \quad (3.13)$$

where $DT_t^* = t - T_B$ if $t > T_B$ and 0 otherwise. The null hypothesis implies that the data are non-stationary. In this test the alternative is taken as trend-stationary with a terminal at time T.

The choice of the breakpoint thus is correlated with the data utilized and the choice of breakpoint cannot be considered as independent of the data. Zivot and Andrews test (Zivot and Andrews 1992) addresses this issue by estimating the structural break data endogenously instead of considering an exogenous break date. I estimate the following equations for the Zivot and Andrews test with the endogenous location of the breakpoint $\lambda = T_B / T$:

$$X_t = \alpha_0 + \alpha_1 DT_t^*(\lambda) + \alpha_2 t + \alpha_3 X_{t-1} + \sum_{i=1}^{l} \beta_i \Delta X_{t-i} + u_t \quad (3.14)$$

The Johansen multivariate cointegration test (Johansen 1995) takes the following form as below:

$$\Delta lnE_t = \alpha + \beta lnE_{t-1} + \sum_{i=1}^{l} \vartheta_i \Delta lnE_{t-i} + \varphi lnY_t + u_{0t} \quad (3.15)$$

Another way to verify the cointegration relationship is to apply an ARDL model (Pesaran et al. 2001), if none of the series I am working with are I(2). The ARDL(p,q) model used in this study is expressed as follows:

$$lnE_t = a_0 + b_1 t + b_2 lnY_t + \sum_{i=1}^{p} a_{1i}\, lnE_{t-i} + \sum_{i=0}^{q-1} a_{2i}\, \Delta(lnY_{t-i}) + u_{1t} \quad (3.16)$$

$$lnY_t = c_0 + d_1 t + d_2 lnE_t + \sum_{i=1}^{p} c_{1i}\, lnY_{t-i} + \sum_{i=0}^{q-1} c_{2i}\, \Delta(lnE_{t-i}) + u_{2t} \quad (3.17)$$

3.4.2 Granger Causality Test and Kink Discontinuity Regression

Although the Johansen cointegration test and the ARDL approach to cointegration, explore whether the time-series data are cointegrated, they do not reveal the causality directions between $\ln E_t$ and $\ln Y_t$. For this purpose, I use the Granger causality (Granger 1969) as below:

$$lnE_t = g_0 + \sum_{i=1}^{l} g_i\, lnY_{t-i} + \sum_{i=1}^{l} h_i\, lnE_{t-i} + \theta_{1t} \quad (3.18)$$

$$lnY_t = v_0 + \sum_{i=1}^{l} v_i\, lnE_{t-i} + \sum_{i=1}^{l} w_i\, lnY_{t-i} + \theta_{2t} \quad (3.19)$$

In order to design an institutional experiment to investigate the causal effect of electricity demand management reform program on electricity consumption, I use the KRD (Kink Regression Discontinuity) approach for robustness analysis (Card et al. 2015). The idea of regression discontinuity design is that there is a continuous variable lnY_t (assignment variable) which determines the treatment variable D_t by a cutoff. The random distribution of samples in a small neighborhood $[\delta - \mu, \delta + \mu]$ of lnE_t is regarded as "quasi experiment". By estimating LATE (Local Average Treatment Effect), it is possible to identify whether the dependent variable (lnE_t) has a cutoff at $lnY_t = \delta$, where bandwidth $\mu = argmin \frac{\sum_{t=1}^{T}[lnE_t - E(lnY_t)]^2}{T}$ and

$\text{LATE} = \lim_{lnY_t \to \delta+} \text{E}(lnE_t) - \lim_{lnY_t \to \delta-} \text{E}(lnE_t)$. The null hypothesis of the test is:

$H_0 \equiv \lim_{lnY_t \to \delta+} lnE_t - \lim_{lnY_t \to \delta-} lnE_t = 0$. Since the electricity demand management reform occurred from 1985, lnY_{1985} is treated as the cutoff.

So, $D_t = \begin{cases} 1, if\ 1985 \le t \le 2016 \\ 0, if\ 1949 \le t \le 1984 \end{cases}$.

A generalization of electricity consumption function based on equation (3.10) allows different trend function for $\mathrm{E}[lnE_{0t}|lnY_t]$ and $\mathrm{E}[lnE_{1t}|lnY_t]$. Modeling both of these conditional expectation functions (CEFs), I have

$$\mathrm{E}[lnE_{0t}|lnY_t] = \beta_0 + \beta_{01}(\mathrm{lnY}_t - lnY_{1985}) + \beta_2\mathrm{lnE}_{t-1}$$

$$\mathrm{E}[lnE_{1t}|lnY_t] = \beta_0 + \beta_3 + \beta_{11}(\mathrm{lnY}_t - lnY_{1985}) + \beta_2\mathrm{lnE}_{t-1}$$

To derive a regression model that can be used to estimate the causal effect of interest in this case, I use the fact that D_t is a deterministic function of lnY_t to write

$$\mathrm{E}[lnE_t|lnY_t] = \mathrm{E}[lnE_{0t}|lnY_t] + (\mathrm{E}[lnE_{1t}|lnY_t] - \mathrm{E}[lnE_{0t}|lnY_t])D_t$$

Substituting regression for conditional expectations, then I have

$$lnE_t = \beta_0 + \beta_{01}(\mathrm{lnY}_t - lnY_{1985}) + \beta_2\mathrm{lnE}_{t-1} + \beta_3 D_t + (\beta_{11} - \beta_{01})(\mathrm{lnY}_t - lnY_{1985})D_t + v_t$$

$$= (\beta_0 - \beta_{01}lnY_{1985}) + \beta_{01}\mathrm{lnY}_t + \beta_2\mathrm{lnE}_{t-1} + [-(\beta_{11} - \beta_{01})lnY_{1985} + \beta_3]D_t + (\beta_{11} - \beta_{01})D_t\mathrm{lnY}_t + v_t$$

And the electricity consumption functions by regression discontinuity reduced form can be expressed as below:

$$lnE_t = \alpha_0 + \alpha_1\mathrm{lnY}_t + \alpha_2\mathrm{lnE}_{t-1} + \alpha_3 D_t + \alpha_4 D_t\mathrm{lnY}_t + v_t \quad (3.20)$$

where $\alpha_0 = \beta_0 - \beta_{01}lnY_{1985}$, $\alpha_1 = \beta_{01}$, $\alpha_2 = \beta_2$, $\alpha_3 = -(\beta_{11} - \beta_{01})lnY_{1985} + \beta_3$, and $\alpha_4 = \beta_{11} - \beta_{01}$.

3.4.3 Background

To estimate the metropolitan electricity consumption function, I utilize time series data from Guangzhou. With over 2,100 years of history, Guangzhou is a major commercial center in south China (He et al. 2017). As the capital of Canton Province, it is located within 120 km of both Hong Kong and Macau. Because Guangzhou is adjacent to Hong Kong (Figure 3.2), which was a colony of the Britain from 1842 to 1997 and is a typical market economy metropolitan in the world, the Chinese central government let Guangzhou be the experimental metropolitan can reduce institutional learning and imitating costs. So, Guangzhou becomes the commercial and free trade center of south China (Bercht 2013).

Guangzhou is the third largest metropolitan area in China, after Beijing and Shanghai, and the largest city in south central China (Yang et al. 2012). Moreover, the Guangzhou Statistical Division provides the most complete and longest duration time series dataset (from 1949 to 2016) among the metropolitans in China. It helps me to observe and estimate the electricity consumption function with electricity demand management reform.

Figure 3. 2: Map of Guangzhou's Location in China

3.4.4 Data

Annual data from 1949 to 2016 were obtained from the Guangzhou statistical yearbook from 2000-2016 and the Guangzhou 50 years. Table 3.2 lists the variables, their definitions and summary statistics for all variables included in the sample. According to the form of electricity consumption function in equation (3.10), the dependent variable is the natural logarithmic of metropolitan electricity consumption (lnE). The main independent variable is the natural logarithmic of metropolitan economic output (lnY).

Table 3. 2: Variable Definitions and Descriptive Statistics

Variable	Definition	Mean	Max	Min	Standard Deviation	Observations
lnE	natural logarithmic of total Electricity Consumption	15.0042	18.22657	10.79384	2.072003	68
lnY	natural logarithmic of (Gross Metropolitan Income*(CPI2016 /CPIt))	25.25871	28.18772	22.55819	1.543671	68

Note: 1) The Megawatt Hours is the unit for measuring electricity consumption (E) and it is equal to 1000 kilowatts of electricity used continuously for one hour; 2) The Yuan is the unit in China for measuring income (Y).

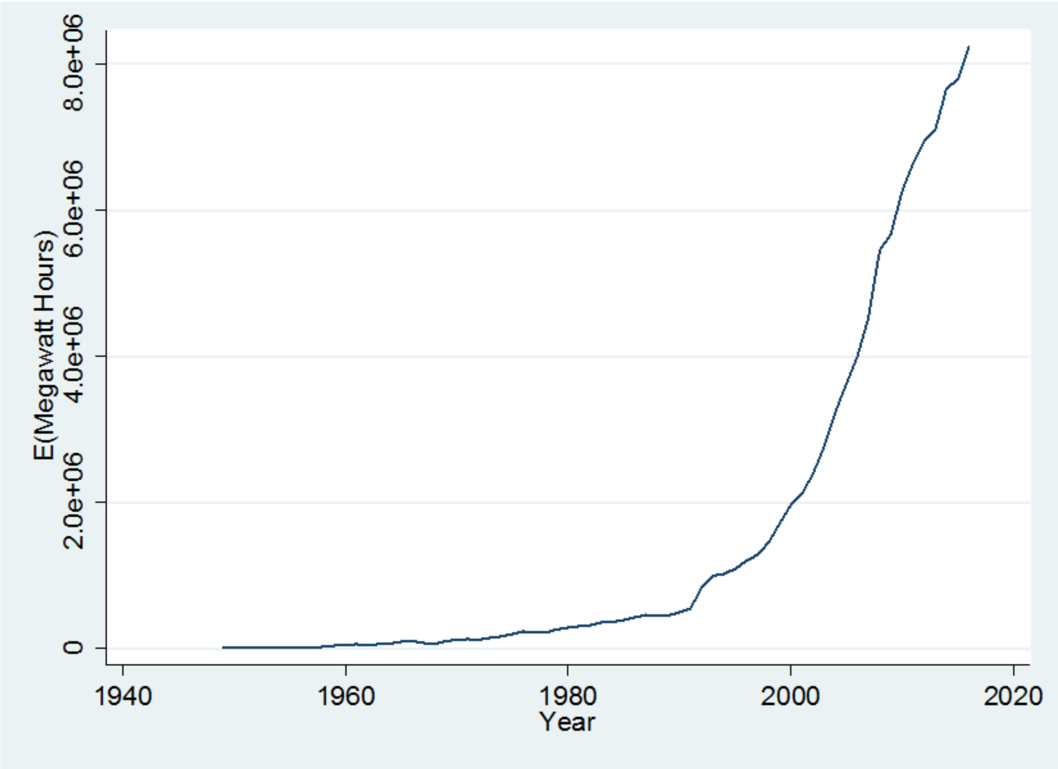

Figure 3. 3: Time Trend of Annual Electricity Consumption in Guangzhou (1949-2016)

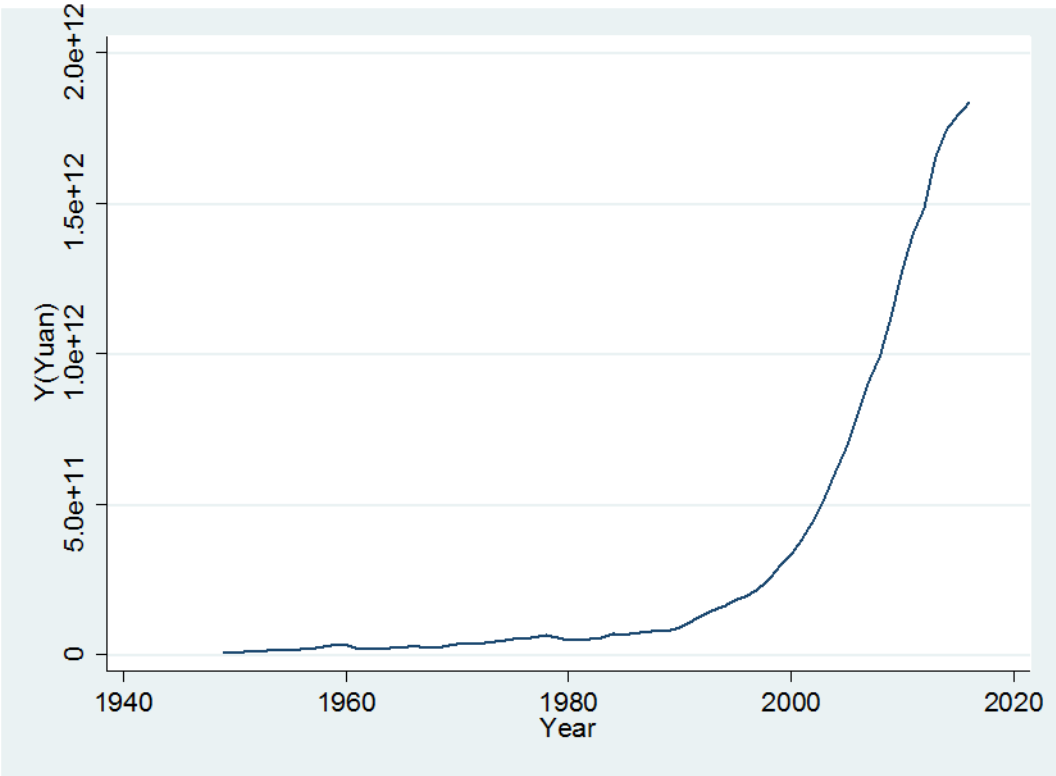

Figure 3. 4: Time Trend of Annual Gross Metropolitan Income in Guangzhou (1949-2016)

Figure 3.3 and Figure 3.4 illustrates the evolution of electricity consumption and gross metropolitan income in Guangzhou throughout the course of the sample period. As can be seen, growth in electricity consumption has accelerated since 1985. This acceleration coincides with the rapid expansion of economic activity observed since 1985 in much of Guangzhou. The growth rates of Y before and after 1985 are 9.9% and 24.7%, while growth rates of E before and after 1985 are 64.51% and 18.34%.

3.5 Empirical Evidence

3.5.1 Unit Root Tests

(1) ADF Test and PP Test

ADF test and PP test are applied to detect the possible presence of unit roots in $\ln Y_t$ and $\ln E_t$. The null hypothesis of unit root can be rejected in favor of the alternative hypothesis of no unit root when the p-value is small (He and Gao 2017). Table 3.3 indicates that no variable is stationary in their levels since the p-values for each variable are greater than 10%. On the other hand, $\ln Y_t$ and $\ln E_t$ are stationary process in their first differences because the p-values for $\ln Y_t$ are smaller than 1% in both ADF test and PP test. Furthermore, the p-values for $\ln E_t$ are smaller than 1% in both tests.

Table 3. 3: ADF and PP Unit Root Tests Results

ADF Test				PP Test			
Variable	ADF-test statistics	C,L,T	P-value	Variable	PP-test statistic	C,B,T	P-value
$\ln Y_t$	5.0033	(0,0,0)	1.0000	$\ln Y_t$	4.4939	(0,1,0)	1.0000
$\ln E_t$	-2.3084	(C,0,T)	0.4235	$\ln E_t$	-2.2259	(C,8,T)	0.4676
$\Delta\ln Y_t$	-6.3046***	(C,0,0)	0.0000	$\Delta\ln Y_t$	-6.2419***	(C,3,0)	0.0000
$\Delta\ln E_t$	-5.4752***	(C,2,0)	0.0000	$\Delta\ln E_t$	-8.2560***	(C,9,T)	0.0000

Note: 1) *** p<0.01, ** p<0.05, * p<0.1; 2) C, L, T, and B represent the constant, and lag length, time trend, bandwidth, respectively.

(2) Perron's modified ADF test and Zivot–Andrews test

The results of Perron's modified ADF test and Zivot–Andrews test are detailed in Table 3.4 and Table 3.5, respectively. They show that non-stationary processes are found in all series at level but variables are found to be stationary at first difference. This confirms that $\ln Y_t$ and $\ln E_t$ are integrated at I(1).

Table 3. 4: Perron's Modified ADF Unit Root Test Results

Variable	Break Data	T-statistic	C,L,T	10%critical value	5%critical value	1%critical value
lnY_t	1988	-3.1969	（0,1,0）	-4.4800	-4.8300	-5.4500
lnE_t	1960	-3.7225	（0,0,T）	-4.4800	-4.8300	-5.4500
ΔlnY_t	1961	-6.8583***	（0,0,T）	-4.4800	-4.8300	-5.4500
ΔlnE_t	1968	-8.8418***	（0,0,T）	-4.4800	-4.8300	-5.4500

Note: 1) *** p<0.01, ** p<0.05, * p<0.1; 2) C, L, and T represent the constant, and lag length, time trend, respectively.

Table 3. 5: Zivot-Andrews Unit Root Test Results

Variable	Break Data	T-statistic	C,L,T	10% critical value	5%critical value	1%critical value
lnY_t	1961	-3.5614	（0,1,T）	-4.5800	-4.9300	-5.3400
lnE_t	1977	-3.7630	（0,1,T）	-4.5800	-4.9300	-5.3400
ΔlnY_t	1964	-7.0979*	（C,0,T）	-4.8200	-5.0800	-5.5700
ΔlnE_t	1961	-6.9224***	（0,1,T）	-4.8200	-5.0800	-5.5700

Note: 1) *** p<0.01, ** p<0.05, * p<0.1; 2) C, L, and T represent the constant, and lag length, time trend, respectively.

3.5.2 Cointegration Tests

Table 3.6 shows the lag order in Johansen test is one.

Table 3. 6: Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-144.6302	NA	0.3883	4.7300	4.7986	4.7569
1	96.2876	458.5210	0.0001	-2.9125*	-2.7066*	-2.8316*
2	99.6402	6.1644	0.0001	-2.8916	-2.5485	-2.7569
3	105.2899	10.0236	0.0001	-2.9448	-2.4645	-2.7562
4	106.5134	2.0916	0.0001	-2.8552	-2.2377	-2.6128
5	108.1155	2.6358	0.0002	-2.7779	-2.0231	-2.4815
6	109.6122	2.3656	0.0002	-2.6971	-1.8051	-2.3469

Note: 1)* indicates lag order selected by the criterion. 2) LR: sequential modified LR test statistic (each test at 5% level).3) FPE: Final prediction error. 4) AIC: Akaike information criterion. 5) SC: Schwarz information criterion. 6) HQ: Hannan-Quinn information criterion.

Based upon unit root test results, integration of variables is of the same order so that I continue to test whether these variables are cointegrated over the sample period (Gao and He 2017). The Johansen cointegration test in Table 3.7 shows the trace statistic for non-cointegrating equations (29.0565) is greater than the 5% critical value (20.2618), but not for the at most one cointegrating equation (p-value 0.2781 is greater than 10%). This test rejects the hypothesis of none cointegration and indicates that there is at least one cointegrating equation at the 5% significance level, demonstrating there is a long-run relationship between lnY_t and lnE_t for Guangzhou.

Table 3. 7: Johansen Cointegration Test Results

Hypothesized Number of Cointegrating equation	Trace Statistic	5%Critical Value	P-value
None***	29.0565	20.2618	0.0024
At most 1	5.0494	9.1645	0.2781

Note: *** p<0.01, ** p<0.05, * p<0.1.

The results of the bound test are given in Table 3.8. From these results, there is a long run relationship exists between lnY_t and lnE_t, because their F-statistic (10.1886) are higher than the upper-bound critical value (5.5800) at the 1% level. This implies that the null hypothesis of no cointegration between lnY_t and lnE_t is rejected, when lnE_t is dependent variable.

Table 3. 8: Bounds Test Results

Estimated model	Lag length	F-statistic
f (lnY_t/lnE_t)	(1,1)	1.2110
f (lnE_t/lnY_t)	(1,3)	10.1886***
1% critical values	I(0)	I(1)
	4.9400	5.5800

Note: *** p<0.01, ** p<0.05, * p<0.1.

3.5.3 VECM Granger Causality Analysis

Table 3.9 reports the Granger causality analysis between lnY_t and lnE_t based on Vector Error Correction Model. Only in the long run, there is a unidirectional Granger causality from lnY_t to lnE_t since the related p-value of ECT_{t-1} (0.0048) is less than a 1% level. Moreover, the coefficient of ECT_{t-1} is negative and significant. Furthermore, this Granger Causality demonstrates that the evidence from Guangzhou supports the conservation hypothesis. This result is inconsistent with the finding that confirms the Granger Causality running from electricity consumption per capita to economic output per capita in the short run for Guangzhou (He et al 2017). However, the latter neglects the further discussion on the Granger Causality test for long-run.

Moreover, the empirical results in Table 3.8 just reflect Granger Causality between electricity consumption and economic output, which means a variable lnY_t is useful in forecasting another variable lnE_t (past values of lnY_t should contain information that helps predict lnE_t above and beyond the information contained in past values of lnE_t alone) but this does not imply that lnY_t actually causes lnE_t, in terms of causal inference (Angrist and Pischke 2008). So as to investigate the actual causal effect between electricity consumption and economic output, I need to continue to conduct the causal inference by using Kink Regression Discontinuity approach (Card et al. 2015).

Table 3. 9: VECM Granger Causality Analysis

Dependent variable	Wald statistics		
	Short run		Long run
	$\Sigma\Delta$ lnY_{t-1}	$\Sigma\Delta lnE_{t-1}$	ECT_{t-1}
ΔlnY_t	-	1.1692 (0.5573)	0.1186 (0.7305) [0.0103]
ΔlnE_t	2.8743(0.2376)	-	7.9511***(0.0048) [-0.0818]

Note: 1) *** p<0.01, ** p<0.05, * p<0.1; 2) Values in parenthesis are p-values; 3) Values in square brackets are estimated coefficients of ECT_{t-1}.

3.5.4 Regression Results from Institutional Experiment using KRD

In order to further examine the effect of institutional reform on electricity consumption, I continue to design an institutional experiment from 1985 using kink regression discontinuity.

Because electricity demand management reform in Guangzhou started in 1985, the natural log of real GDP in 1985 (lnY_{1985}) serves as a cutoff to compare electricity consumption prior to and after this date. Therefore, the $\ln Y_t$ prior to 1985 are not exposed to reform while $\ln Y_t$ in 1985 and thereafter are exposed to reform.

Table 3. 10: Results of Local Wald Estimation

Period	1949-2016
Cutoff Time	1985
Variable	Coefficient
lwald	0.3694** (0.1702)
N	68

Note: 1) *** p<0.01, ** p<0.05, * p<0.1; 2) Standard errors in parentheses.

Table 3.10 demonstrates that the local Wald estimator with one bandwidth during the period 1949 to 2016 is significantly positive, which confirms that the natural log of real GDP on 1985 is the cutoff, statistically (Appendix B2 Figure B1). Table 3.11 illustrates that the total marginal effects of $\ln Y_t$ are significantly positive both prior to 1985 (0.3774) and after 1985 (0.2207=0.3774-0.1567). This result means that while real GDP drives up electricity consumption throughout the entire time-period in Guangzhou, after electricity institutional reform, its impact is lessened. Since the total marginal effect of $\ln Y_t$ represents the income elasticity of electricity demand, I find that electricity consumption under the context of electricity demand management reform increases by 0.2207%, for an 1% change in economic output. Therefore, these results also confirm that there is true causality relationship running from economic output to electricity consumption, which is consistent with the empirical results from Granger Causality Test in Table 3.9.

Table 3. 11: Results of Kink Regression Discontinuity (Dependent Variable：$\ln E_t$)

Variable	Coefficient	Robust standard errors
D_t	0.0207	0.0463
$\ln Y_t$	0.3774 ***	0.1201
$D_t * \ln Y_t$	-0.1567*	0.0829
$\ln E_{t-1}$	0.8014***	0.0462
Constant	2.6401 ***	0.5982
Adjusted R-squared	0.9955	
Bandwidth	2.3461	
N	55	

Note: 1) *** $p<0.01$, ** $p<0.05$, * $p<0.1$; 2) bandwidth =2.3400.

Moreover, since the coefficient of $D_t * \ln Y_t$ is negative and statistically significant, after the electricity demand management reform, I conclude that the income elasticity of electricity consumption is lower after reform. I attribute this result to the electricity demand management reform where electricity use has transitioned from community (public) usage to individual (private) usage for the residential customers (households). So, it is presumed that the consumers prefer to purchase more energy-efficient appliances (such as compact fluorescent lamp or light emitting diode lamp) when their income increases after reform.

This reform created incentives for households to save electricity (He and Gao 2017). In addition, the regime of peak period rate also constrains commercial and industrial customers' demand for electricity. Finally, the coefficient of $\ln E_{t-1}$ is positive and statistically significant (Table 3.11). This result means that previous electricity consumption habits have a "path dependence" effect on current electricity consumption, because the consumer has formed the habits of consuming electricity.

3.6 Conclusions

To analyze the nexus between electricity consumption and metropolitan economic output in Guangzhou City, China, I develop a theoretical framework utilizing an inter-temporal constrained optimization of societal income with government investments in electricity infrastructure which includes aspects of electricity consumption habits by consumers and electricity demand management reform. A natural experiment design with a kink regression discontinuity method is utilized to evaluate the electricity consumption function after reform. Therefore, a metropolitan electricity consumption function is derived and estimated including GDP, electricity consumption habits, and electricity demand management reform in this study.

Previous studies have explored the nexus between electricity consumption and GDP by only examining empirical relationships without developing an underlying theoretical basis for this relationship (Ghosh 2002; Ikegami and Wang 2016; He et al 2017). It implies that previous studies of electricity consumption and income that don't develop a theory model. Although some empirical researchers have examined Granger causality between electricity consumption and GDP, they do not provide an underlying theoretical explanation for the logic of such a linkage between economic output and electricity consumption.

Based on the theoretical hypothesis, the empirical results demonstrate three findings: (1) unidirectional Granger causality running from economic output to electricity consumption, (2) given electricity consumption habits under the context of the electricity demand management reform, an economic output increase of 1% results in the increase of electricity consumption by 0.22% (the income elasticity demand of electricity), and (3), after the electricity demand management reform, economic output continues to increase electricity consumption, but at a lower rate than prior to reform.

The empirical results in this study imply that the ‘conservation hypothesis’ is upheld over the long-run at the regional level in Guangzhou. That outcomes of Granger Causality Test before and after electricity demand management reform are similar to what has been conducted using the whole data from 1949 to 2016 for Guangzhou (Tables B1 and B2 in Appendix B2). It is instructive that, electricity consumption is the consequence of income growth.

This study is also helpful in balancing the relationship between electricity use and economic reform. Especially, the experience of electricity demand management reform in Guangzhou provides the evidence that the “ammeter sole use system” improves the electricity use efficiency (units of electricity use per unit of GDP), because the individual pays any units of electricity that he or she actually uses.

Different from the conventional research on economic impact of energy use (Collins et al. 2012), the literature on the electricity-growth nexus is dominated by empirical research (Payne 2010). However, these are variability of causality results, particularly across sample periods, sample sizes, and model specification (Smyth 2013). Further research in these areas may shed light on regional variations in the functional form of electricity consumption.

Chapter 4: The Effect of Information Structure on Farmland Lease Contractual Choice: Evidence from Canton, China

4.1 Introduction

The farmland leasing contractual choice has been discussed in the economic literature on land tenancy efficiency from the class theory of share tenancy by Cheung (1968) to a recent synthesis by (Allen and Lueck 2018). The dominant view before Cheung (1968) maintained that share contract resulted in inefficient resource allocation because the share-tenant is said to result in less intensive farming because the tenant's incentive to work or invest in land is reduced (Johnson 1950). But Cheung (1968) argues that share contract can also result in the efficient resource allocation, the same as fixed-rent contract, under the assumption of zero cost of contracting. However, in the real world with non-zero transaction costs, what types of farmland leasing contract will be optimal in the agrarian economy?

The prolific literature on land tenancy has focused on the choice between share and fixed-rent tenancy contracts (Hayami and Otsuka 1993). The literature abounds with studies that investigate the efficiency of land rent sharing contract which can be divided into three groups (He et al. 2018): The first is based on moral hazard model (Stiglitz 1974). The second set of papers emphasize on empirical transactional costs paradigm (Allen and Lueck 1999). To the best of our knowledge, the main study recently focuses on the contract matching model (Niederle 2007).

According to the literature above, I ask the following questions: (1) What is the relationship between information structure and farmland contractual choice? (2) Under what kind of information environment would fixed-rent contract be the optimal institutional arrangement? (3) Under what kind of condition would land lessor regard a share contract as optimal rather than a fixed-rent contract? and (4) What are the results of different empirical methods in examining the effect of information structure on farmland contractual choice?

So, the effect of information structure on farmland leasing contractual choice can be estimated by understanding rural community relations that reinforce the mechanism of contract enforcement envisaged by quasi-experiment of propensity scores matching based on the treatment assuming that contracts between internal individuals (inside the same village) operate under complete information and that contracts between external individuals (tenant is from outside the village) operate under incomplete information.

Therefore, this study combines a theoretical model with an empirical analysis of farmland lease contracts. The theoretical part derives implications which explore farmland lease contractual choice under different information structures. Two related hypotheses are derived in this research. The first relates to complete information, under which it is found that land lessor prefers a fixed-rent contract as the optimal institutional arrangement. The second hypothesis involves incomplete information between the tenant and land lessor where a share contract is found to be the optimal choice for land lessor. Based upon the two hypotheses above, empirical evidence will be presented to confirm that land lessor who leases the farmland to an internal individual (inside the lessor's own village) which is assumed to be a tenant under complete information has a higher probability of choosing a fixed-rent contract. Conversely, land lessor who leases to an external individual outside their village (operating as a tenant under incomplete information) is more likely to choose share contract.

The empirical part of this study applies the econometric methods to test the theoretical implications utilizing field survey data collected from Canton of China. Although similar contracts have been observed in several provinces in China, Canton has been chosen for the empirical part of this study. During the phase of the reform and openness program in China, farmland leasing in Canton is more frequent than other provinces because Canton is the main and the first province to adopt marketization reform program especially involving farmland leasing market reform in China (Wang and Zhang 2017).

However, Cheung (1968)'s share contract theory bases on two assumption-private property rights and zero transactional costs. But they are contradictory. Private property rights imply that State have to invest resource to define and protect individual's property rights, so the value of such investment is transactional cost. It means that private property rights and zero transactional costs cannot exist at the same time. Furthermore, Cheung (1968) failed to arrive at general equilibrium solutions, owing to an inability to derive some specific transaction-cost functions and to disentangle some problems of choice theory involving risk. So, the contributions of this essay include: (1) I do not need the assumption of private ownership in Cheung (1968)'s tenancy theory, and I integrate transaction costs into the theoretical model of contractual choice; (2) the moral hazard model (Stiglitz 1974) that is derived through asymmetric information game theory separates from conventional tax-equivalent approach, but I obtain a new solution by combining principal-agent model and revised tax-equivalent approach. My finding is that share contract is not the optimal choice for lessors under complete information, but it is the optimal choice under incomplete information. Thus, I provide new evidence from Canton of China to support the theoretical hypothesis above by use of the matching propensity score method; (3) Based on the theoretical implication in this study, given incomplete information, a share contract will be preferred by land lessor. This result is consistent with the theoretical findings from Newbery (1977) and Hallagan (1978), and is supported by the empirical results from Ackerberg and Botticini (2000) and Bellemare (2012), which are based on the postulate of risk aversion, but my model does not need such assumption.

The rest of the paper is organized as follows (see Figure 4.1). A literature review and theoretic models are presented in sections 4.2 and 4.3, respectively. Section 4.4 describes the data and econometric methodology using a Logit model and propensity score matching. The empirical results of these analyses are presented section 4.5 and, finally, conclusions are presented in section 4.6.

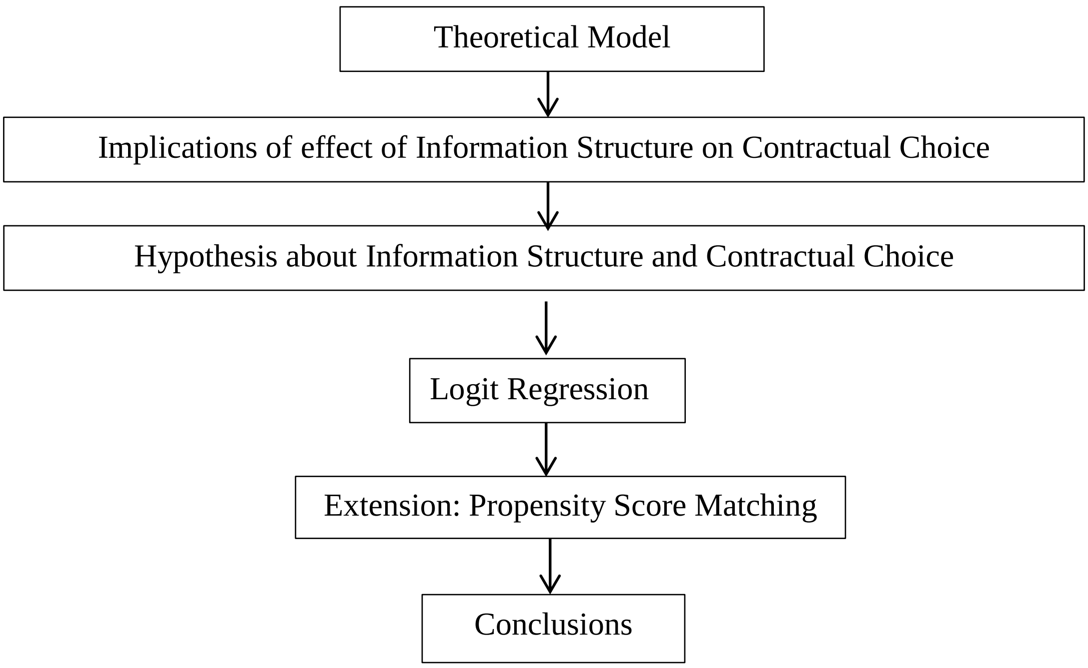

Figure 4. 1: Structural Flow Chart of the Theory and Econometric Methods Utilized in Chapter 4

4.2 Literature Review

The class of share tenancy theory proves that sharecropping results in efficient allocation of resources as illustrated by Cheung (1968). He argues that under the condition of zero transaction cost, a share contract, the same as the other forms of contracts, can result in efficient resource allocation (Cheung 1968). Specifically, “the rent per acre of land equals the marginal product of land in equilibrium under share contract, which is a condition identical to that of a fixed-rent contract" (Cheung 1969). The tenant alone controls the residual claim under fixed-rent contract, while residual claim is mutually shared by the land lessor and the tenant under share contract (Cheung 1969). From the perspective of Coasian Theorem, given zero transaction costs, the efficient outcome will be achieved by private negotiation, regardless of who control the property rights (Coase 1960). Based on this logic, who controls the residual claim of farmland will not affect the efficiency of resource allocation, without transaction costs, through different kinds of contracts.

Furthermore, Stiglitz (1974) derives a moral hazard model and proves that if the tenant's effort is costly to monitor, then the share contract may be rationalized as a risk-sharing device. Following Stiglitz's share contract theory above, economists have applied moral hazard model to conduct the empirical research on this topic. For example, Allen and Lueck (1999) find no evidence that it is important for the choice of contract between cash rent and crop share. Janvry and Sadoulet (2007) predict that contract terms will vary with the value to the tenant of unreported output as well as with any capacity of the principal to directly supervise the agent. Thus, the impression in the literature is that share tenancy results in low efficiency (Johnson 1950), because a share contract usually requires the tenant to pay the land lessor a specified proportion of the farm's production being similar to the taxation resulting in dead weight loss (Shavell 1979). However, the basic tenet of this essay is that the efficiency of a share contract must consider the information structure between the tenant and land lessor. In other words, different lease agreements will be the optimal institutional choice under different information conditions. However, instead of economic model of information, a transaction costs framework is developed to explain the choice in agricultural contracts (Alston and Ferrie 1993).

Furthermore, in my theoretical model, I consider contracting cost as a part of transaction cost that dissipates additional income.

The general treatment of land tenancy contracts is based on the theory of the principal-agent relationship (Hayami and Otsuka 1993), but it is extended to multitasking problem, mechanism design, and contractual choice between different organizations (Niu et al. 2016). Melkonyan (2004) examines how each of the supply-side effects manifests themselves in agricultural contracts. Schieffer et al. (2006) suggest that the determination of efficient policies to regulate agricultural contracts becomes dramatically more difficult and complex. Katchova (2010) shows that prices of agricultural contracts with cooperatives are not significantly different from those with investor-owned firms.

A recent focus of economic literature is on the contract matching model (Niederle 2007; Hatfield and Kojima 2009; Klaus and Walzl 2009;Hatfield and Kojima 2010; Westkamp 2010; Kominers 2012; Flanagan 2014;Risma 2015). However, this essay will try to design a one-to-one matching experiment in rural China on contractual choice in the empirical section.

In terms of empirical studies in China, Lai et al. (2017) show that farmland leasing market contract interlinks with rural labor market contract in a non-specialized production system. Furthermore, He et al.(2018) introduce a game theoretical framework for farmland rent contract choice which incorporates the characteristic uncertainty about the quality of agricultural factors and heterogeneous agricultural attributes matching with rural land leasing contract and the dynamic contracting behavioral equilibrium. Their game theoretic model shows that farmland rent sharecropping is a Pareto optimum contract and that a different farmland use contractual arrangement will match with specific agricultural factors combination between farmland and labor. In addition, sequentially rational tenants will make the game lease from Nash Equilibrium to Perfect Bayesian Equilibrium. Their empirical results indicate that the tenant's age has significant negative effect on share contract, and social security, soil fertility and the number of plots have significant positive effects.

4.3 Theoretic Model

4.3.1 The Basic Model

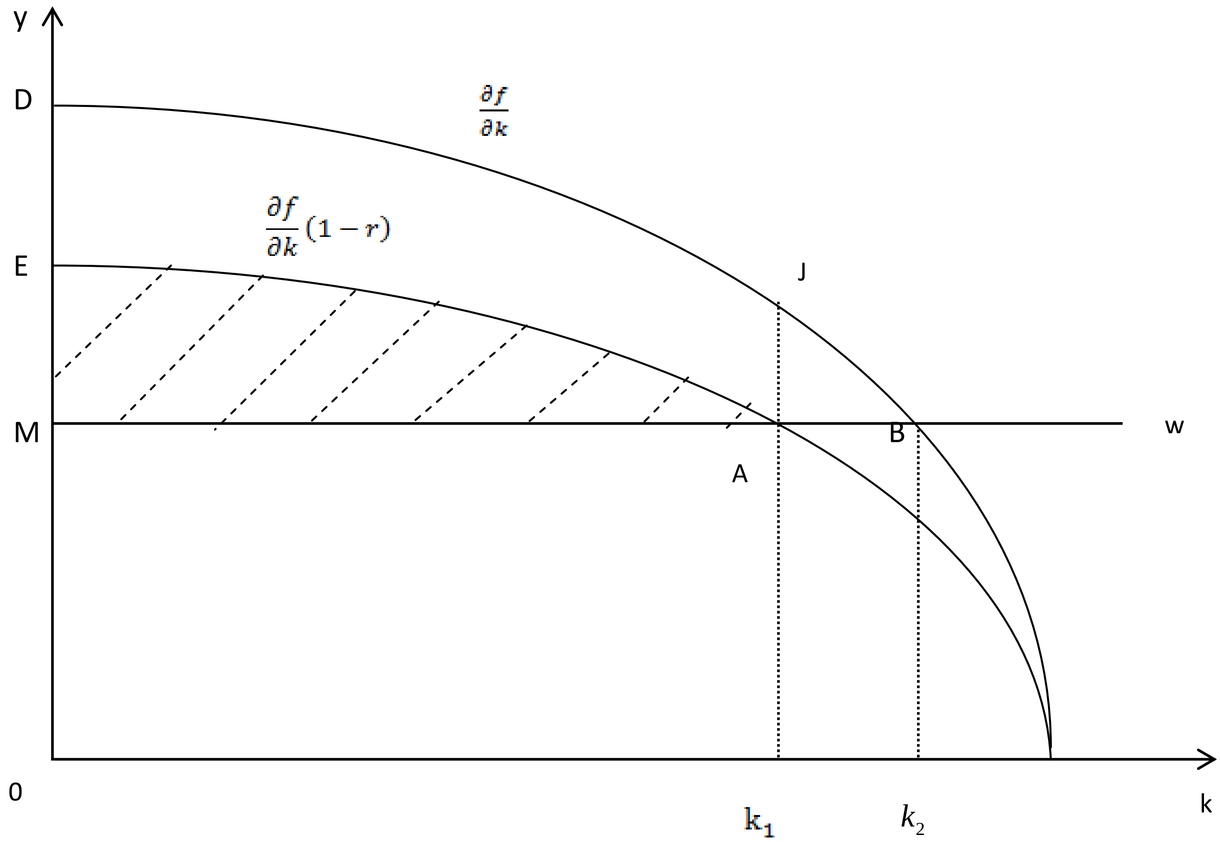

Figure 4. 2: A Revised Cheung's Approach

In this section, a theory of choice for farmland leasing contracts under different information structures is derived. The model is based on the premise of a competitive market. This model consists of a land lessor and a tenant. Let $Y = f(t, l)$ be the homogeneous production function, where t denotes tenant's labor input and l denotes the quantity of farmland leased by the tenant. Let $y = \frac{Y}{l}$ and $k = \frac{t}{l}$, then the homogeneous production function becomes $y = \frac{Y}{l} = f\left(\frac{t}{l}, \frac{l}{l}\right) = f(k, 1)$, where $\frac{\partial y}{\partial k} = \frac{\partial (ly)}{\partial (lk)} = \frac{\partial Y}{\partial t}$>0 and $\frac{\partial y^2}{\partial^2 k} < 0$. The marginal tenant cost, $\frac{\partial (wk)}{\partial k}$, is horizontal under a competitive labor market, with w reflecting the prevailing wage rate. It is important to note that in Cheung's model (1968), the horizontal axis is total labor of tenant t, so that the marginal product of labor diminishes as l increases. Cheung's model utilizes the assumption that farmland leased by the lessee is constant. By employing ratios of production and labor relative to land, the model developed in this essay does not need this assumption. Thus, it is a more generalized than Cheung's model. For instance, regardless of in the theoretical world or in the real world, tenants rent from more than one lessor so the amount of land leased can vary. So, Cheung's model does not consider this situation, but my model does.

In Figure 4.2, according to the law of diminishing marginal productivity, the marginal product of labor per unit of farmland area, $\frac{\partial f}{\partial k}$, diminishes as k increases. Suppose the rent charged by the land lessor is r percent of the annual yield. So, $\frac{\partial f}{\partial k}(1 - r)$ is the marginal tenant income, defined as the change in tenant's income with respect to a change in tenant's labor input per farmland area used by the tenant.

Under Cheung's approach of analyzing share tenancy, if the land lessor takes r percent of the annual yield and the tenant takes (1-r) percent, $\frac{\partial f}{\partial k}(1 - r)$ will be (1-r) percent of $\frac{\partial f}{\partial k}$ at every point. With the tenant's decision made at the margin, it is said, equilibrium is at A, where $\frac{\partial (\mathrm{wk})}{\partial k} = \frac{\partial f}{\partial k}(1 - r)$. The associated quantity of tenant labor per unit of farmland area is k_1, represents tenant's optimal investment under share contract. Under this condition, the total product is represented by the area S_{ODJk_1}, with the land lessor getting a rent equaling area S_{EDJA} and the tenant's share equaling area S_{0EAk_1}. So, the shaded area S_{MEA}, $\int_0^{k_1}[\frac{\partial f}{\partial k}(1-r)-w]dk$, represents the additional income over and above tenant's alternative earning (area $S_{0MAk_1} = wk_1$), which is gained from his working on other economic activities. But in the long run equilibrium, there should be no such additional income for tenant. So, as we know, on the equilibrium A, the additional income is finally offset by tenant's transaction costs under incomplete information ($TC_p^{incomplete}$):

$$TC_p^{incomplete} = S_{MEA} = \int_0^{k_1}[\frac{\partial f}{\partial k}(1-r)-w]dk \qquad (4.1)$$

In the real world, tenants will seek to increase efficiency in agricultural production by leasing farmland under different types of contracts. The formation of the contract involves either a share contract or a fixed-rent contract. Any such leases, along with the associated coordination of land lessor in agricultural production, are costly events (Cheung 1969). These costs are composed of three components: (1) negotiating costs between the contracting parties, (2) land lessor's local community organization cost for keeping an efficient personal connection network, and (3) the tenant's contracting costs from investment in specific asset (Williamson 1979). Of these three costs, the first one is probably the largest of the three transaction costs.

The contracting costs from investment in specific asset refer to the facts that tenant has to invest in acquiring skills for cultivating, cultivation equipment (such as hoe) and agricultural machine (such as the combine for harvest) to satisfy an agricultural production. If the tenant cannot find a land to lease, he or she will lose his or her job in rural area and has to switches to the other industry in urban, the investment in agricultural specific assets becomes his or her loss. So, the more the tenant invests in agricultural specific assets, however, the easier the hold-up problem arises (Klein et al 1978). In order to avoid being threatened by the land lessor who intends to increase the rent, tenant has to sign a formal contract. But the contracting activities will consume resources. The value of resources consumed for contracting is the contracting cost which is a part of transaction costs. So, the tenant's transaction costs include negotiation costs and contracting costs from investment in specific asset, which are supposed to be identical under contracts between external individuals and contracts between internal individuals ($TC_p^{incomplete} = TC_p^{complete}$).

In terms of land lessor's transaction costs ($TC_l^{incomplete}$), when contracts between external individuals (tenant is from outside the village) operate, these costs are negotiating costs only ($bc_l^{incomplete}$), and then I obtain $TC_l^{incomplete} = bc_l^{incocmplete}$. However, when contracts between internal individuals (both inside the same village) operate, lessor's transaction costs ($TC_l^{complete}$) are composed of both negotiating ($bc_l^{complete}$) and local community organization (cc_l) costs. The local community organization costs regard land lessor's investment in forming good reputation within his or her residential village community and keeping healthy relationships (friendship and being neighborly) with other villagers by providing personal help, financial support, and communication (talking and sharing of emotions). Even when assuming that land lessors have grown up in the village and know other villagers well, as the environment around their village changes because of impact of urbanization, land lessors still have to incur costs to maintain knowledge about and relationships with others in the village.

In this kind of network organization, it is easy for land lessor to monitor tenant's contracting activities. Hence, I consider farmland contracting within personal network as land lessor monitoring tenant's behavior under relatively complete information environment. In this case, however, the community organization costs to form and hold a good personal connection network within the village community are higher. Outside the village, the land lessor does not spend any resources to invest in keeping relationship with other persons who are not from his or her personal connection network. In that case, the local community organization costs for land lessor are limited. Therefore, there are a great number of community costs when contracts between internal individuals operate under complete information, but the community costs approximately approach to zero when contracts between external individuals operate under incomplete information. It means that such community organization costs actually are land lessor's expense for making the information more complete. Because the land lessor's revenue under incomplete information is expressed as the area S_{EDJA}, the land lessor's profits are $\pi_l^{incomplete} = S_{EDJA} - bc_l^{incomplete}$. To make land lessor's profits indifferent under different information structure, and $\pi_l^{complete} = S_{EDBA} - bc_l^{complete} - cc_l$ denotes land lessor's profits under complete information. So, given land lessor's bargaining costs are identical ($bc_l^{incomplete} = bc_l^{complete}$) and profits are indifferent ($\pi_l^{incomplete} = \pi_l^{complete}$) under different information structure, I derive that the land lessor's local community organization costs (cc_l) are identical to the area S_{AJB}, which actually was considered as the economic waste by Cheung (1968).

According to the property of the tenant's production $\frac{\partial y}{\partial k} > 0$ and $\frac{\partial y^2}{\partial^2 k} < 0$, let me assume that the production function can be expressed as $y = \ln k + \varepsilon = K + \varepsilon$, where $K = \ln k$ and ε denotes the exogenous variable with 0 mean value. So, $E(y) = E(K + \varepsilon) = E(K) + E(\varepsilon) = E(K) = K$. Following Stiglitz (1974), I use piecewise function to express the return to the tenant (s) based on a leasing contract either under a share or fixed-rent contract where a parameter (a) representing the fixed payment which corresponds to a=0 under share contract and to a<0 under fixed rent contract:

$$s(y)=(1-r)y+a, if \begin{cases} r=0 \Rightarrow fixed \quad rent \quad contract \\ r>0 \Rightarrow sharing \quad contract \end{cases} \qquad (4.2)$$

Following the model strategy from Holmstrom and Milgrom (1987), I assume tenant's production cost function is $C(K)=\frac{1}{2}\beta K^2$ and the coefficient of production cost $\beta > 0$.

4.3.2 Monitoring under Complete Information

Now, the tenant's expected profit function under complete information is

$$\begin{aligned} E\pi_p^{complete} &= E[s(y)-C(K)-TC_p^{complete}] \\ &= E[(1-r)y+a]-\tfrac{1}{2}\beta K^2-TC_p^{complete} \\ &= (1-r)E(y)+a-\tfrac{1}{2}\beta K^2-TC_p^{complete} \\ &= (1-r)K+a-\tfrac{1}{2}\beta K^2-TC_p^{complete} \qquad (4.3) \end{aligned}$$

Under complete information, the tenant's optimal input ratio (k_1) can be easily monitored by land lessor. So, in order to maximize the expected profits under complete information, land lessor can induce tenant to invest at his ideal level by negotiation. Then, the tenant's investment is contractually specified at an optimum level. In this case, the land lessor can successfully stipulate that the tenant invest up to k_1. Then, land lessor's expected profit maximum problem under complete information is:

$$\begin{aligned} \underset{k_1}{\text{Max}} E\pi_l^{complete} &= E\left[y-s(y)-TC_l^{complete}\right] = E\left[y-(1-r)y-a-TC_l^{complete}\right] \\ &= E\left[y-y+ry-a-TC_l^{complete}\right] = E\left[ry-a-TC_l^{complete}\right] \\ &= E[ry]-E[a]-E\left[TC_l^{complete}\right] = rE[y]-a-TC_l^{complete} \\ &= rK-a-TC_l^{complete} \quad (4.4) \end{aligned}$$

$$\text{s.t.}\ (1-r)K+a-\tfrac{1}{2}\beta K^2-TC_p^{complete} \geq V_c \qquad (4.5)$$

It means that the tenant's expected profits from leasing farmland at least should be identical to his reservation income (V_c), because land lessor has to guarantee that tenant is willing to receive his or her offer. So, tenant's expected profit function becomes land lessor's constraint condition of maximizing his or her expected profit, which is considered as the participation constraint. From (4.5), there should be a non-negative constant b satisfying that $(1-r)K + a - \frac{1}{2}\beta K^2 - TC_p^{complete} - V_c = b \geq 0$, and then $(-a) = (1 - r)K - \frac{1}{2}\beta K^2 - TC_p^{complete} - V_c - b$ (The Kuhn-Tucker Method is discussed in AppendixC1).If I put $(-a)$ into (4.4), then I will have：

$$\underset{k_1}{\text{Max}}\, E\pi_l^{complete} = rK + [(1-r)K - \frac{1}{2}\beta K^2 - TC_p^{complete} - V_c - b] - TC_l^{complete}$$

$$= K - \frac{1}{2}\beta K^2 - TC_p^{complete} - TC_l^{complete} - V_c - b$$

$$= K - \frac{1}{2}\beta K^2 - \int_0^{k_1} [\frac{\partial f}{\partial k}(1-r) - w]dk - \int_{k_1}^{k_2} (\frac{\partial f}{\partial k} - w)dk - bc_l^{complete} - V_c - b \quad (4.6)$$

The first order condition of equation (4.6) is as below:

$$\frac{\partial E\pi_l^{complete}}{\partial k_1} = w - \frac{\partial f}{\partial k}(1-r) + \frac{\partial f}{\partial k} - w = 0$$

So, I obtain that $r^* = 0$ (4.7)

Hence, the land lessor's optimal share percentage $r^* = 0$ satisfies the rent requirement for fixed-rent contract in formula (4.2), and it means that tenant obtains all residual claim income and land lessor receives the fixed rental income. Actually, as I have shown above, this optimal solution is based on the assumption of complete information between land lessor and tenant. The economic intuition of it is that under complete information, land lessor can obtain enough information referring to tenant's contractual enforcement. So, the land lessor is able to sign a contract with tenant to guarantee that land lessor can receive the fixed income from leasing farmland and tenant can obtain all of the residual claims, prior to the agricultural production. In that case, land lessor can unambiguously determine the amount of the fixed rental income, and tenant is encouraged to invest at land lessor's optimal target level by full residual claims. In Figure 4.2, k_2 is the optimal investment and then fixed-rent contract is the optimal arrangement under such information structure. Now, the equilibrium point is B, under complete information. According to this logic, given the complete information, a fixed-rent contract will be preferred by land lessor.

Implication 1 Under complete information, land lessor chooses fixed-rent contract as the optimal institutional arrangement.

In order to apply this proposition into the real case of farmland lease experiment in the empirical section, I consider the farmer who leases his or her right to using farmland represents the land lessor in my model and the internal individuals that lease in the right to use from the former within lessor's village (including neighbor, relatives, internal small farms, and internal large farms) represents the tenants under complete information in above model. Compared with collecting information regarding external individuals involving external small farms, external large farms, cooperatives, and agricultural corporations outside lessor's village, the land lessor relatively has more information about his or her neighbor, relatives and other farms within his or her own village. It means that land lessor can easily monitor the contractual performing activities of internal individuals. If the internal individual is supposed to be the tenant under complete information, according to this logic, I derive the first hypothesis from implication 1:

Hypothesis 1 Land lessor prefers to lease the right to using farmland to internal individuals by fixed-rent contract.

4.3.3 Monitoring under Incomplete Information

Basically, the tenet of implication one is that fixed-rent contract is optimal choice where information is complete. To the extent that information is incomplete, land lessor cannot efficiently induce tenant invest at land lessor's ideal level under fixed-rent contract, because it is difficult for land lessor to precisely measure tenant's inputs and determine the amount of rental income before tenant's cultivation. Therefore, fixed-rent contract cannot achieve land lessor's profit maximization.

According to Holmstrom and Milgrom (1987), when land lessor is not able to monitor tenant's contractual performing, tenant can determine his or her ideal k (and K) to maximize his or her expected profits. So, given tenant's transaction costs are the same regardless of the structure of information ($TC_p^{incomplete} = TC_p^{complete}$), then the tenant's expected profit function under incomplete information is

$$\underset{K}{\text{Max}} E\,\pi_p^{incomplete} = E[s(y) - C(K) - TC_p^{incomplete}]$$

$$= (1 - r)K + a - \tfrac{1}{2}\beta K^2 - \int_0^{k_1} [\tfrac{\partial f}{\partial k}(1-r) - w]dk$$

Therefore, the first order condition of tenant's expected profit function above is：

$$\frac{\partial E\pi_p^{incomplete}}{\partial K} = 1 - r - \tfrac{1}{2}\beta 2K = 0$$

That is as below：

$$K^* = \frac{1 - r}{\beta} \qquad (4.8)$$

That is the second constraint condition for land lessor to encourage tenant to contribute investment into agricultural production under incomplete information, which is supposed as the incentive compatibility constraint. Although land lessor cannot determine tenant's investment by contracts, he or she is still able to bargain with tenant on the rental sharing percentage (r), which can be specified on the contract under incomplete information. So, under incomplete information, land lessor can successfully stipulate his or her optimal sharing percentage. Hence, along with equation (4.4), land lessor's optimal problem becomes as below：

$$\underset{r}{\text{Max}} E\,\pi_l^{incomplete} = rK^* - a - TC_l^{incomplete} \qquad (4.9)$$

s.t. $(1-r)K^* + a - \frac{1}{2}\beta K^{*2} - \int_0^{k_1} [\frac{\partial f}{\partial k}(1-r) - w]dk \geq V_{in}$ (4.10)

$$K^* = \frac{1-r}{\beta} \qquad (4.8)$$

From (4.10), there should be a non-negative constant d satisfying that $(1-r)K^* + a - \frac{1}{2}\beta K^{*2} - \int_0^{k_1} [\frac{\partial f}{\partial k}(1-r) - w]dk - V_{in} = d \geq 0$, and

then $(-a) = (1-r)K^* - \frac{1}{2}\beta K^{*2} - \int_0^{k_1} [\frac{\partial f}{\partial k}(1-r) - w]dk - V_{in} - d$ (The Kuhn-Tucker Method is discussed in AppendixC1). If I put (4.8) and $(-a)$ into (4.9), then I will obtain:

$$\begin{aligned} E\pi_l^{incomplete} &= rK^* + \{(1-r)K^* - \tfrac{1}{2}\beta K^{*2} - \int_0^{k_1} [\tfrac{\partial f}{\partial k}(1-r) - w]dk - V_{in} - d\} - TC_l^{incomplete} \\ &= K^* - \tfrac{1}{2}\beta K^{*2} - \int_0^{k_1} [\tfrac{\partial f}{\partial k}(1-r) - w]dk - V_{in} - d - bc_l^{incomplete} \\ &= \tfrac{1-r}{\beta} - \tfrac{1}{2}\beta(\tfrac{1-r}{\beta})^2 - \int_0^{k_1} [\tfrac{\partial f}{\partial k}(1-r) - w]dk - V_{in} - d - bc_l^{incomplete} \qquad (4.11) \end{aligned}$$

So, the first order condition of equation (4.11) is as following:

$$\frac{\partial E\pi_l^{incomplete}}{\partial r} = -\frac{1}{\beta} - \frac{1}{2}\beta 2(\frac{1-r}{\beta})(-\frac{1}{\beta}) + \int_0^{k_1} \frac{\partial f}{\partial k} dk = 0 \qquad (4.12)$$

So, $\frac{1-r}{\beta} = \frac{1}{\beta} - \int_0^{k_1} \frac{\partial f}{\partial k} dk \Rightarrow 1-r = 1-\beta\int_0^{k_1} \frac{\partial f}{\partial k} dk$ (4.13).

The solution is that $r^{**} = \beta \int_0^{k_1} \frac{\partial f}{\partial k} dk > 0$ (4.14)

Hence, under incomplete information, the land lessor's optimal share percentage $r^{**} > 0$ satisfies the rent requirement of share contract in formula (4.2), and it means that tenant and land lessor both acquire one part of residual claim income under share contract. The optimal solution is equilibrium A in Figure 4.2, which assumes incomplete information between land lessor and tenant. It implies that it is difficult for the land lessor to observe tenant's contractual enforcement, so the former cannot efficiently specify the latter's investment and precisely determine the amount of rental income, under incomplete information. In that case, however, they can still make an agreement regarding the rental share percentage by share contract. The residual claim can be divided and allocated to the contracting parties according to the share percentage. Sharing tenancy can also play a vital role for incentive the land lessor and the tenant to perform the contract, under incomplete information. So, I derive the second implication as below:

Implication 2 The share contract is the best choice for land lessor under incomplete information.

It means that if the share percentage is greater than zero, and then the tenant's investment (such as k_1 in Figure 4.2) under incomplete information is less than that under complete information (k_2), because the share contract provides tenant just a part of residual claims but the fixed-rent contract provides tenant full residual claims, resulting in the total agricultural production under share contract is less than that under fixed-rent contract. However, land lessor does not need to take the responsibility for the local community organization costs under incomplete information, so share contract is chosen to reduce such a great deal of transaction costs. Based on this logic, if the information becomes incomplete, fixed-rent contract will be replaced by share contract for reducing transaction costs. Therefore, share contract is efficient under incomplete information. This result is consistent with the theoretical findings from Newbery (1977) and Hallagan (1978), and is supported by the empirical results from Ackerberg and Botticini (2000) and Bellemare (2012), which are based on the postulate of risk aversion, but my model does not need such assumption.

Similarly, in order to apply this proposition into the real case of farmland lease experiment below, I consider the external individuals that lease in the right to use from the land lessor outside the latter's village (including external small farms, external large farms, cooperatives, and agricultural corporations) represents the tenants under incomplete information in my model. Because compared with acquiring knowledge about the internal individuals, the land lessor relatively has less information about the external individuals outside his or her own village. If the external individual is supposed to be the tenant under incomplete information, according to this logic, I derive the second hypothesis from implication 2:

Hypothesis 2 Land lessor prefers to lease the right to using farmland to external individuals by share contract.

4.4 Empirical Tests

4.4.1 Data and Descriptive Statistics

I use the survey data from the Project of National Natural Science Foundation in China on the topic of farmland lease deregulation and Cantonese agricultural organization location game mechanism. The survey collected information from 547 rural households in Canton of China from January 2015 to March 2015. The main part of questionnaire is attached in the appendix C3.

The target population of the survey is farm households associated with farmland leasing businesses in 16 representative cites located in Canton of China (see Table 4.1). The selection of research sites for this survey was based on clustering analysis of five indicators (total population, per capita GDP, total area of farmland, agricultural population, and share of agricultural output). Finally, 16 representative cites within Guangdong (Canton) province were selected. The survey collects data from cross sectional data with 547 farmland lease observations from 600 households in 60 villages, so the effective sample rate is about 91.2%. Table 4.1 provides summary statistics of farmland contract samples distribution across the 16 cities.

Table 4.1 shows that the number of farmers (349) who choose fixed-rent contract is greater than that of farmers choosing share contract (198). The highest proportion of farmers choosing fixed-rent contract occurs in Shaoguan (92.5%), the north of Canton, and in Maoming (89.19%), the west of Canton; that of farmers choosing sharing contract appears in Qingyuan (69.23%) and Zhongshan (62.5%), the pearl river delta of Canton.

Table 4. 1: Summary Statistics of Farmland Contract Samples Distribution

City	Fixed-Rent Contract		Share Contract		Total	
	Number	Percentage (%)	Number	Percentage (%)	Number	Percentage (%)
Shanwei	20	50%	20	50%	40	7.31%
Zhuhai	17	77.27%	5	22.73%	22	4.02%
Meizhou	27	67.5%	13	32.5%	40	7.31%
Huizhou	14	43.75%	18	56.25%	32	5.85%
Maoming	33	89.19%	4	10.81%	37	6.76%
Heyuan	29	76.32%	9	23.68%	38	6.95%
Chaojiu	33	82.5%	7	17.5%	40	7.31%
Zhongshan	15	37.5%	25	62.5%	40	7.31%
Jieyang	23	60.53%	15	39.47%	38	6.95%
Shaoguan	37	92.5%	3	7.5%	40	7.31%
Qingyuan	12	30.77%	27	69.23%	39	7.13%
Yangjiang	33	86.84%	5	13.16%	38	6.95%
Zhanjiang	22	59.46%	15	40.54%	37	6.76%
Yangjiang	33	86.84%	5	13.16%	38	6.95%
Guangzhou	20	50%	20	50%	40	7.31%
Zhaoqing	14	53.85%	12	46.15%	26	4.75%
Total	349	63.8%	198	36.2%	547	100%

Table 4. 2: Descriptive Statistics

Item	Variable	Coding	Mean	Max	Min	S.D
Dependent Variable	contractualtype	1= Fixed-Rent Contract,0= Share Contract	0.638	1	0	0.4810
Independent Variables	informationstructure	1= farmland is leased to farmers, farms, agricultural corporations and cooperatives outside the subject's village, 0= farmland is leased to relatives, neighbors, farmers, farms, agricultural corporations and cooperatives in the same village with the subject	0.7659	1	0	0.4237
	popularname	1=land lessor's family name is seldom,2= land lessor's family is not seldom and not common, 3= land lessor's family name is common	2.5192	3	1	0.7419
	neighborhood	1=none relative and friend,2=a few of relatives and friends, 3= many relatives and friends	2.4351	3	1	0.5998
	publicpension	1=purchase governmental insurance,0=no	0.3784	1	0	0.4854
	privateinsurance	1=purchase commercial insurance,0=no	0.0439	1	0	0.2050
	farmlandreadjustment	1=farmland has not been readjusted in 5 years,2=part of farmland has been readjusted in 5 years, 3=all farmland has been readjusted in 5 years	1.1938	3	1	0.5437
	agriculturalincome	share of agricultural income to total household income*100%	29.10	100	0	32.38
	contracting	1= oral agreement, 2=paper contract not recognized by court,3=formal contract recognized by court	2.6782	3	1	0.6309
	farmlandtitling	1= titling on specific land area and share of land in rural land stock cooperative system, 2= titling on specific land area, 3= titling on share of land in rural land stock cooperative system, 4= under the process of titling, 5= none	2.1243	5	1	1.3407

Notes: 1) popularname represents land lessor's blood relationship within the village community. Especially for the village in Canton of China, most of members in the same village have the same family name, because they have the same ancestors. It means that land lessors and tenants who have the same family name are probably relatives in the same village. Hence, if the land lessor's family name is common in his or her village, then the probability that land lessor leases right to using farmland to internal individuals by fixed-rent contract is higher, according to implication 1.

2) The number of relatives and friends represents the land lessor's friendship status in the village community. When land lessor has many relatives and friends in his or her village, he or she has a good relationship with other village members and easily forms an efficient private network that reduces contracting costs if the farmland is leased within that network. So, the probability that land lessor leases right to using farmland to internal individuals by fixed-rent contract is higher under the condition that land lessor owns a well-organized social connection capital, according to implication 1.

3) The core of Chinese farmland policy is the coexistence of individual land-use rights with village-level land ownership. Individual rights are intended to motivate farmers to invest in land, while village-level ownership allows officials to reallocate that land periodically and impose other land use adjustments (Zhang et al. 2011). In order to keep equity in the village of Chinese, the right to using farmland is reallocated by the village officials each five years, according to the village population and of village member's family size (Mullan et al. 2011).

4) farmlandtitling is a form of farmland reform in China where rural household and families are given formal user rights of farmland with legal permits by the village government (Li 2012). Titling on specific land area means the information about the location and area of farmer's land is included in the permit clearly. Titling on share of land in rural land stock cooperative system means that the information about the location and area of the land is not included in the permit, so the information is ambiguous, but the share percentage of the village land is converted to the stock in the rural land stock cooperative system and the share percentage of land stock is involved in the permit.

5) The insurance purchase status represents the subject's risk attitude.

Table 4.2 presents summary statistics for each of the variables in the analysis. As shown in Table 4.2, contractual choice (contractualtype) is the main explanatory variable (I define it as 1 given the fixed-rent contract and as 0 given sharing contract). Information structure is taken as the main explanatory variable: I define “informationstructure” as 0 if farmland is leased to internal individuals, others as 1, according to the implication one and two in theoretical section. According to the sample, 23.41% farmland is leased to internal individuals and 76.59% farmland is leased to external individuals. Most of local farmers in Canton prefer to migrate to urban and lease their farmland to the external individuals who usually come from the north of Canton such as Hunan Province (He 2019). So, the farmland in Canton is mainly leased to external individuals, which is the result of the local rural population urbanization (Lai et al. 2017)

4.4.2 Econometric Methodology

(1) Binary Dependent Variable Regression: Logit Model

To empirically estimate the choice of contracts, I set up a binary regression model with a vector of exogenous explanatory X (informationstructure, popularname, neighborhood, publicpension, privateinsurance, agriculturalincome, farmlandreadjustment, contracting, farmlandtitling), a random disturbance term e_i and dependent variable

$$contractualtype_i = \begin{cases} 1, & fixed - rent\ contract \\ 0, & share\ contract \end{cases}.$$

So, the probability model of choosing fixed-rent contract for farmer i is expressed as follows:

$$p = P_{i1} = \Pr\left[contractualtype_i = 1 | X_i\right] = \mathrm{F}_e\left(X_i^{'}\beta\right) = \frac{\exp\left(X_i'\beta_i\right)}{1+\exp\left(X_i'\beta_i\right)} \qquad (4.15)$$

where $\mathrm{F}_e(.)$ is the logistic distribution function of e_i. So the probability model specification of share contractual choice for the i^{th} farmer can now be written as:

$$1-p=P_{i0}=\Pr\left[contractualtype_i=0|X_i\right]=\frac{1}{1+\exp\left(X_i'\beta_i\right)} \qquad (4.16)$$

From (4.15), $\frac{\mathrm{p}}{1-\mathrm{p}}=\exp(X_i'\beta)$ and then the natural logarithm of relative odds is

$\ln\left(\frac{\mathrm{p}}{1-\mathrm{p}}\right)=X_i'\beta$ (4.17).

Since I cannot interpret the parameters of probability model directly, I can use marginal effect of parameters for estimation. For the farmer i, the marginal effect of a change in the kth independent variable on the probability that the farmer i chooses fixed-rent contract as follow.

$$\frac{\partial \Pr\left[contractualtype_i=1|X_i\right]}{\partial X_k}$$

$$=\frac{\partial \Pr\left[contractualtype_i=1|X_i\right]}{\partial(X_i'\beta_i)}\frac{\partial P(X_i'\beta_i)}{\partial X_k}=F_e^{'}(X_i'\beta_i)\beta_k=f_e(X_i'\beta_i)\beta_k \qquad (4.18)$$

where $F_e^{'}(.)=f_e$ is the probability intensity function.

(2) Propensity Score Matching (PSM)

A Logit Model regression may yield selection bias if unobservable farmer behavior and psychology characteristics (e.g., individual value preference, community common beliefs, and so on) influence farmland being leased to internal individuals. This may arise from farmer self-selection for leasing farmland to internal individuals, resulting in an endogenous problem. Therefore, estimation of Logit Model will lead to biased estimates. The propensity score matching method, however, solves for selection bias by estimating a counterfactual outcome for a control group with similar attributes with a treatment group (Pan 2014).

In principle, the impact on contractual choice of the information structure is as below: For farmer i, with $\mathrm{i}=1,\cdots,547$, I follow Abadie and Imbens (2006) and let $contractualtype_{i0}$ and $contractualtype_{i1}$ denote the two potential outcomes given lessors who lease to internal lessees ($informationstructure_i = 0$) considered the control group and lessors who lease to external lessees ($informationstructure_i = 1$) as the treatment group. The variable $informationstructure_i$, with $informationstructure_i \in \{0,1\}$, indicates the treatment is received or not such that $informationstructure_i = 0$ represents complete information or farmland leased to internal individuals as controlled group and $informationstructure_i = 1$ represents incomplete information or farmland leased to external individuals as treated group. The basic idea of PSM is to match treatment lessors who lease to external individuals with control lessors who lease to internal individuals and have similar attributes with the treatment group individuals.

For farmer i, I observe $informationstructure_i$ and the outcomes for this treatment, $contractualtype_i = \begin{cases} contractualtype_{i1} = 0, \ if \ informationstructure_i = 1 \\ contractualtype_{i0} = 1, \ if \ informationstructure_i = 0 \end{cases}$ as well as a vector of covariates, denoted by X_i. My main focus is on the average treatment effect for the treated (ATT).

Controlling for endogenous matching has an impact on parameters of interest, and tenants' risk aversion appears to have influenced contract choice (Ackerberg and Botticini, 2001). According to that literature, I address this endogenous matching problem using PSM on farmland contracts.

So, the average treatment effect for the treated (ATT) estimation with propensity score ($\mathrm{p}(\mathrm{X}_i) = E[\mathrm{informationstructure}_i|\mathrm{X}_i] = Pr[\mathrm{informationstructure}_i = 1|\mathrm{X}_i]$) is:

$$\tau_{ATT}^{PSM} = \mathrm{E}[contractualtype_{i1} - contractualtype_{i0}|\mathrm{informationstructure}_i = 1]$$
$$= \mathrm{E}\{\mathrm{E}[contractualtype_{i1} - contractualtype_{i0}|\mathrm{p}(\mathrm{X}_i), \mathrm{informationstructure}_i = 1]|\mathrm{informationstructure}_i = 1\}$$

$$= \text{E}\{\text{E}[contractualtype_{i1}|\text{p}(\text{X}_i), \text{informationstructure}_i = 1] - \text{E}[contractualtype_{i0}|\text{p}(\text{X}_i), \text{informationstructure}_i = 1]|\text{informationstructure}_i = 1\}$$

Under the conditional independence assumption (CIA), I obtain

$$\text{E}[contractualtype_{i0}|\text{p}(\text{X}_i), \text{informationstructure}_i = 1] = \text{E}[contractualtype_{i0}|\text{p}(\text{X}_i), \text{informationstructure}_i = 0] \quad (4.19)$$

Equation (4.19) means that the distributions of potential outcomes between the treated and the controlled groups are the same, with the same covariates. So, the expectation values are identical. The left-hand side of (4.19) represents the counterfactual outcome of the treatment group, which is unobserved. The right-hand of (4.19) represents the observed outcome of the control group. Then I can use the observable outcome of the control group as the estimation of the counterfactual outcome of the treated. Therefore,

$$\tau_{ATT}^{PSM} = \text{E}\{\text{E}[contractualtype_{i1}|\text{p}(\text{X}_i), \text{informationstructure}_i = 1] - \text{E}[contractualtype_{i0}|\text{p}(\text{X}_i), \text{informationstructure}_i = 0]|\text{informationstructure}_i = 1\}$$
$$= \text{E}\{\text{E}[contractualtype_{i}|\text{p}(\text{X}_i), \text{informationstructure}_i = 1] - \text{E}[contractualtype_{i}|\text{p}(\text{X}_i), \text{informationstructure}_i = 0]|\text{informationstructure}_i = 1\} \quad (4.20)$$

Hence, (4.20) is the average difference between the average outcome of the treated (farmland leased to external individuals) and average outcome of the controlled (farmland leased to internal individuals), given the treatment. Generally speaking, there are various matching propensity scores algorithms, asymptotically, all matching methods should yield the same results (Stuart 2010). However, in practice, there are trade-offs in terms of bias and efficiency with each method (Todd 1999). In order to design one to one matching experiment to guarantee the causal effect above, I utilize nearest neighbor matching approach (Heckman et al 1998).

4.5 Empirical Results

4.5.1 Estimation by Logit Model

Table 4.3 reports estimation results for the Logit Model. A negative regression coefficient means that an increase in the explanatory variable is associated with decreased probability of choosing a fixed-rent contract. Before expounding on the results, it is worth mentioning that the estimated model demonstrated a good predictive capability as indicated by McFadden pseudo-R^2 value of 0.2759, because it is far less than 1.

Turning my attention to the coefficient estimates in Table 4.3, the informationstructure coefficient has a negative and significant effect on the choice of fixed-rent contract. The marginal effect of -0.1361 suggests that when farmland is leased to an external individual, the farmer is 13.61% to less likely to lease out farmland by fixed-rent lease contract compared to a share contract. It means that the farmer is more likely to lease out farmland by share contract, if the farmland is leased to an external individual. This result is consistent with hypothesis two.

Results in Table 4.3 also show that 1% increase in the agricultural income ratio (agriculturalincome) is 0.52% more likely to lease farmland by fixed-rent contract. The agricultural income ratio reflects the degree to which agriculture is the primary revenue source for the land lessor. The higher the agricultural income ratio, the more the land lessor depends on agricultural land for income. It means that the lessor with higher agricultural income ratio is more likely to work and stay in his or her village, instead of to migrate outside the village and work in non-agricultural industry (Zou and Luo 2018). Therefore, lessors who are farmers are more likely to lease farmland by fixed-rent contract. Conversely with a lower agricultural income ratio, a land lessor is less able to monitor the tenant easily, given he or she has likely migrated outside his or her own village for non-agricultural work. In that case, most of his or her income comes from non-agricultural production. Hence, with lower agricultural income ratio, land lessor is more likely to lease farmland under a share contract. Thus, this result supports the hypothesis one in the theoretical section.

Finally, Table 4.3 reveals that the farmer who has experience with large scale of readjustment of farmland in the last five years is about 10.04% more likely to choose fixed-rent contract (marginal effect in Table 4.3). Further, the coefficient on choosing fixed-rent contract is positive and significant at the 10% level of significance. This result suggests that when property rights of farmland are unstable, farmer is more likely to lease farmland by fixed-rent contract, so as to guarantee that a fixed-rental income will be obtained and reduce the impact from farmland readjustment (Zou et al. 2018).

Table 4. 3: Regression Results for Logit Model (Dependent Variable: contractualtype)

Variable	coefficient	marginal effect
informationstructure	-0.8430**	-0.1361**
	(0.3987)	(0.0643)
popularname	0.3174	0.0512
	(0.2744)	(0.0435)
neighborhood	-0.055	-0.0090
	(0.2474)	(0.0399)
publicpension	-0.2875	-0.0464
	(0.3989)	(0.0645)
privatepension	0.3201	0.0517
	(0.8817)	(0.1420)
farmlandreadjustment	0.6221*	0.1004*
	(0.3685)	(0.0589)
agriculturalincome	0.0323***	0.0052***
	(0.0089)	(0.0012)
contracting	-0.0959	-0.0154
	(0.3100)	(0.0500)
farmlandtitling	-0.019	-0.0030
	(0.1316)	(0.0212)
constant	-1.4633	
	(1.9147)	
Pseudo R^2	0.2759	
Observations	547	547

Note: 1) *** p<0.01, ** p<0.05, * p<0.1; 2) Robust standard errors in parentheses.

4.5.2 Extension by PSM

As shown the PSM methodology section, in order to conduct the Nearest Neighbor Matching (Caliendo and Kopenig 2008), especially for one to one matching with replacement (Pan, 2014), I examine the impact of information structure on farmland contractual choice behavior with NNM in Table 4.4.

Table 4. 4: Estimates of the Average Treatment Effect for Treatment Variable (ATT)

Matching Status	Number of External Individuals	Number of Internal Individuals	Total Observations	Probability of Choosing Fixed-rent Contract by External Individuals	Probability of Choosing Fixed-rent Contract by Internal Individuals	Difference or ATT	t-stat
Before Matching	419	128	547	0.6574	0.6111	0.0463	0.82
After Matching	216	108	324	0.6536	0.8040	-0.1504	-1.83*

Note: *** p<0.01, ** p<0.05, * p<0.1.

Before matching, the probabilities of treated group (lessors leasing to external individuals) and controlled group (lessors leasing to internal individuals) choosing fixed-rent contract are 0.6574 and 0.6111, respectively. It means that 65.74% of the 419 external individuals choosing fixed-rent contract, while 61.11% of the 128 internal individuals choosing fixed-rent contract, which implies that 34.26% of the 419 external individuals choosing share contract, while 38.89% of the 128 internal individuals choosing share contract, before matching. And the probability of a fixed-rent contract by the treatment group is greater than that of control group by 0.0463. This difference, however, is not statistically significant. Matching is a method to design an experiment under a randomized tries environment in which the selection bias will be solved. So, I pay more attention on the empirical results by matching.

Again, Table 4.4 shows that after matching, the probabilities of treated group (lessors leasing to external individuals) and controlled group (lessors leasing to internal individuals) choosing fixed-rent contract are 0.6536 and 0.8040, respectively. It means that 65.36% of the 216 external individuals responding chose fixed-rent contract, while 80.40% of the 108 internal individuals responding chose fixed-rent contract, which implies that 34.64% of the 216 external individuals responding chose share contract, while 19.60% of the 108 internal individuals responding chose share contract, after matching. Moreover, ATT changes from 0.0463 to -0.1504 and the t-stat becomes significant at a 10% level after matching, implying that after matching, the probability of the treatment group is less than that of the control group by 0.1504. The NNM indicates that farmland being leased to external individuals under incomplete information has a negative impact on fixed-rent contractual choice behavior, which is consistent with hypothesis 2. This result also means when selection bias is not accounted for there is estimation bias about causal effect of information structure on farmland contractual choice. Hence, after considering farmer's contractual selection bias, information structure impacts farmland contractual choice significantly.

To check the stability of the propensity score matching results, kernel density test using the NNM are shown in Appendix C2. The result of this test shows that the difference in kernel density between lessor leasing to external individuals and lessors leasing to internal individuals groups after matching becomes much smaller than before matching. Before matching, there are significant differences in the characteristics between these two groups, so the propensity score curve of the treated departs from propensity score curve of the controlled. After matching, they are overlapping, which means that the differences in the characteristics between these groups have been balanced. These two overlapping curves imply that the attributes between the treated and the controlled are similar. So, it means that the PSM satisfies the balancing requirement by kernel density test.

4.6 Conclusions

This research examines whether the informational structure between tenants and land lessors impacts farmland leasing contractual choice. The theoretic model results show that: (1) under complete information, a farmland lessor prefers a fixed-rent contract as the optimal institutional arrangement; and (2) a share contract will be the optimal choice for a farmland lessor under incomplete information. Furthermore, if I consider the farmer who leases farmland to an internal individual from lessor's village represents a land lessor under complete information, then this lessor prefers a fixed-rent contract. In contrast, if I consider the farmer who leases farmland to an external individual (one outside a lessor's village) as a land lessor under incomplete information, then this lessor prefers to lease the right to using farmland through a share contract.

Empirical testing of this theoretical model with a Logit Model confirms that when land lessor engages in a farmland lease contract with an external individual, there is a negative and statistically significant effect on being likely to choose a fixed-rent contract. The test of propensity score matching (PSM) confirms the presence of estimation bias from sample self-selection between lessors who lease to internal individuals versus and lessors who lease to external individuals, so PSM approach utilized simulates the effect of randomization trials. It implies that the PSM with nearest-neighbor is suitable, which is consistent with the canonical model of sharecropping by making the strength of the land lessor's property right increasing in the amount of risk she bears within the contract (Bellemare, 2009).

The theory of contractual choice under different information structure developed in this research may also be extended to other leasing arrangements. Share and fixed-rent contracts are observed not only in farmland, but also are common among farm machinery rentals.   However, the attributes between farmland and farm machine are different. For example, the quality of farmland is different when the land leased by tenant in different location, while the quality of farm machine is roughly the same even though it is used in different places. For example, when farmland quality is very low, landlord would choose sharing contract to exposure risk, so sharing contract is designed for risk sharing partnerships (He et al. 2018). Of course, when the attributes of subjects differ, modifications need to be made in the theory of information structure to interpret contractual choice in these fields. Finally, more formal analyses of the choice of contractual arrangements involved wage contract and of subject's other attributes (such as quality of land or ability of labor) is needed (He et al. 2018).

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Chapter 5: Conclusions

This study has analyzed the environmental pollution, electricity consumption and farmland contractual choice in China by: (1) assessing the impacts of environmental pollution and institutional abatement targets on real average housing prices across China, (2) deriving a metropolitan electricity consumption function under electricity demand management reform, and (3) determining optimal farmland leasing contractual choice under different informational structures.

The nation of China is the world's largest source of sulfur dioxide emissions. The objective of the first essay is to examine the effects of sulfur dioxide emissions and institutional abatement targets on real average housing prices in China. Three econometric models are used to investigate these effects: Fixed Effects, Spatial Fixed Effects, and Spatial Difference-In-Difference. The contributions of this chapter are: (1) providing a theoretical framework for the impacts of environmental pollution and SO_2 institutional abatement targets on real average housing prices, (2) designing an institutional experiment integrated with spatial factors to assess the impact of institutional abatement targets on real average housing prices, and (3) distinguishing and examining both water and air pollution impacts on housing prices.

This framework reveals that both types of environment pollution have negative impacts on real average housing prices. In addition, the empirical results confirm the theoretical expectations for SO_2 emissions and discharges for industrial wastewater using both Fixed Effects and Spatial Fixed Effects Models. The empirical results from institutional experiment also demonstrate that the institutional abatement targets increase real average housing price during the Eleventh Five-Year Plan in China. Based on the empirical results, I can conclude that the impact of air pollution is greater than the impact of water pollution.

Electricity use is vitally important for a developing metropolitan. In the second essay, the purpose is to investigate the effect of economic output combining electricity demand management reform on electricity consumption by setting up an optimal control model and deriving a basic electricity consumption function. The research contributions include: (1) use of an inter-temporal total income optimization model that connects electricity consumption to economic output and consumption habits, which has not been examined previously in the literature, and (2) design of a natural experiment using kink regression discontinuity approach to investigate the effect of the 1985 electricity demand management reform that occurred in Guangzhou on electricity consumption.

Based on the theoretical hypothesis, the empirical results demonstrate three findings: (1) a unidirectional Granger causality running from economic output to electricity consumption; (2) previous electricity consumption habits have a "path dependent" effect on current electricity consumption; and (3) given the electricity demand management reform, economic output drives up the electricity consumption, but at a lower rate than prior to reform–indicating possible efficient improvements in electricity usage.

For the third essay, the research objective is to examine the effect of information structure on the farmland contractual choice behavior. Farmland was not allowed to be leased before the 1978 agricultural system reform in China. Therefore, the farmland lease contractual choice behavior is considered as a case study of land lessor and tenant choices occurring after reform in rural China. The contributions of this essay are: (1) the assumption of private ownership in Cheung (1968)'s tenancy theory is shown not to be needed and transaction costs are integrated into the theoretical model of contractual choice; and (2) the moral hazard model (Stiglitz 1974) separates from conventional tax-equivalent approach, but I obtain new solution by combining principal-agent model and revised tax-equivalent approach. The findings are that share contract is inefficient under complete information, but this type of contract is the optimal choice under incomplete information. Empirical evidence from Canton, China is provided to support the theoretical hypotheses above by use of the Matching Propensity Score method. Finally, based on the theoretical implications in this study, given incomplete information, a share contract will be preferred by the land lessor.

The results of theoretic models derived that: (1) under complete information, land lessor chooses fixed-rent contract as the optimal institutional arrangement; and (2) share contract will be considered as the best choice for land lessor under incomplete information. Furthermore, I consider that the farmer who leases his or her farmland represents the land lessor in my model and the internal individual who leases in the right to use farmland from a land lessor within lessor's village represents the tenant under complete information in my model. The land lessor, in this case of an internal individual as a tenant, prefers a fixed-rent contract. In contrast, when an external individual (one outside a lessor's village) is the tenant leasing in farmland, this lessor and tenant relationship is a share contract under incomplete information. As a result, the land lessor prefers to lease the right to using farmland to external individuals by share contract.

As a concluding remark linking all three essays, each one involves the development of econometric model which utilize methods to incorporate an institutional change experiment involving regulatory reform. These methods by experimental econometrics are less prone to specification errors than standard methods involving selection bias (Angrist and Pischke 2008). Because the former makes the empirical research be closed to randomized trial. For example, matching method in Chapter 4 is considered as a stratified randomized experiment: each farmer who leases land to external individuals finds (at least) one from internal individuals equal in covariates. It means that the population of farmers is divided into different groups randomly. Furthermore, in terms of the panel data in Chapter 2, fixed effects or difference in difference strategy actually is an incremental stratified randomized experiment, so it is a typical design for natural experiment. Finally, the regression discontinuity approach is the most closed to complete randomized experiment: the individual is not able to control the cut-off, so the data around the cut-off (or kink point in Chapter 3) are highly similar. Near cut-off, whether the data belongs to the left-hand side or right-hand side is completely determined by uncontrolled random factors. Therefore, the assignment of treatment can be considered as a complete randomized experiment.

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Appendix A

Appendix A1

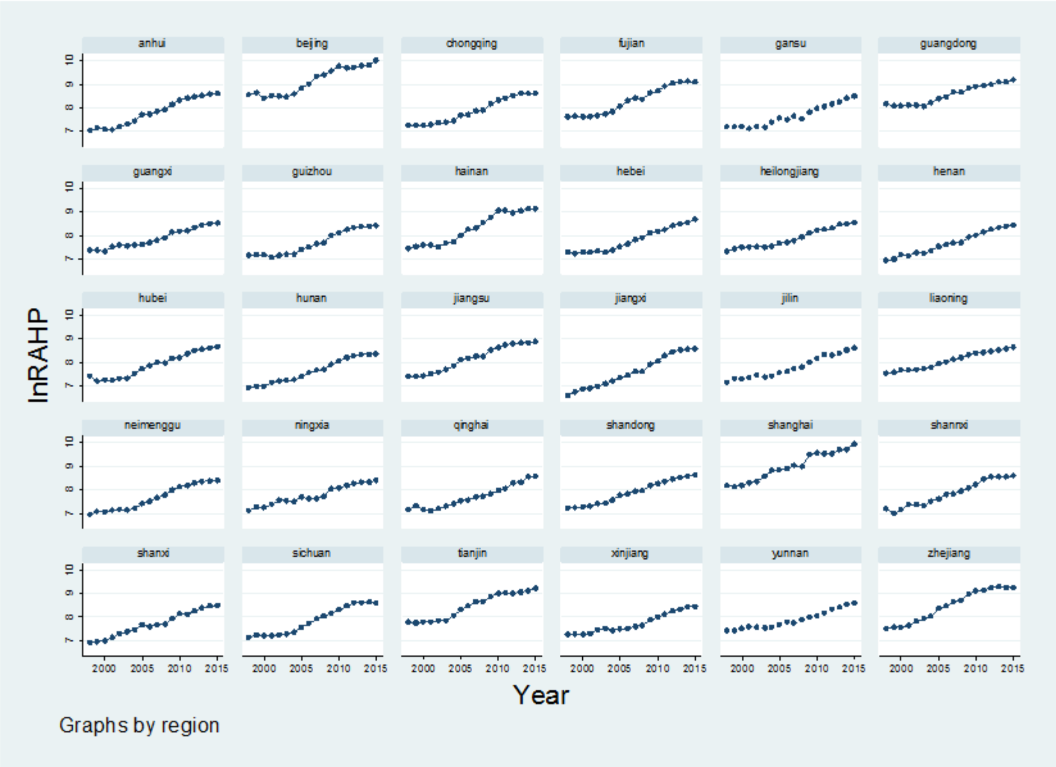

Figure A 1: Time Trend of Natural Logarithmic of Real Average Housing Prices in Sample Provinces of China (1998-2015)

Appendix A2

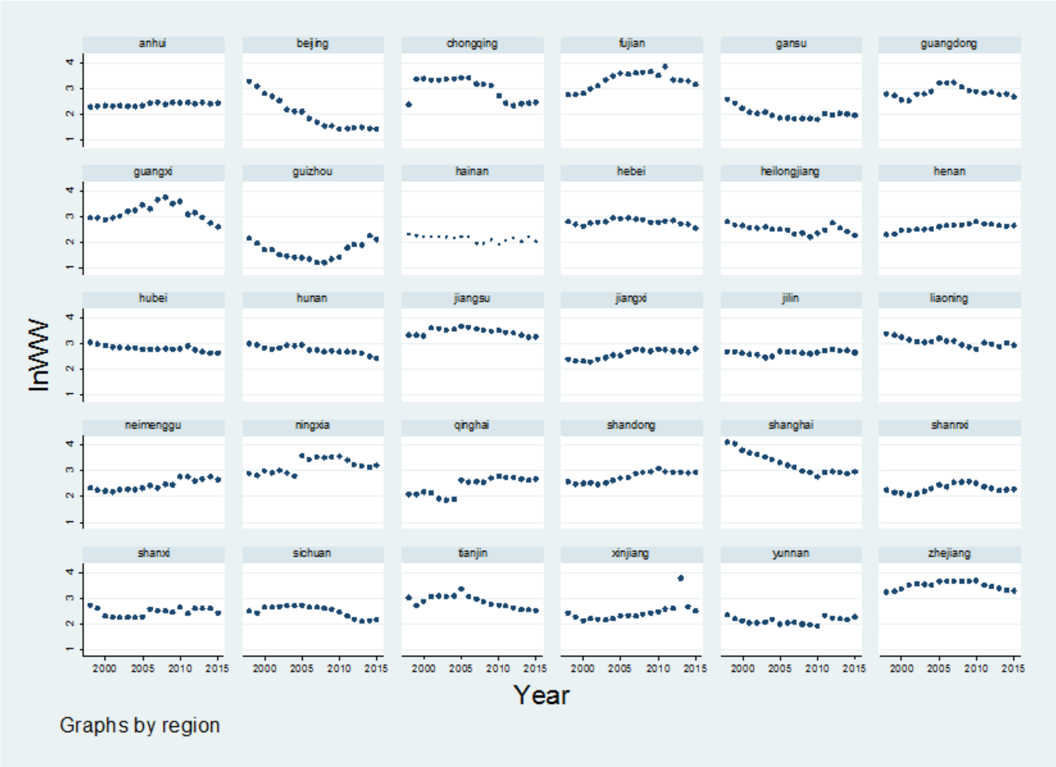

Figure A 2: Time Trend of Natural Logarithmic of Discharges of Industrial Wastewater Per Capita in Sample Provinces of China (1998-2015)

Appendix A3

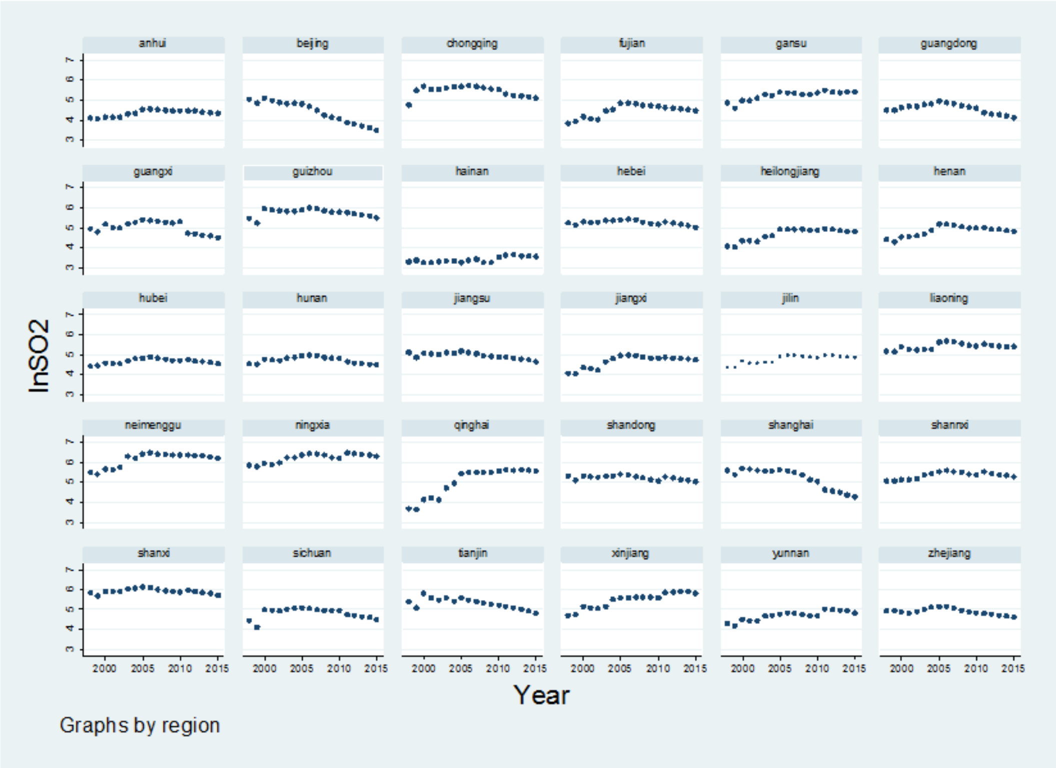

Figure A 3: Time Trend of Natural Logarithmic of Sulfur Dioxide Emissions Per Capita in Sample Provinces of China (1998-2015)

Appendix A4

Table A 1: Results of Panel Unit Root Test (Levin-Lin-Chu)

Variable	Statistics	P value
lnRAHP	-3.8771***	0.0001
lnWW	-2.7734***	0.0028
lnSO2	-8.2299***	0.0000
lnBC	-6.7486***	0.0001
lnUR	-84.0679***	0.0000
lnI	-8.7403***	0.0000

Note: 1) *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendix B

Appendix B1

This appendix provides a derivation of equation (3.10). This derivation starts with the current Hamiltonian Function from the optimal control problem in equation (3.9):

$$\mathcal{H}_C = \mathrm{A}_t\mathrm{K}_t^a(\mathrm{f}\,\varepsilon_t(D_t)\,\mathrm{F}_t)^b\mathrm{L}_t^d + (\frac{1}{1+\theta})\varphi_{t+1}[\mathrm{A}_t\mathrm{K}_t^a(\mathrm{f}\,\varepsilon_t(D_t)\,\mathrm{F}_t)^b\mathrm{L}_t^d - \mathrm{C}_t - G_t - \delta\mathrm{K}_t] + (\frac{1}{1+\theta})\tau_{t+1}(\mathrm{G}_t - \pi\mathrm{F}_t) \quad \text{(B1)}$$

where φ_t is the shadow price of capital at year t and τ_t is the shadow price of stock of electricity infrastructure at year t. The Pontryagin necessary conditions (PNC) are as below:

$$\frac{\partial\mathcal{H}_C}{\partial\mathrm{G}_t} = -\left(\frac{1}{1+\theta}\right)\varphi_{t+1} + (\frac{1}{1+\theta})\tau_{t+1} = 0 \quad \text{(B2)}$$

$$\frac{\partial\mathcal{H}_C}{\partial F_t} = b\mathrm{A}_t\mathrm{K}_t^a(\varepsilon_t(D_t)\,\mathrm{f})^b\mathrm{F}_t^{b-1}\mathrm{L}_t^d + \left(\frac{1}{1+\theta}\right)\varphi_{t+1}b\mathrm{A}_t\mathrm{K}_t^a(\varepsilon_t(D_t)\,\mathrm{f})^b\mathrm{F}_t^{b-1}\mathrm{L}_t^d - \left(\frac{1}{1+\theta}\right)\tau_{t+1}\pi =$$

$$-[(\frac{1}{1+\theta})\tau_{t+1} - \tau_t] \quad \text{(B3)}$$

$$\frac{\partial\mathcal{H}_C}{\partial\mathrm{K}_t} = a\mathrm{A}_t\mathrm{K}_t^{a-1}(\mathrm{f}\,\varepsilon_t(D_t)\,\mathrm{F}_t)^b\mathrm{L}_t^d + \left(\frac{1}{1+\theta}\right)\varphi_{t+1}[a\mathrm{A}_t\mathrm{K}_t^{a-1}(\mathrm{f}\,\varepsilon_t(D_t)\,\mathrm{F}_t)^b\mathrm{L}_t^d - \delta] =$$

$$-[(\frac{1}{1+\theta})\varphi_{t+1} - \varphi_t] \quad \text{(B4)}$$

From (B2), I obtain: $\varphi_{t+1} = \tau_{t+1}$ (B5)

From (B4), I obtain:

$$\left[1 + \left(\frac{1}{1+\theta}\right)\varphi_{t+1}\right]a\mathrm{A}_t\mathrm{K}_t^{a-1}(\mathrm{f}\,\varepsilon_t(D_t)\,\mathrm{F}_t)^b\mathrm{L}_t^d = \left(\frac{1}{1+\theta}\right)\varphi_{t+1}\delta - \left(\frac{1}{1+\theta}\right)\varphi_{t+1} + \varphi_t$$

According to the condition that each profit maximizing firm should hire any input up to the point at which the input's marginal contribution to production is equal to the marginal cost of hiring any input, I assume that there are n units of homogeneous firms in the metropolitan, so $\mathrm{Y}_t = \mathrm{ny}_t$ and $\mathrm{K}_t = \mathrm{nk}_t$, where y_t and k_t denote each firm's output and capital input at year t, respectively. Hence, each firm's marginal productivity of capital should be identical to the interest rate that is supposed to be social discount rate ($\theta = \frac{\partial \mathrm{y}_t}{\partial \mathrm{k}_t} = \frac{\partial(\mathrm{ny}_t)}{\partial(\mathrm{nk}_t)} = \frac{\partial \mathrm{Y}_t}{\partial \mathrm{K}_t} = a\mathrm{A}_t\mathrm{K}_t^{a-1}(\mathrm{f}\,\varepsilon_t(D_t)\,\mathrm{F}_t)^b\mathrm{L}_t^d$), so

$$\left[\left(\frac{1+\theta}{1+\theta}\right) + \left(\frac{1}{1+\theta}\right)\varphi_{t+1}\right]\theta = \left(\frac{1}{1+\theta}\right)\varphi_{t+1}\delta - \left(\frac{1}{1+\theta}\right)\varphi_{t+1} + \varphi_t$$

Or

$$(1+\theta+\varphi_{t+1})\theta = \varphi_{t+1}\delta - \varphi_{t+1} + (1+\theta)\varphi_t$$

Or

$$\theta + \theta^2 + \theta\varphi_{t+1} - \varphi_{t+1}\delta + \varphi_{t+1} = (1+\theta)\varphi_t$$

Or

$$\varphi_{t+1}(\theta - \delta + 1) - (1+\theta)\varphi_t = -(\theta + \theta^2)$$

Or

$$\varphi_{t+1} + \left(-\frac{1+\theta}{\theta-\delta+1}\right)\varphi_t = -\frac{\theta(1+\theta)}{\theta-\delta+1}$$

According to the general solution of the first order difference equation, I get

$$\varphi_t = W[-\left(-\frac{1+\theta}{1+\theta-\delta}\right)]^t + \frac{-\frac{\theta(1+\theta)}{\theta-\delta+1}}{1+(-\frac{1+\theta}{\theta-\delta+1})}$$

$$= W(\frac{1+\theta}{1+\theta-\delta})^t + \frac{-\theta(1+\theta)}{\theta-\delta+1-1-\theta}$$

$$= W(\frac{1+\theta}{1+\theta-\delta})^t + \frac{(1+\theta)\theta}{\delta} \qquad \text{(B6)}$$

where W is an initial value in the solution of the first order difference equation of φ_t, so it is a constant. Based on (B6), I get

$$\varphi_{t+1} = W\left(\frac{1+\theta}{1+\theta-\delta}\right)^{t+1} + \frac{(1+\theta)\theta}{\delta}$$

$$= W\left(\frac{1+\theta}{1+\theta-\delta}\right)^{t}\left(\frac{1+\theta}{1+\theta-\delta}\right) + \frac{(1+\theta)\theta}{\delta}$$

$$= \left[\varphi_t - \frac{(1+\theta)\theta}{\delta}\right]\left(\frac{1+\theta}{1+\theta-\delta}\right) + \frac{(1+\theta)\theta}{\delta}$$

$$= \varphi_t\left(\frac{1+\theta}{1+\theta-\delta}\right) - \frac{(1+\theta)\theta}{\delta}\left(\frac{1+\theta}{1+\theta-\delta}\right) + \frac{(1+\theta)\theta}{\delta}$$

$$= \varphi_t\left(\frac{1+\theta}{1+\theta-\delta}\right) + \frac{(1+\theta)\theta}{\delta}\left[1 - \left(\frac{1+\theta}{1+\theta-\delta}\right)\right]$$

$$= \varphi_t\left(\frac{1+\theta}{1+\theta-\delta}\right) + \frac{(1+\theta)\theta}{\delta}\frac{(1+\theta-\delta-1-\theta)}{1+\theta-\delta}$$

$$= \varphi_t\left(\frac{1+\theta}{1+\theta-\delta}\right) - \frac{(1+\theta)\theta}{1+\theta-\delta}$$

$$= (\varphi_t - \theta)\left(\frac{1+\theta}{1+\theta-\delta}\right) \qquad \text{(B7)}$$

Furthermore, from (B3), I obtain

$$\left[1 + \left(\frac{1}{1+\theta}\right)\varphi_{t+1}\right] b\mathrm{A}_t\mathrm{K}_t^a(\varepsilon_t(D_t)\,\mathrm{f})^b\mathrm{F}_t^{b-1}\mathrm{L}_t^d = \left(\frac{1}{1+\theta}\right)\tau_{t+1}\pi - \left(\frac{1}{1+\theta}\right)\tau_{t+1} + \tau_t$$

Or

$$\left[\left(\frac{1+\theta}{1+\theta}\right) + \left(\frac{1}{1+\theta}\right)\varphi_{t+1}\right] b\mathrm{A}_t\mathrm{K}_t^a(\varepsilon_t(D_t)\,\mathrm{f})^b\mathrm{F}_t^{b-1}\mathrm{L}_t^d = \left(\frac{1}{1+\theta}\right)\tau_{t+1}\pi - \left(\frac{1}{1+\theta}\right)\tau_{t+1} + \tau_t$$

Or

$$(1+\theta+\varphi_{t+1})b\frac{\mathrm{A}_t\mathrm{K}_t^a(\varepsilon_t(D_t)\,\mathrm{f})^b\mathrm{F}_t^b\mathrm{L}_t^d}{F_t} = \tau_{t+1}(\pi-1) + (1+\theta)\tau_t$$

Or

$$(1+\theta+\varphi_{t+1})b\frac{Y_t}{F_t}=\tau_{t+1}(\pi-1)+(1+\theta)\tau_t$$

Or

$$F_t=\frac{(1+\theta+\varphi_{t+1})b}{\tau_{t+1}(\pi-1)+(1+\theta)\tau_t}Y_t \ =\frac{(1+\theta+\varphi_{t+1})b}{\varphi_{t+1}(\pi-1)+(1+\theta)\varphi_t}Y_t \qquad \text{(B8)}$$

Plug (B6), (B7) into (B8), I obtain:

$$F_t=\frac{[1+\theta+(\varphi_t-\theta)\left(\frac{1+\theta}{1+\theta-\delta}\right)]b}{(\varphi_t-\theta)\left(\frac{1+\theta}{1+\theta-\delta}\right)(\pi-1)+(1+\theta)\varphi_t}Y_t$$

$$=\frac{\frac{(1+\theta)(1+\theta-\delta)+(1+\theta)(\varphi_t-\theta)}{1+\theta-\delta}}{\frac{(\pi-1)(\varphi_t-\theta)(1+\theta)}{1+\theta-\delta}+\frac{(1+\theta-\delta)(1+\theta)\varphi_t}{1+\theta-\delta}}bY_t$$

$$=\frac{(1+\theta)(1+\theta-\delta+\varphi_t-\theta)}{(1+\theta)[\varphi_t(\pi-1+1+\theta-\delta)-\theta(\pi-1)]}bY_t$$

$$=\frac{(1-\delta+\varphi_t)}{\varphi_t(\pi+\theta-\delta)+\theta(1-\pi)}bY_t$$

$$=\frac{[1-\delta+W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t+\frac{(1+\theta)\theta}{\delta}]b}{[W(\frac{1+\theta}{1+\theta-\delta})^t+\frac{(1+\theta)\theta}{\delta}](\pi+\theta-\delta)+\theta(1-\pi)}Y_t \qquad \text{(B9)}$$

According to the transfer relationship between electricity capacity and electricity consumption$E_t=fF_t\,\varepsilon_t(D_t)$, plug (B9) into it, I obtain the optimal electricity function

$$E_t=\frac{[W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t+\frac{(1+\theta)\theta}{\delta}+1-\delta]b}{[W(\frac{1+\theta}{1+\theta-\delta})^t+\frac{(1+\theta)\theta}{\delta}](\pi+\theta-\delta)+\theta(1-\pi)}f\,\varepsilon_t(D_t)\,Y_t \quad \text{(B10)}$$

If I let $\beta_t=\frac{[W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t+\frac{(1+\theta)\theta}{\delta}+1-\delta]bf\,\varepsilon_t(D_t)}{[W(\frac{1+\theta}{1+\theta-\delta})^t+\frac{(1+\theta)\theta}{\delta}](\pi+\theta-\delta)+\theta(1-\pi)}$, then the metropolitan electricity consumption function can be expressed as:$E_t=\beta_t Y_t$. Therefore,

$lnE_t = ln\beta_t + lnY_t$

$$= \ln\left[W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t + \frac{(1+\theta)\theta}{\delta} + 1 - \delta\right] + \ln(bf) + \ln(\varepsilon_t(D_t))$$

$$- \ln\left\{\left[W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t + \frac{(1+\theta)\theta}{\delta}\right](\pi+\theta-\delta) + \theta(1-\pi)\right\} + lnY_t$$

$$= \ln\left[W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t + \frac{(1+\theta)\theta}{\delta} + 1 - \delta\right]$$

$$- \ln\left\{\left[W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t + \frac{(1+\theta)\theta}{\delta}\right](\pi+\theta-\delta) + \theta(1-\pi)\right\} + \ln(bf)$$

$$+ lnY_t + \ln(\varepsilon_t(D_t)) = B_0 + B_1 + B_2 \ln Y_t^e + \epsilon_t \quad \text{(B11)}$$

where $B_1 = \ln(bf)$ and $\epsilon_t = \ln(\varepsilon_t(D_t))$. $B_2 \ln Y_t^e = lnY_t$ means that expected income is assumed to be linearly associated with current income ($\ln Y_t^e = \frac{lnY_t}{B_2}$), which is supported by the evidence from Campbell and Mankiw (1990).

Since $\frac{(1+\theta)\theta}{\delta} + 1 - \delta > 0$, and then

$\ln\{W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t + [\frac{(1+\theta)\theta}{\delta} + 1 - \delta]\} > \ln\left[W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t\right] = lnW + ln\left(\frac{1+\theta}{1+\theta-\delta}\right)^t = lnW + tln(\frac{1+\theta}{1+\theta-\delta})$. So, there should be a positive constant z_1 satisfying that

$$z_1 = \ln\{W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t + [\frac{(1+\theta)\theta}{\delta} + 1 - \delta]\} - [lnW + tln\left(\frac{1+\theta}{1+\theta-\delta}\right)]$$

Therefore, $\ln\{W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t + [\frac{(1+\theta)\theta}{\delta} + 1 - \delta]\} = lnW + tln\left(\frac{1+\theta}{1+\theta-\delta}\right) + z_1$

Similarly, $\ln\left\{\left[W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t + \frac{(1+\theta)\theta}{\delta}\right](\pi+\theta-\delta) + \theta(1-\pi)\right\} = \ln\{W(\pi+\theta-\delta)\left(\frac{1+\theta}{1+\theta-\delta}\right)^t + [\frac{(1+\theta)\theta(\pi+\theta-\delta)}{\delta} + \theta(1-\pi)]\} = \ln[W(\pi+\theta-\delta)] + tln\left(\frac{1+\theta}{1+\theta-\delta}\right) + z_2$,

where $z_2 = \ln\left\{\left[W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t + \frac{(1+\theta)\theta}{\delta}\right](\pi+\theta-\delta) + \theta(1-\pi)\right\} - \{\ln[W(\pi+\theta-\delta)] + tln\left(\frac{1+\theta}{1+\theta-\delta}\right)\}$.

Therefore, $\ln\left[W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t + \frac{(1+\theta)\theta}{\delta} + 1 - \delta\right] - \ln\left\{\left[W\left(\frac{1+\theta}{1+\theta-\delta}\right)^t + \frac{(1+\theta)\theta}{\delta}\right](\pi + \theta - \delta) + \theta(1-\pi)\right\} = \left[lnW + tln\left(\frac{1+\theta}{1+\theta-\delta}\right) + z_1\right] - \left\{\ln[W(\pi+\theta-\delta)] + tln\left(\frac{1+\theta}{1+\theta-\delta}\right) + z_2\right\} = lnW + z_1 - \ln[W(\pi+\theta-\delta)] - z_2 = z_1 - z_2 - \ln(\pi+\theta-\delta) = B_0$

In terms of equation (3.20), current electricity consumption is dependent on indirectly determined by consumers' income to be spent on purchasing appliance in the future. The values of durable goods are relatively higher and the life span of them is longer than that of nondurable goods. Therefore, I use the expectation of income to purchase durable items that use electricity (Modigliani 1985). Appliances are durable goods, so consumers must utilize electricity to create consumption. Therefore, the appliance consumption is determined by consumer's future income and then electricity consumption is indirectly associated to consumer's expectation income. Based on this logic, if I estimate electricity consumption function, and then I suppose the natural log of metropolitan electricity consumption at year t lnE_t can also the linear function of expectation of the natural log of real GDP ($\ln Y_t^e$), time trend t and error term ϵ_t.

Furthermore, according to the theory of rational expectation (Muth 1961), let $\ln Y_t^e$ be the expectation value composed of natural log of current real GDP ($\ln Y_t$) and expectation of natural log of previous real GDP ($\ln Y_{t-1}^e$):

$$\ln Y_t^e = (1-b)ln Y_t + b\ln Y_{t-1}^e \quad \text{(B12)}$$

So, plug (B12) into (B11), electricity consumption function can be express like this:

$$lnE_t = B_0 + B_1 + B_2[(1-b)ln Y_t + b\ln Y_{t-1}^e] + \epsilon_t \text{ (B13)}$$

According to equation (B12), I obtain:

$$\ln Y_{t-1}^e = (1-b)ln Y_{t-1} + b\ln Y_{t-2}^e \quad \text{(B14)}$$

$$\ln Y_{t-2}^e = (1-b)ln Y_{t-2} + b\ln Y_{t-3}^e \quad \text{(B15)}$$

Plug (B14) and (B15) into (B12):

$$\ln Y_t^e = (1-b)ln Y_t + b[(1-b)ln Y_{t-1} + b\ln Y_{t-2}^e]$$

$$= (1-b)ln Y_t + b(1-b)ln Y_{t-1} + b^2[(1-b)ln Y_{t-2} + b\ln Y_{t-3}^e]$$

$$= (1-b)\ln Y_t + (1-b)b\ln Y_{t-1} + (1-b)b^2\ln Y_{t-2} + b^3\ln Y_{t-3}^e$$

$$= (1-b)(\ln Y_t + b\ln Y_{t-1} + b^2\ln Y_{t-2} + \cdots) \quad \text{(B16)}$$

Plug (B16) into (B13):

$$lnE_t = B_0 + B_1 + B_2[(1-b)ln Y_t + b\ln Y_{t-1}^e] + \epsilon_t$$

$$= B_0 + B_1 + B_2(1-b)ln Y_t + B_2 b\ln Y_{t-1}^e + \epsilon_t$$

$$= B_0 + B_1 + B_2(1-b)ln Y_t + B_2 b[(1-b)(\ln Y_{t-1} + b\ln Y_{t-2} + b^2\ln Y_{t-3} + \cdots)] + \epsilon_t$$

$$= B_0 + B_1 + B_2(1-b)(\ln Y_t + b\ln Y_{t-1} + b^2 ln Y_{t-2} + b^3 ln Y_{t-3} + \cdots) + \epsilon_t \quad \text{(B17)}$$

So, I obtain:

$$lnE_{t-1} = B_0 + B_1 + B_2(1-b)(\ln Y_{t-1} + b\ln Y_{t-2} + b^2\ln Y_{t-3} + b^3 ln Y_{t-4} + \cdots) + \epsilon_{t-1} \quad \text{(B18)}$$

Let (B17)-b*(B18):

$$lnE_t - blnE_{t-1}$$

$$= B_0 + B_1 - \mathrm{b}B_0 - bB_1 + B_2(1-b)(\ln Y_t + b\ln Y_{t-1} + b^2\ln Y_{t-2} + b^3 ln Y_{t-3} + \cdots) - B_2(1-b)(\mathrm{b}\ln Y_{t-1} + b^2\ln Y_{t-2} + b^3 ln Y_{t-3} + b^4 ln Y_{t-4} + \cdots) + \epsilon_t - b\epsilon_{t-1}$$

$$= B_0(1-b) + B_1(1-b) + B_2(1-b)[(\ln Y_t + b\ln Y_{t-1} + b^2\ln Y_{t-2} + b^3 ln Y_{t-3} + b^4 ln Y_{t-4} + \cdots) - (\mathrm{b}\ln Y_{t-1} + b^2\ln Y_{t-2} + b^3\ln Y_{t-3} + b^4 ln Y_{t-4} + \cdots)] + (\epsilon_t - b\epsilon_{t-1})$$

$$=[(B_0 + B_1)(1-b)] + B_2(1-b)\ln Y_t + (\epsilon_t - b\epsilon_{t-1}) \quad \text{(B19)}$$

Hence, from (B19), the reduced form of metropolitan electricity consumption is

$$lnE_t = [(B_0 + B_1)(1-b)] + B_2(1-b)\ln Y_t + blnE_{t-1} + (\epsilon_t - b\epsilon_{t-1})$$

$$= \beta_0 + \beta_1\ln Y_t + \beta_2\ln E_{t-1} + e_t \quad \text{(B20)}$$

where $\beta_0 = (B_0 + B_1)(1-b)$, $\beta_1 = B_2(1-\mathrm{b})$, $\beta_2 = b$ and $e_t = \epsilon_t - b\epsilon_{t-1} =$

$h(\varepsilon_t(D_t))$. Equation (3.29) means that the current electricity consumption is determined by the previous electricity consumption and the current real GDP, and other factors in error term. Here, previous electricity consumption can be considered as the electricity consumption habits (Carroll et al. 1996).

Finally, if I assume $e_t = h(\varepsilon_t(D_t)) = \beta_3 D_t + v_t$, where v_t denotes the unobservable factors excluding electricity demand management reform, then the electricity consumption function is as below:

$$lnE_t = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln E_{t-1} + \beta_3 D_t + v_t \quad \text{(B21)}$$

Appendix B2

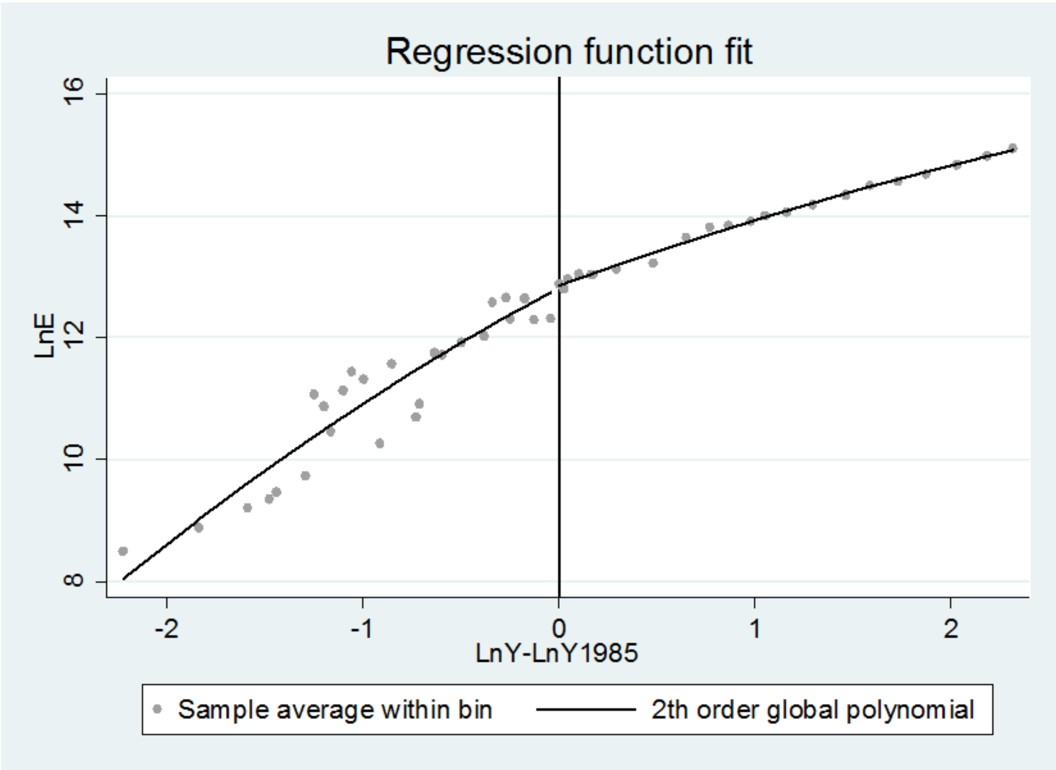

Figure B 1: Relationship Plots between Outcome Variable and Assignment Variable

Table B 1: VECM Granger Causality Analysis from 1949 to1985

Dependent variable	Wald statistics		
	Short run		Long run
	$\Sigma\Delta \ln Y_{t-1}$	$\Sigma\Delta \ln E_{t-1}$	ECT_{t-1}
$\Delta \ln Y_t$	-	0.4918	0.0446
		(0.4831)	(0.8327)
			[0.0103]
$\Delta \ln E_t$	1.607654	-	9.8158***
	(0.2048)		(0.0017)
			[-0.3813]

Note: 1) *** p<0.01, ** p<0.05, * p<0.1; 2) Values in parenthesis are p-values; 3) Values in square brackets are estimated coefficients of ECT_{t-1}.

Table B 2: VECM Granger Causality Analysis from 1986 to 2016

Dependent variable	Wald statistics		
	Short run		Long run
	$\Sigma\Delta \ln Y_{t-1}$	$\Sigma\Delta \ln E_{t-1}$	ECT_{t-1}
$\Delta \ln Y_t$	-	0.109459	0.6560
		(0.7328)	(0.4179)
			[0.1882]
$\Delta \ln E_t$	0.001906	-	5.0499**
	(0.9957)		(0.0246)
			[-0.6372]

Note: 1) *** p<0.01, ** p<0.05, * p<0.1; 2) Values in parenthesis are p-values; 3) Values in square brackets are estimated coefficients of ECT_{t-1}.

Appendix C

Appendix C1

1. **Monitoring under Complete Information**

$$\underset{k_1}{\text{Max}} E\pi_l^{complete} = rK - a - TC_l^{complete} \quad (4.4)$$

$$\text{s.t.} (1-r)K + a - \tfrac{1}{2}\beta K^2 - TC_p^{complete} \geq V_c \qquad (4.5)$$

From Kuhn-Tucker Theorem

$$L = rK - a - TC_l^{complete} + \mu\left[(1-r)K + a - \tfrac{1}{2}\beta K^2 - TC_p^{complete} - V_c\right]$$

$$= rK - a - \int_{k_1}^{k_2}(\tfrac{\partial f}{\partial k} - w)dk - bc_l^{complete} + \mu[(1-r)K + a - \tfrac{1}{2}\beta K^2 - \int_0^{k_1}[\tfrac{\partial f}{\partial k}(1-r) - w]dk$$

$$- V_c]$$

$\frac{\partial L}{\partial k_1} = \frac{\partial f}{\partial k} - w - \mu[\frac{\partial f}{\partial k}(1-\text{r}) - \text{w}] \leq 0$, with complementary slackness $\frac{\partial L}{\partial k_1}k_1 = 0$ and $k_1 \geq 0$.

$\frac{\partial L}{\partial \mu} = (1-r)K + a - \frac{1}{2}\beta K^2 - \int_0^{k_1}[\frac{\partial f}{\partial k}(1-r) - w]dk - V_c \geq 0$, with complementary slackness $\frac{\partial L}{\partial \mu}\mu = 0$ and $\mu \geq 0$.

If $\mu = 0$, then $\lim_{k_1 \to 0}\frac{\partial L}{\partial k_1} = \lim_{k_1 \to 0}\left(\frac{\partial f}{\partial k} - w\right) = \lim_{k_1 \to 0}\frac{1}{k_1} - w = +\infty$, which violates with $\frac{\partial L}{\partial k_1} \leq 0$.

If $\mu > 0$, then $\frac{\partial L}{\partial \mu} = (1-r)K + a - \frac{1}{2}\beta K^2 - \int_0^{k_1}[\frac{\partial f}{\partial k}(1-r) - w]dk - V_c = 0$

Or

$$(-a) = (1-r)K - \tfrac{1}{2}\beta K^2 - \int_0^{k_1}[\tfrac{\partial f}{\partial k}(1-r) - w]dk - V_c$$

Hence, it means that (4.5) is a binding constraint and b=0 in (4.6), and then there is no corner solution in this optimization problem. If I put $(-a)$ into (4.4), then I will have:

$$\underset{k_1}{\mathrm{Max}} E\pi_l^{complete}$$

$$= rK + \left[(1-r)K - \tfrac{1}{2}\beta K^2 - \int_0^{k_1}[\tfrac{\partial f}{\partial k}(1-r)-w]dk - V_c\right] - \int_{k_1}^{k_2}(\tfrac{\partial f}{\partial k}-w)dk$$

$$- bc_l^{complete} - V_c$$

$$= K - \tfrac{1}{2}\beta K^2 - \int_0^{k_1}[\tfrac{\partial f}{\partial k}(1-r)-w]dk - \int_{k_1}^{k_2}(\tfrac{\partial f}{\partial k}-w)dk - bc_l^{complete} - V_c$$

Therefore,

$$\frac{\partial E\pi_l^{complete}}{\partial k_1} = w - \tfrac{\partial f}{\partial k}(1-r) + \tfrac{\partial f}{\partial k} - w = 0$$

So, I obtain that $r^* = 0$

2. **Monitoring under Incomplete Information**

$$\underset{r}{\mathrm{Max}} E\,\pi_l^{incomplete} = rK^* - a - TC_l^{incomplete} \qquad (4.9)$$

$$\text{s.t.} \quad (1-r)K^* + a - \tfrac{1}{2}\beta K^{*2} - \int_0^{k_1}[\tfrac{\partial f}{\partial k}(1-r)-w]dk \geq V_{in} \qquad (4.10)$$

$$K^* = \frac{1-r}{\beta} \qquad (4.8)$$

From Kuhn-Tucker Theorem

$$\mathcal{L} = rK^* - a - TC_l^{incomplete} + \lambda\left[(1-r)K^* + a - \tfrac{1}{2}\beta K^{*2} - \int_0^{k_1}[\tfrac{\partial f}{\partial k}(1-r)-w]dk - V_{in}\right]$$

$$+ \pi[K^* - \tfrac{1-r}{\beta}]$$

$$= rK^* - a - bc_l^{incomplete} + \lambda[(1-r)K^* + a - \tfrac{1}{2}\beta K^{*2} - \int_0^{k_1}[\tfrac{\partial f}{\partial k}(1-r)-w]dk - V_{in}] + \pi[K^*$$

$$- \tfrac{1-r}{\beta}]$$

$\frac{\partial L}{\partial r} = K^* - \lambda K^* + \lambda \int_0^{k_1} \frac{\partial f}{\partial k} \mathrm{dk} + \frac{\pi}{\beta} \leq 0$, with complementary slackness $\frac{\partial L}{\partial r} r = 0$ and $r \geq 0$.

$\frac{\partial L}{\partial \lambda} = (1-r)K^* + a - \frac{1}{2}\beta K^{*2} - \int_0^{k_1} [\frac{\partial f}{\partial k}(1-r) - w] dk - V_{in} \geq 0$, with complementary slackness $\frac{\partial L}{\partial \lambda} \lambda = 0$ and $\lambda \geq 0$.

$\frac{\partial L}{\partial \pi} = K^* - \frac{1-r}{\beta} = 0$, with $\pi > 0$.

If $= 0$ and $\pi > 0$, then $\frac{\partial L}{\partial r} = K^* + \frac{\pi}{\beta} > 0$, which violates with $\frac{\partial L}{\partial r} \leq 0$.

If $\lambda > 0$ and $\pi > 0$, then $\frac{\partial L}{\partial \lambda} = (1-r)K^* + a - \frac{1}{2}\beta K^{*2} - \int_0^{k_1} [\frac{\partial f}{\partial k}(1-r) - w] dk - V_{in} = 0$

Or

$$(-a) = (1-r)K^* - \frac{1}{2}\beta K^{*2} - \int_0^{k_1} [\frac{\partial f}{\partial k}(1-r) - w] dk - V_{in}$$

Hence, it means (4.10) is a binding constraint and d=0 in (4.11), and then there is no corner solution in this optimization problem. If I put (4.8) and $(-a)$ into (4.9), then I will obtain：

$$\begin{aligned} E\pi_l^{incomplete} &= rK^* + \{(1-r)K^* - \tfrac{1}{2}\beta K^{*2} - \int_0^{k_1} [\tfrac{\partial f}{\partial k}(1-r) - w] dk - V_{in}\} - bc_l^{incomplete} \\ &= K^* - \tfrac{1}{2}\beta K^{*2} - \int_0^{k_1} [\tfrac{\partial f}{\partial k}(1-r) - w] dk - V_{in} - bc_l^{incomplete} \\ &= \tfrac{1-r}{\beta} - \tfrac{1}{2}\beta(\tfrac{1-r}{\beta})^2 - \int_0^{k_1} [\tfrac{\partial f}{\partial k}(1-r) - w] dk - V_{in} - bc_l^{incomplete} \end{aligned}$$

Therefore,

$$\frac{\partial E\pi_l^{incomplete}}{\partial r} = -\frac{1}{\beta} - \frac{1}{2}\beta 2(\frac{1-r}{\beta})(-\frac{1}{\beta}) + \int_0^{k_1} \frac{\partial f}{\partial k} dk = 0$$

So, $\frac{1-r}{\beta} = \frac{1}{\beta} - \int_0^{k_1} \frac{\partial f}{\partial k} dk \Rightarrow 1 - r = 1 - \beta \int_0^{k_1} \frac{\partial f}{\partial k} dk$.

The solution is that $r^{**} = \beta \int_0^{k_1} \frac{\partial f}{\partial k} dk > 0$

Appendix C2

Table C 1: Variables Differences in Means of Treated Group and Controlled Group Before Matching

Variables	External Individuals		Internal Individuals		Difference
	Mean	SD	Mean	SD	T-stats
popularname	2.5179	0.0359	2.5234	0.0674	0.0738
neighborhood	2.4319	0.0295	2.4453	0.0518	0.2199
contractualtype	0.6516	0.0233	0.5938	0.0436	-1.1903
publicpension	0.3532	0.0234	0.4609	0.0442	2.2049**
privateinsurance	0.0382	0.0094	0.0625	0.0215	1.1748
farmlandreadjustment	1.1504	0.0231	1.3359	0.0630	3.4120***
agriculturalincome	30.9451	1.6213	23.0859	2.5540	-2.4139**
contracting	2.6062	0.0329	2.9141	0.0333	4.9335***
farmlandtitling	2.1098	0.0662	2.1719	0.1148	0.4582

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table C1 presents differences in the characteristics of treated group and controlled group with their t-stats before matching. The t-stats indicate that there are significant differences in publicpension, farmlandreadjustment, agriculturalincome and contracting. The differences in the mean characteristics between treated group (external individuals) and controlled group (internal individuals) indicated a potential source of bias, hence, the need for matching and selection bias tests.

In addition, Figure C1 gives the histogram of the estimated propensity scores for external individuals and internal individuals. The bottom half of the graph shows the propensity scores distribution for the internal individuals and the upper half refers to the external individuals. The densities of the scores are on the y-axis. So, Figure 4.5 shows that most of sample observations under the PSM are within the range of common values, only a small number of samples lost, so this propensity score matching with nearest-neighbor is suitable.

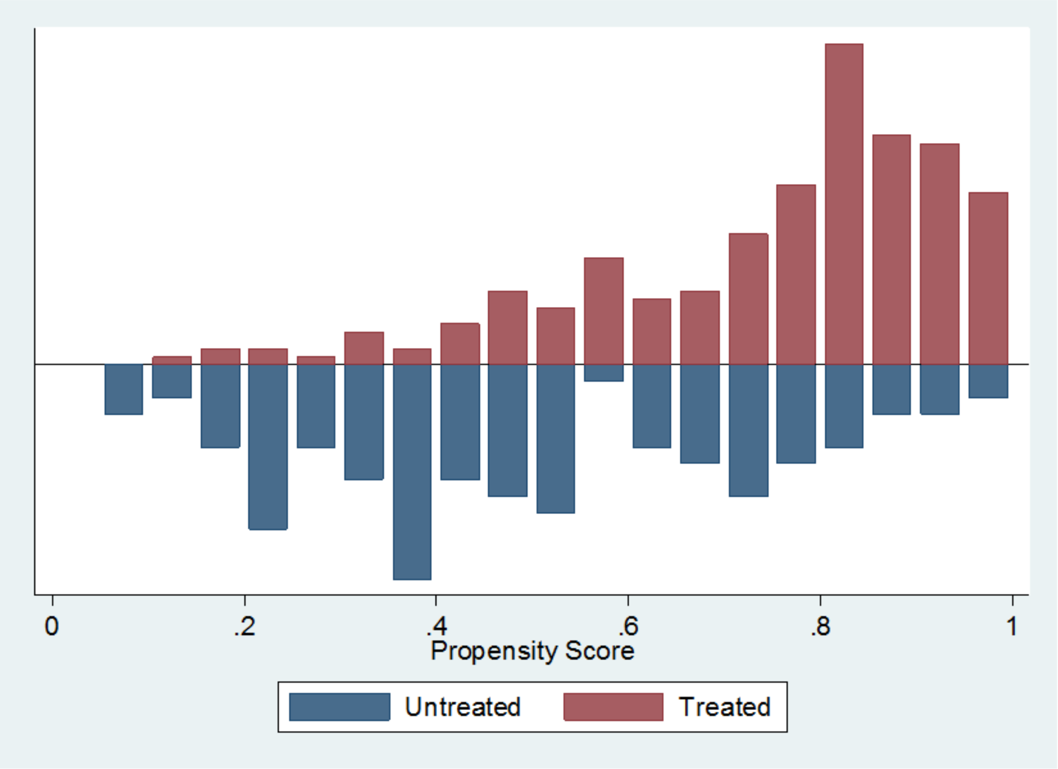

Figure C 1: Propensity Score Distribution

The corresponding density diagram that is a fundamental data smoothing method to estimate the propensity score histogram distribution in Figure C1 between external individuals and internal individuals is reported in Figure C2. It illustrates that the difference in kernel density between treated group and controlled group after matching becomes much smaller than before matching. Before matching, there are significant differences in the characteristics between treated group and controlled group, so the propensity score curve of the treated departs from propensity score curve of the controlled. After matching, they are overlapping, which means that the differences in the characteristics between treated group and controlled group have been balanced. Because the basic idea of matching method is that in terms of the treated farmers who lease farmland to external individuals, I search for some controlled farmers who lease farmland to internal individuals and have similar attributes with the treated to match with them. These two overlapping curves imply that the attributes between the treated and the controlled are similar. So, it means that the PSM satisfies the balancing requirement by kernel density test.

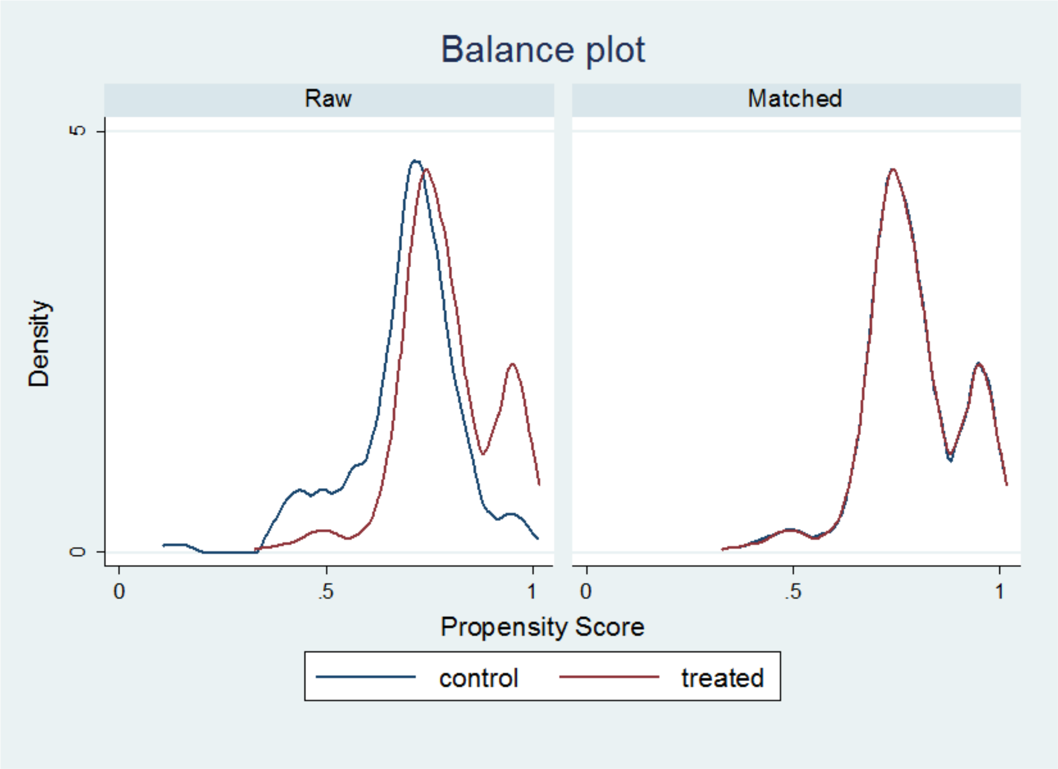

Figure C 2: Density Distribution

Appendix C3

Survey Summary

These questions will be used for statistical purposes only. THIS INFORMATION WILL BE KEPT STRICTLY CONFIDENTIAL AND WILL BE DESTROYED UPON COMPLETION OF THE STUDY.

1. Whether your family name is common in your village? (Circle one)

1) seldom 2) not seldom but not common 3) common

2. How many relatives and friends do you have in your village? (Circle one)

1) none relative and friend 2) a few of relatives and friends 3) many relatives and friends

3. Do you purchase governmental insurance? (Circle one)

1) yes 2) no

4. Do you purchase commercial insurance? (Circle one)

1) yes 2) no

5. Whether your farmland has been readjusted in 5 years? (Circle one)

1) none of farmland has been readjusted in 5 years 2) part of farmland has been readjusted in 5 years 3) all farmland has been readjusted in 5 years

6. Do you obtain farmland titling permit? (Circle one)

1) titling on specific land area and share of land in rural land stock cooperative system 2) titling on specific land 3) titling on share of land in rural land stock cooperative system 4) under the process of titling 5) none

7. Your agricultural income ratio ______________

8. Do you lease farmland by contract? (Circle one)

1) by oral agreement 2) by paper contract not recognized by court 3) by formal contract recognized by court

9. What kind of contract do you choose when leasing farmland? (Circle one)

1) Fixed-Rent Contract 2) Sharing Contract

10. Who leases your farmland? (Circle one)

1) relatives, neighbors, farmers, farms, agricultural corporations and cooperatives in your village 2) farmers, farms, agricultural corporations and cooperatives outside your village

Name_______________ ID number____________ telephone number___________