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Determinants of the Behavioral Lock-in of Rural Residents' Direct Biomass Energy Consumption in China

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Abstract: The transition from traditional to modern energy is widely accepted as a critical facilitator of improved health, social, and livelihood outcomes, but over three quarters of China's rural population are still persisting with traditional energy practices. Using panel data on 28 provinces during 1991–2014, this paper investigates how institutional pressure, status quo inertia, and the allure of power and control affect rural residents' direct biomass energy consumption (RRDBEC) in China. The empirical results show that: (1) the institutional pressure of the number of staff in rural energy administrative agencies facilitates the lock-in of RRDBEC, but government funding on rural energy development has an opposite impact; (2) status quo inertia, depicted by the lagged term of planting proportion of grain and the expenditure proportion of meat, is verified to lock RRDBEC; (3) the allure of power and control, depicted by the lagged term of ownership of firewood-saving stoves, strengthens the lock-in of RRDBEC; (4) income level, education level, and dependency ratio are verified as significant and negative determinants of RRDBEC, while fuel prices lock RRDBEC. Therefore, the policy implications include transforming the functions of rural energy administrative agencies, increasing government funds, carrying out public education of health and environment awareness, and providing economic incentives.

Keywords: Behavioral lock-in; institutional pressure; status quo inertia; allure of power and control; rural residents' direct biomass energy consumption

1. Introduction

Along with socioeconomic development, residents' energy consumption is switching from biomass energy, through fossil fuels, to modern energy [1–4]. Although energy transition has significantly decreased biomass consumption in regions such as non-OECD countries, biomass is still the fourth largest energy source, following oil, coal, and natural gas, and global biomass energy consumption increased from 610.59 million tons of oil equivalent (MTOE) to 1051.01 MTOE over the period of 1973–2015 [5–9]. The residential sector is the major consumer of biomass, which is mainly used for cooking, heating, and energy production [10]. In 2015, about 2.7 billion people, almost 40% of the global population, used solid biomass for cooking [11], and the rate in some countries was as high as 80% [12]. Among these residents, the majority adopted the traditional use mode of direct combustion on open fires or inefficient stoves [9], which was blamed for the results of energy waste [13–15], air pollution [16,17], and public health damage [18,19]. Despite the ever-increasing concern about energy-related environmental issues and the on-going energy transition, many people are still stuck to traditional energy patterns [20].

Efforts have been made to understand biomass energy consumption behaviors, so as to facilitate energy transition. Due to the prevalence of technology optimism, for the past three decades literature has focused on energy efficiency rather than energy conservation, namely, the technological lock-in [21–23]. Meanwhile, the rational choice theory believes that rational consumers utilize all available information of costs and benefits to maximize their utility [24–26]. However, technological lock-in and the rational choice model are respectively criticized by "the focus on efficiency" and "the "incentive obsession", and have failed in delivering energy reduction [20]. Energy consumption is never been simply a choice according to technical or rational criteria [27]; the concept of behavioral lock-in sheds an insightful light on such sticking behaviors [20,27]. Behavioral lock-in "*occurs when the behavior of the agent (consumer or producer) is 'stuck' in some sort of inefficiency or sub-optimality due to habit, organizational learning, or culture*", and is influenced by institutional pressure, reluctance to give up power and control, and status quo "inertia" [21]. Institutional pressure from government policies can help to achieve the technical and economic feasibilities of RRDBEC [28–30]. For rural residents, biomass is principally used for cooking practices [31], which are embedded in daily routines, involving utilization of cooking stoves and collection of biomass, and demonstrate a strong status quo inertia against transformation [32]. Further, considering individual existing benefits, RRDBEC behaviors may be affected by allure of power and control [21].

Currently, the literature on lock-in of energy consumption focus on the industrial sector and the residential sector. The industrial sector, [33] first put forward with the concept of carbon lock-in, finds that technological and institutional co-evolution motivated by path-dependent rising returns to scale locks the industrial sector to fossil fuel-based energy systems. Further, [34] discovered that when carbon-intensive industries continue to expand, the path dependence of the existing economic structure will be further strengthened, and these energy-intensive industries will have greater political influence. Reference [35] applies path dependence theory and examines China's coal consumption path evolution and strategy. Despite there existing strong preferences for a transition from a large centralized energy system to a small distributed system after the Fukushima accident of 2011, [36] finds that Japan is within a locked-in or reorganization transition, and regime actors are determinants of such lock-in.

In the residential sector, [37] evaluates the impacts of lifestyle on energy consumption, and finds that once the energy-intensive lifestyle is chosen, a large amount of energy will be locked in daily routines. One study [38] finds that expanding social aspirations and structural lock-in co-explain increasing energy consumption in Britain, which offsets the efficiency improvements in energy technologies. In addition to the expanding lifestyle aspirations, [39] emphasize that infrastructures and institutions result in considerable amounts of energy being locked up in basic household activities. Reference [20] points out that residential habits are a key determinant of energy consumption, which explains the increasing energy consumption during global energy crisis. Additionally, [27] evaluates the role of habits in explaining the reduced energy effectiveness of traditional instruments, such as incentives. To encourage sustainable energy use in Guinea, [40] analyze behavioral lock-in of energy consumption and policy interventions in terms of status quo and loss aversion. However, the existing literature either rest on theoretical discussion of behavioral lock-in of energy consumption, or consider one or two aspects of the theory. How do three types of factors physically influence the behavioral lock-in of RRDBEC? No conclusion is reached.

As the largest agricultural country in the world, China has abundant biomass resources, and the average annual yield is about 460 million tons coal equivalent (MTCE) [5]. Despite the completion of nationwide electrification in China, approximately 455 million people, principally living in rural areas, still use solid fuels for cooking and heating, and the number is projected to be 315 million in 2040 [10,19]. Besides, over 70% of the biomass is wasted or utilized inefficiently, among which 37% is used for combustion in traditional stoves, 15% is abandoned during collection process, and 20.5% is directly burnt in the fields [41]. Accompanying traditional utilization modes are both outdoor and indoor air pollution [42,43] and deterioration of public health [28,44,45]. For instance, the combustion residue of straw is detected as one of the sources for $PM_{2.5}$ and haze shrouding in China in recent years [46]. What's worse, the biomass-based energy consumption structure is actually a mirror reflecting energy inequity between urban and rural China [47]. For rural residents in China, biomass is principally used for cooking practices [31], which are embedded in daily routines involving utilization of cooking stoves and collection of biomass, and demonstrate a strong status quo inertia against transformation [32]. Considering individual existing benefits, RRDBEC behaviors may be affected by allure of power and control [21]. Despite private sectors' increasing influence on biomass utilization, examples are successful implementations of public-private partnerships in Italy and Greece [48,49]. Government still plays an important role in the utilization of biomass energy in China, posing institutional pressure for rural residents' biomass energy utilization. It is of great importance to figure out the determinants underlying the behavioral lock-in of RRDBEC in China, so as to facilitate energy transition.

The purpose of this paper is first to investigate the influence of institutional pressure, depicted by the number of staff in rural energy administrative agencies and government funding for rural energy development, and on behavioral lock-in of RRDBEC, because the Chinese government has advocated energy transition in rural areas for decades. Besides, this paper aims to evaluate the impact of status quo inertia, depicted by the planting proportion of grain and the expenditure proportion of meat, on the behavioral lock-in of RRDBECPC, because food culture, farming culture, and energy consumption habits often impede the adoption of new energy. Further, energy transition from biomass energy to modern energy often implies the upgrade of relevant energy utilizing equipment, while existing equipment is an important asset for rural residents. The allure of power and control on existing energy utilizing equipment, depicted by the ownership of firewood-saving stoves, may influence the behavioral lock-in of RRDBEC. Hence, this paper is supposed to contribute to the existing literature in three ways. Firstly, to the authors' knowledge, this paper is the first one applying the theoretical framework of behavioral lock-in to the context of RRDBEC in China. Secondly, while the existing literature relating to behavioral lock-in of energy consumption rests on theoretical discussion, such as [20,27,40,50,51], the empirical analysis explores the roles of the three categories of factors simultaneously. Thirdly, while the majority of existing literature focus on total energy consumption or biomass energy as a part of an energy mix, this paper only pays attention to RRDBEC.

The remainder of the paper is organized as follows: beginning with the situation of RRDBEC in China, the second section also applies the framework of behavioral lock-in to the context of RRDBEC, and categorizes possible determinants. The third section discusses the methodology and data utilized in this study. The fourth section comprises the empirical results and corresponding analysis. The paper ends with some conclusions and policy implications.

2. Behavioral Lock-in of RRDBEC in China: Current Situation and Theoretical Discussion

2.1. RRDBEC and Biomass Energy Policies in China

In China, biomass resources include agricultural residues, forestry residues, energy crops, and residential waste. Among the 460 MTCE of annual biomass yield, only 53 MTCE is effectively or commercially used, while the rest is mainly utilized for cooking and heating by rural residents [5,52]. Figure 1 illustrates RRDBEC and its proportion of residents' energy consumption in China during 1991–2014. RRDBEC decreased from 26716.16 MTCE in 1991 to 20293.00 MTCE in 1999, increased to 29190.00 MTCE in 2009, and then decreased to 18720.00 MTCE in 2014. Meanwhile, the proportion of RRDBEC decreased from 80.41% to 58.14%. Despite the overall downwards trend of the two indicators, biomass energy still plays an important role in meeting rural residents' energy demands. To some degree, their fluctuation tendencies reflect the evolution of China's rural energy issues, changing from energy shortage through national energy security to climate change [47].

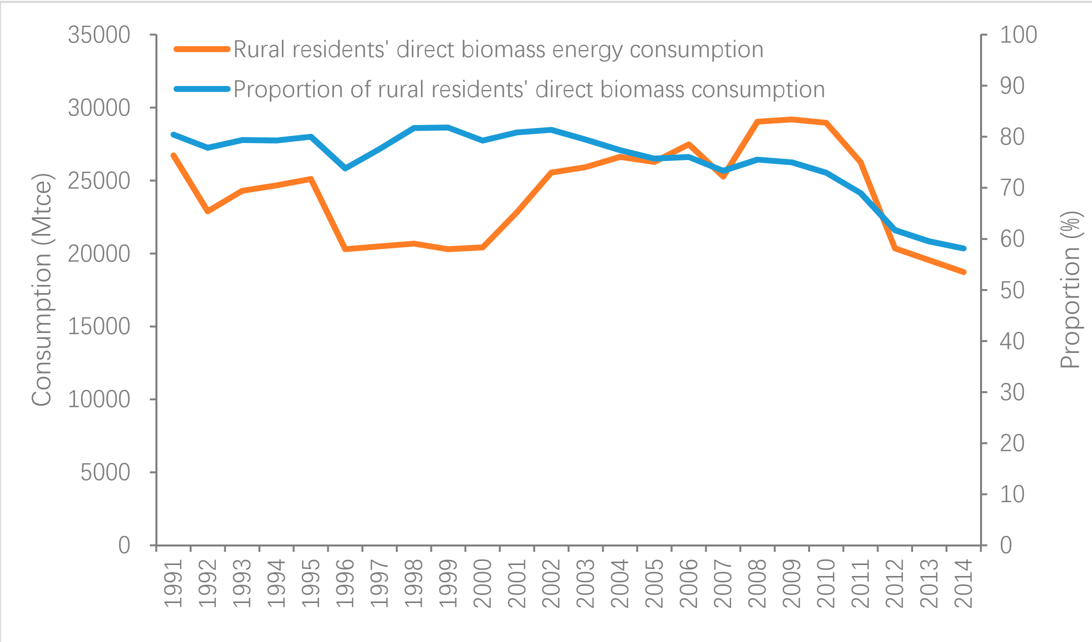

Figure 1. Rural residents' direct biomass energy consumption and its proportion of residents' energy consumption in China. Data source: Author's own calculation using published data from [53] and unpublished data from Ministry of Agriculture and Rural Affairs of China (MOA).

The intention of energy policies is to regulate residents' energy consumption behaviors [54]. The focus of Chinas rural energy policies has changed since the reform and opening up [47], and so has that of biomass energy policies (see Table 1). In the early 1990s, the problem of energy shortage was basically solved, and hence, the focus of biomass energy policies was balancing insufficient supply and growing energy demand. After becoming a net oil-importing country in 1993, China placed national energy security on its agenda [55]. In 1996, the National People's Congress approved The Ninth Five-year Plan for National Economy and Social Development and Outline for Vision 2010, which put forward a strategic framework of sustainable development, and initiated the transformation from an extensive growth to an intensive growth [56]. Correspondingly, the focus of biomass energy policies turned to developing renewable energy, so as to improve energy diversification, and both biomass energy and energy agriculture became the policy priority [57].

As a contracting country of The Kyoto Protocol, China faced tremendous pressure to reduce CO_2 emission [47]. Enacted in 2005, The Renewable Energy Law established a general framework of renewable energy policies [30]. Besides, rural energy was endued with the mission of improving China's capacity of mitigating and adapting to climate change by virtue of transforming its coal-based energy consumption structure, which was reflected by China's National Program to Address Climate Change [57]. The program promoted the development and utilization of biomass energy through biomass power generation, biogas, biomass solid fuels, and liquid fuels. During 2005–2014, straw policies focused on its comprehensive utilization, and biogas policies focused on the establishment of biogas systems.

In this study, RRDBEC refers to rural residents' direct consumption of straw and firewood through traditional utilization modes, excluding biogas consumption. The reason is that biogas is a clean and efficient utilization mode of biomass when compared to the consumption of straw and firewood, and the objective of this paper is to investigate factors locking the traditional utilization of biomass. As is shown in Figure 2, of biomass consumption, the proportion of straw and firewood consumption decreased from 61.25% and 38.45% in 1991 to 60.32% and 34.10% in 2014, respectively, while the proportion of biogas increased from 0.31% to 5.59%. In parallel, rural residents' direct biomass energy consumption per capita (RRDBECPC) increased from 304.99 kilograms of standard coal equivalent (kgce) in 1991 to 437.15 kgce in 2010, and then decreased to 307.59 kgce in 2014.

Table 1. Energy issues, policies relating to rural energy in China.

Phase		**1991–1995**	**1996–2006**	**2007–2014**
Energy issue		Energy shortage	Energy security	Climate change
Policy purpose		To utilize local resources to meet energy demand.	To diversify energy supply and guarantee national energy security.	To develop carbon-neutral and renewable energy to fight against climate change.
Policy tool	Straw	(1) Banning open-air burning (2) Comprehensive utilization	(1) Banning open-air burning (2) Comprehensive utilization	(1) Straw gasification (2) Straw solidification (3) Straw fertilization (4) Ban open-air burning (5) Straw power generation
	Firewood	(1) Developing fuel wood forest (2) Promoting the use of efficient stoves (3) Forest energy projects	(1) Developing fuelwood forests (2) Replacing firewood with straw, biogas, and other forms of biomass (3) Promoting the use of firewood-saving stoves	(1) Conversion of firewood into commercial energy (2) Protection of forest resource (3) Promotion of the use of firewood-saving stoves
	Biogas	(1) Developing biogas energy (2) Constructing biogas plant	(1) Developing household biogas (2) Developing biogas project in livestock and poultry farms (3) Clean utilization (4) Treasury bond projects for biogas construction	(1) Constructing biogas service system (2) Developing large and medium-sized biogas projects (3) Developing household biogas, centralized biogas, and scale biogas (4) Improving rural biogas construction mechanism

Data source: Author's own summarization according to biomass energy policies in Appendix A.

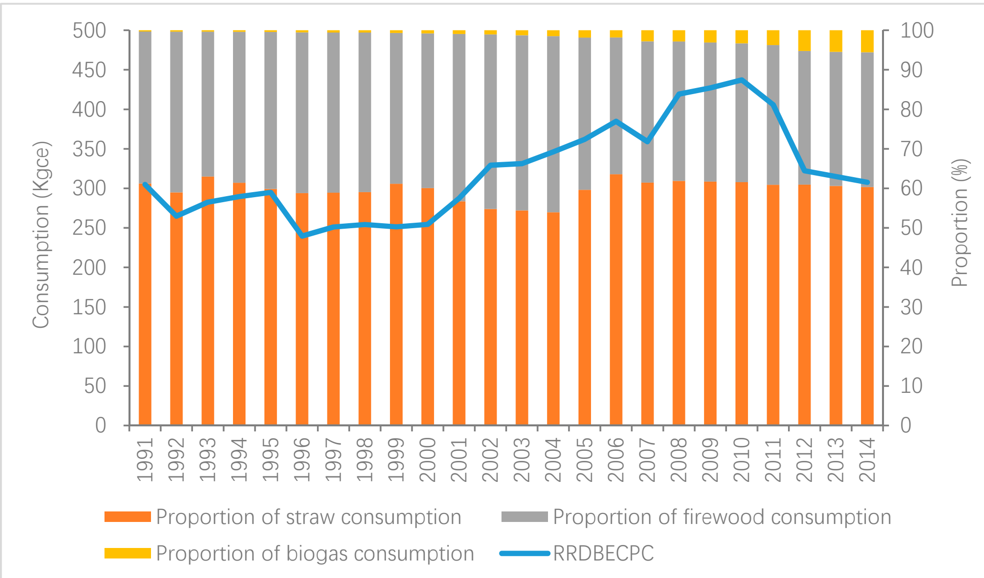

Figure 2. RRDBECPC and biomass consumption structure in rural China. Data source: Author's own calculation using published data from [53] and unpublished data from MOA.

2.2. Behavioral Lock-in of RRDBEC in China: Theoretical Discussion

Theoretically, behavioral lock-in is influenced by institutional pressure, status quo inertia, and allure of power and control [21]. This framework is applied to the context of RRDBEC in China.

2.2.1. Institutional Pressure for RRDBEC in China

Both formal institutions and public policies impose legally binding constraints on economic actors' behaviors, thereby accustoming them over time to some specific behaviors [21,58]. RRDBEC is greatly determined by its technical and economic feasibility [28,59]. However, such feasibility is challenged by issues relating to policies of changing the way of producing and converting biomass energy, including limited financial subsidies [60], restricted access to finance [61], inefficient operation of biomass energy projects [62], and inaccessible markets and technologies [61]. Government policies play a fundamental role in achieving such feasibility [27,29,63]. For example, the governments play a crucial role in creating a suitable environment for its public-private partnerships scheme and associated activities in Greece and Italy [49,50]. The Chinese government has established province-level and county-level rural energy administrative agencies to be in charge of the construction and management of rural energy. These agencies are responsible for organizing the promotion of technologies in rural areas, including technologies of biogas comprehensive utilization, technologies of biomass gasification, curing and carbonization, conservation technologies of life and production, technologies of solar energy and wind power, and so on [64,65].

While constitutive rules of formal institutions are steady and constant, public policies are more easily and frequently revised or altered to serve a certain political agenda. Founded on laws and supported by the state's coercive forces, policies direct to actors what must and mustn't be done, and provide corresponding rewards and penalties concerning specific behaviors [58]. Due to the existence of political inertia forces, most policies are extremely durable [66]. Particularly nowadays, "*institutions frequently provide incentives that encourage individuals to act in ways that lock in a particular path of policy development, creating societal commitments that may be quite difficult to reverse*" [21]. To normalize biomass energy utilization in rural areas, the Chinese government has issued extensive policies relating to the development of biomass energy, including laws, regulations, development outline, notifications, measures, and suggestions, and the evolutionary process is listed in Appendix A.

In rural China, energy policies undertake roles of guiding the development of the energy industry, regulating the energy market, and guaranteeing energy construction [56]. Furthermore [67–69], two consecutive and statistically sufficient institutional arrangements relating to RRDBEC make the characterization of institutional pressure possible, including government funding for rural energy development, and the number of staff in rural energy administrative agencies. The former represents Chinese government's fiscal arrangement, which influences rural residents' energy consumption behaviors through technological progress and energy availability [60,67,68]. The latter stands for the personnel arrangement, which is the implementing basis of rural energy policies and the information source for policy formulation, because the staff are responsible for facilitating technology promotion of biomass energy [69,70].

The left vertical axis of Figure 3 shows per capita government funding for rural energy development in China, whose variation generally follows the enactment of government policies. The indicator reveals obvious fluctuation characteristics, namely being stable before 2000, increasing moderately during 2000–2004, rising rapidly during 2004–2008, declining sharply during 2008–2012, and keeping stable after 2012. Specifically, per capita government funds soared from 3.72 China Yuan (CNY) in 1991 to 20.31 CNY in 2014, and reached the peak in 2008, at 41.68 CNY. The right vertical axis of Figure 3 shows the average number of staff in rural energy administrative agencies, which grew from 0.33 employee per 10,000 rural residents in 1991 to 0.60 employee per 10,000 rural residents in 2014. It can be seen that the intensity of personnel arrangement on rural energy development has been largely improved.

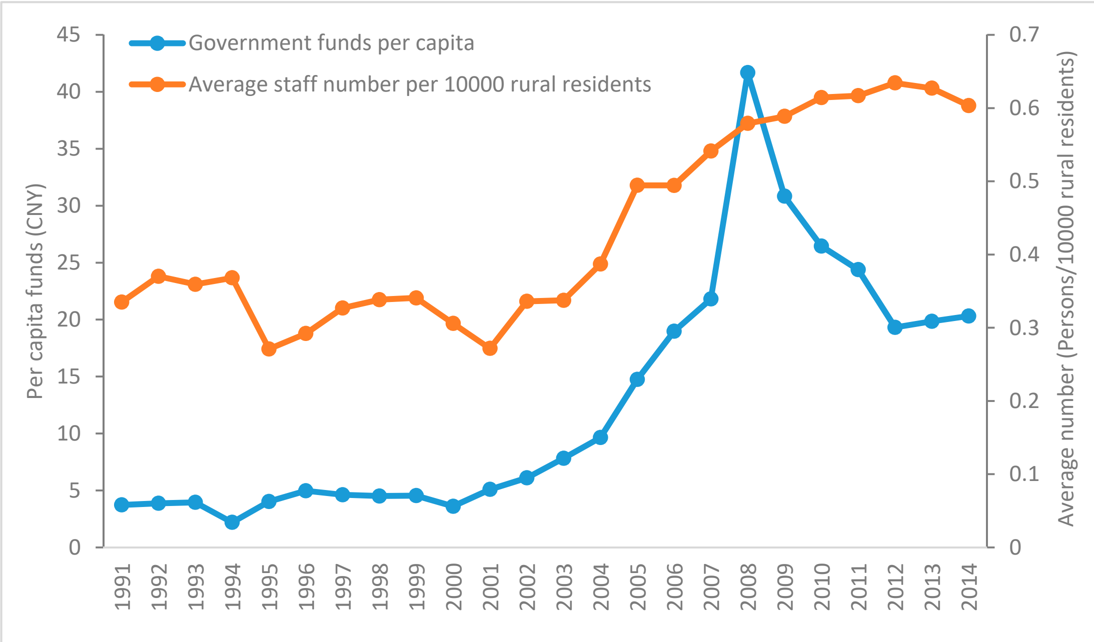

Figure 3. Government fund on rural energy development and average number of staff in rural energy administrative agencies. Data source: Author's own calculation using data from [71].

2.2.2. The status quo inertia for RRDBEC in China

The status quo inertia is defined as the persistency of incumbent behavioral patterns [72]. "Once a particular behavior is embedded in organizations (for whatever reason), a strong status quo inertia may discourage other behavior" [21], even when other behaviors are more rational [20]. Status quo inertia mediates the intention-behavior relationship in the realm of energy consumption [27]. For instance, instead of completely shifting from animal draught to tractors, farmers are observed to substitute animal power partially and adopt the energy portfolio of both animal power and tractors for some particular practices, which can be explained by cultural preferences relating to practices, habits, and religious beliefs, other than technical and economic preferences [73,74]. While rural residents' energy consumption behaviors cover cooking, heating, lighting, household appliances, and other residential purposes in China, RRDBEC behaviors are primarily related to cooking practices, which occupies 35-45% of energy usage [31,75]. In consequence, cooking practices, as one of the elements constituting status quo inertia indigenous to each region, greatly influence RRDBEC.

Traditional cooking practices, deeply rooted in cultural and social norms, are embedded in daily routines involving the collection of biomass, and demonstrate a strong status quo inertia against transformation [32]. As the intermediate link between biomass production and consumption, biomass collection process makes the centralized utilization of scattered biomass resources possible. However, biomass collection process is significantly influenced by availability of biomass resources, and agricultural planting structure is an important element affecting its availability [76]. In other words, the status quo inertia of agricultural planting structure influences biomass collection through the variation of its distribution and density, thereby affecting RRDBEC. Straw is the principal form of biomass resource in China (See Figure 2), which is composed of crop straw, oil crop straw, cotton, hemp stalk, sugar crop stem, tobacco stem, and vines [76]. Among them, grain straw, including cereal straw, bean straw, and tuber straw, has the biggest production. The left vertical axis of Figure 4 shows the proportion of grain planting area to total planting area in rural China, from which an overall tendency of rising first and then falling can be observed. To be specific, the proportion decreased from 75% in 1991 to 65.22% in 2003, and increased to 68.13% in 2014.

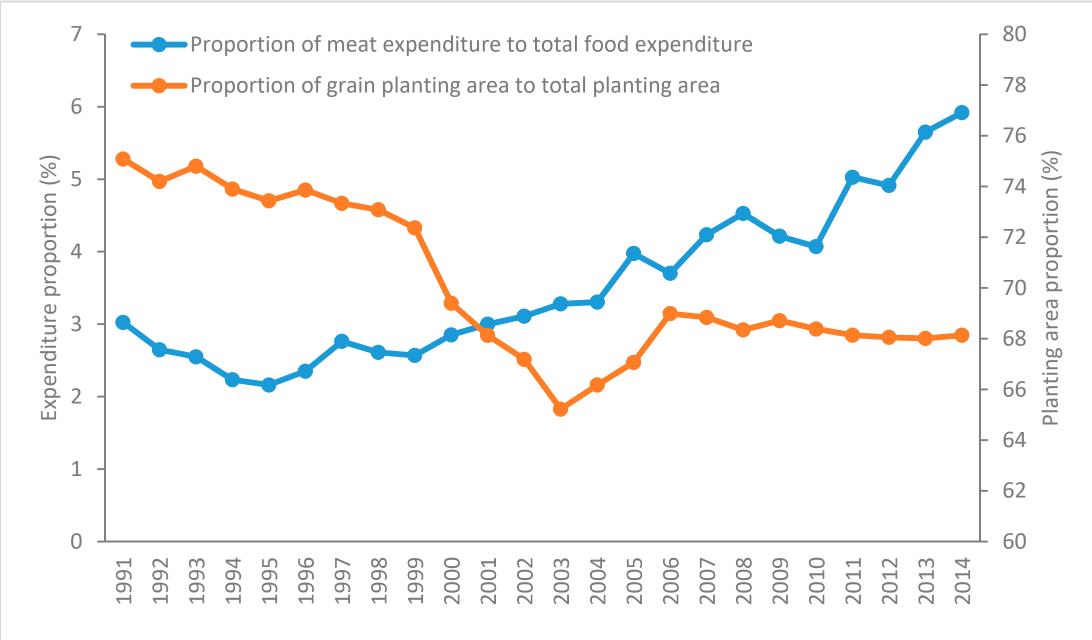

Figure 4. Proportion of meat expenditure to total food expenditure, and proportion of crop planting area to total planting area. Data source: Author's own calculation using data from [77].

Particular cooking practices serve particular dietary culture, implying that the status quo inertia of dietary culture may act on energy consumption behaviors [74]. For example, most residents in Jaracuaro, who are used to eating the tortillas prepared on a clay comal with firewood, reject the transition from firewood to LPG for tortillas preparation, as the tortillas cooked with LGP are unpalatable [78]. From the perspective of dietary structure, lower meat consumption decreases energy demand due to the decline of livestock numbers and the increase of corresponding arable land and grassland used for the production of raw materials for renewable energy [79]. Limited by low economic development level, the vegetarian-based diet structure had been dominant in rural China for a long time, and meat was considered as precious food supplied only in some special festivals [80]. The right vertical axis of Figure 4 shows the proportion of meat expenditure to total food expenditure in rural China, which grew from 3.02% in 1991 to 5.92% in 2014.

2.2.3. The Allure of Power and Control for RRDBEC in China

The allure of power and control is initially proposed to explain the phenomenon that the professional groups, such as physicians and engineers, have long established claims to cultural assets, which are usually accumulated through "*training, credentialism, legal statue, and the wider institutional structures*" [81]. With cultural assets primarily in the form of professional knowledge, the professional groups are able to confer their power and statue [82]. However, professional knowledge is in a constant state of flux, and new standards or practices may restructure the professional base [83]. When new standards or practices, potentially threatening their professional power, are introduced, the professional groups are apt to resist violently. In essence, the allure of power and control provides the existing interest groups the incentives of resisting shifting practices, so as to protect their vested benefits and capacity to seeking future interests, thereby exerting an enormous function on habituating economic actors [21].

Similarly, the allure of power and control on biomass resources provides rural residents incentives in habituating RRDBEC behaviors, which is related to the asset specificity of firewood-saving stoves. Traditional cooking practices are embedded in daily routines, which involves the utilization of cooking stoves as well [32]. Improving the utilization efficiency of biomass was the central concern of China's rural energy polices, and promoting firewood-saving stoves was a significant policy instrument to solve rural energy shortage in the 1990s and the beginning of the 21st century, which largely improved the efficiency of cooking practices. When rural energy shortage was alleviated, and despite the improved energy efficiency, firewood-saving stoves are considered to be abandoned during the energy transition process. However, firewood-saving stoves are a kind of asset for rural residents. Even though the transition from cooking stoves brings them potential benefits, many residents, however, are unable to abandon or reject the conventional cooking practices and stoves, which may be explained by the allure of flavor, taste, cooking style, and cultural preference [42,84–87].

In addition, rural residents collect and use biomass resources free of charge, which, from their perspective, and to some degree, is a privilege endowed to them [88]. On the contrary, the variant prices of commercial energy bring them financial burden and uncertainty. In order to safeguard their privilege and considering the cost of energy transition, the firewood-saving stoves will be maintained and their behavior of biomass consumption may be locked in. Figure 5 shows that the total ownership of firewood-saving stoves increased from 136.73 million units in 1991 to 223.41 million units in 2005, and decreased to 118.83 million units in 2014, and the average ownership of firewood-saving stoves per 100 households rose from 63.68 million units to 91.41 units, and decreased to 56.43 units correspondingly.

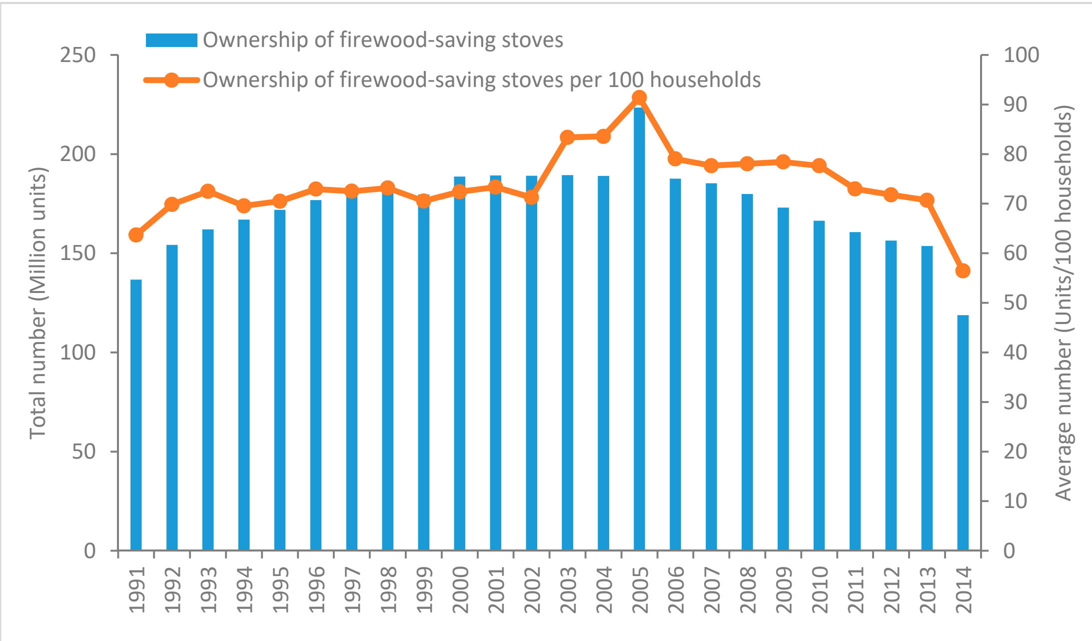

Figure 5. Total and average number of firewood-saving stoves in rural China. Data source: Author's own calculation using data from [71].

3. Methodology and Data

3.1. Economic Model

To empirically examine the factors underlying behavior lock-in of RRDBEC in China, a panel data regression is employed in this study. Compared to conventional cross-sectional data models and time-series data models, panel data models possess several major advantages, including decreasing multicollinearity among explanatory variables, controlling the impact of omitted variables, allowing for heterogeneity between individuals, providing more accurate inference of model parameters, and uncovering dynamic relationships [89], which can successfully satisfy our research needs for an econometric method. Hence, a panel data model as follows is employed to explore the impact of the institutional pressure, the status quo inertia, and the allure of power and control on RRDBEC in China.

$$RRDBECPC_{it} = \beta_0 + \beta_1 IP_{it} + \beta_2 SQI_{it} + \beta_3 APC_{is} + \beta_4 X_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (1)$$

where $RRDBECPC_{it}$ is the rural residents' direct biomass energy consumption per capita for province i in year t. Considering the consumption mode and quantity, biomass energy here consists of straw and firewood. IP_{it} represents the institutional arrangements for province i in year t, including the number of staff in rural energy administrative agencies and government fund on rural energy development; SQI_{it} represents the status quo inertia for province i in year t, including the proportion of grain planting area in total planting area and the proportion of meat expenditure in food expenditure. One point in particular is that the lagged term of the former variable is adopted to represent habits, because it is physical form of the status quo inertia, while current term of the latter variable is adopted because it is the behavioral form of status quo inertia. APC_{it} represents the allure of power and control for province i in year t, represented by the ownership of firewood-saving stoves. X_{it} is a set of other potential covariates, including net income per capita of rural residents, the weighted price index of coal and oil (WPICO), the weighted price index of electricity and LPG (WPIEL), education level of working-age population, and dependency ratio; β_0 is the constant; λ_t are the year-specific effects and μ_i are the province-specific effects; ε_{it} is an error term with $E(\mu_{it}) = 0$ for all i and t, capturing all other omitted factors; and β_1, β_2, β_3, and β_4 are parameters to be estimated.

3.2. Data and Descriptive Statistics

The data of rural residents' direct biomass energy consumption in China comes from the Ministry of Agriculture (MOA) and the National Bureau of Statistics (NBS). MOA collects data through rural energy authorities distributed around China, and NBS collects data through provincial and county survey offices. Hence, the data for this study derives from two sources. One is internal data from the MOA; the other is statistical yearbooks, including China Energy Statistical Yearbook, China Rural Statistical Yearbook, China Statistical Yearbook, China Population and Employment Statistics Yearbook, and China Agriculture Statistical Report. One point in particular is that although rural energy consumption data in China is collected at the village level, it is an expedient to employ the province-level data, because Chinese government only releases the province-level data to the public, which may cause the issue of information loss in this study.

Detailed yearly observations of 32 provinces, autonomous regions, and directed-controlled municipalities during 1991–2014 are gathered, consisting of 23 provinces, 5 autonomous regions, and 4 directed-controlled municipalities. Due to missing data, Tibet Autonomous Region, Taiwan Province, Shanghai City, and Chongqing City are removed, and the other 28 provinces, autonomous regions, and municipalities enter into the econometric model. The consumption data of straw and firewood for the years of 1994, 1997, and 2009–2013 were not published, during which the missing data is completed through the method of linear interpolation, so as to keep the sample size when missing data is not serious [90]. In total, there are 672 observations.

Table 2 lists summary statistics of the variables. RRDBECPC refers to rural residents' direct biomass energy consumption per capita, which is the sum of per capita consumption of straw and firewood. Staff is the number of staff in rural energy administrative agencies. Fund is government fund on rural energy development per capita. Stove is the ownership of firewood-saving stoves per 100 households. Meat is the proportion of meat expenditure in total food expenditure. Grain is the planting proportion of grain, which is the sum of corn, legumes, and potato. Income denotes net income per capita of rural households after income tax. Education is designated as the weighted average years of schooling of the working-age population, and the weights are the proportions of students with of 6, 9, 12, and 16 schooling years to the sample population. Dependency is computed as the rate of the sum of the youth population (0–14 years old) and the elderly population (over 65 years old) to the working-age population (15–64 years old). WPICO and WPIEL are, respectively, the weighted price index of coal and oil, and the weighted price index of electricity and LPG. Agency is the number of rural energy administrative agencies. Biogas is the annual biogas output of biogas projects invested by government. Straw is the annual of output of straw from rice, wheat, corn, beans, tubers, peanuts, rapeseeds, sesames, cotton, fiber crops, sugarcane, beetroots, and tobacco. One in particular is that fund and income are deflated at the 1991constant price.

Table 2. Summary statistics for variables.

Variables	Unit	Mean	S.D.	Min	Max
RRDBECPC	100 kgce per capita	3.40	1.92	0.11	12.61
Staff	workers per 10,000 residents	0.54	0.41	0	75.69
Fund	1000 CNY per capita	2.63	1.91	0.25	10.15
Stove	units per 100 households	21.46	9.44	0	75.69
Meat	%	0.03	0.02	0.01	0.11
Grain	%	65.42	11.78	32.00	94.00
Income	1000 CNY per capita	3.84	3.26	0.43	19.37
Education	years	6.76	1.07	2.21	11.08
Dependency	ratio	0.46	0.10	0.23	0.73
WPICO	ratio	4.36	2.76	0.97	14.26
WPIEL	ratio	3.34	2.14	0.98	15.94
Agency	100 units	3.84	3.06	0.01	13.85
Biogas	10^8 square meters	2.35	3.81	0	23.66
Straw	10^8 tons	2.09	1.61	0.08	7.52

Data source: Author's own calculation.

4. Discussion

4.1. Basic Empirical Results and Discussion

Table 3 reports the estimation results, and columns (1)–(6) summarize the estimation results of the model. When panel data are adopted, it is vital to determine whether to use a random-effect model or a fixed-effect model, which can be achieved by Hausman test [90]. A fixed-effect model hypothesizes that the residuals composed of unobservable regional effects are related to independent variables, while a random-effect model hypothesizes that the residuals composed of unobservable regional effects are randomly distributed and strictly independent of the independent variables [91]. Through Hausman test, a fixed-effect model is adopted. Column (1) shows the result of regression only, considering institutional arrangements. Column (2) shows the result of regression only, considering status quo inertia. Column (3) shows the result of regression only, considering allure of power and control. Column (4) employs a broader specification which incorporates the three types of factors and the control variables.

Pooled OLS (POLS) is adopted as a baseline of reference (Column (5)). However, when heteroscedasticity exists, the parameters estimated by POLS are linear and unbiased, but inefficient. Contemporaneous correlation may exist when the stochastic disturbances of different groups interact with each other. Also, when missing important explanatory variables, setting models improperly, and existing random interference factors and autocorrelation will appear, leading to inaccurate estimation of parameters and inefficiency of POLS. Through Wald test for groupwise heteroscedasticity [92], Wooldridge test for autocorrelation within panel [93], and Friedman test for contemporaneous correlation [94], it is discovered that groupwise heteroscedasticity, autocorrelation within panel, and contemporaneous correlation exists simultaneously. Hence, the comprehensive feasible general least squares (FGLS) is adopted, solving the problems identified by former three tests (Column (6)).

Table 3. Estimation results for the panel data model.

	(1)	(2)	(3)	(4)	(5)	(6)
	FE	FE	FE	FE	POLS	FGLS
Staff	0.883 ***			1.020 ***	0.629 **	0.723 ***
	(4.87)			(5.15)	(3.17)	(42.76)
Fund	−0.592 ***			−0.496 ***	−0.175 ***	−0.261 ***
	(−6.61)			(−4.02)	(−4.34)	(−45.87)
Meat		22.39 **		16.03 *	9.738	0.143
		(2.91)		(2.27)	(1.66)	(0.32)
Lagged grain		0.0644 ***		0.0408 ***	0.0585 ***	0.0348 ***
		(5.49)		(3.77)	(7.98)	(36.39)
Lagged stove			0.0608 ***	0.0292 **	0.0437 ***	0.0151 ***
			(7.04)	(3.30)	(6.07)	(18.23)
WPICO				0.393 ***	0.172 ***	0.163 ***
				(5.86)	(4.19)	(21.37)
WPIEL				0.215 **	0.135 ***	0.0939 ***
				(3.29)	(3.35)	(21.77)
Income				−0.0125	−0.208 ***	−0.132 ***
				(−0.22)	(−5.82)	(−15.53)
Education				−0.317	0.0518	−0.114 ***
				(−1.49)	(0.53)	(−8.38)
Dependency				−4.332 **	−0.876	−1.785 ***
				(−3.18)	(−0.86)	(−22.67)
Constant	4.794 ***	−2.002 *	1.931 ***	−0.454	−1.955	2.098 ***
	(12.79)	(−2.10)	(6.19)	(−0.19)	(−1.55)	(14.81)
Province effect	Yes	Yes	Yes	Yes		
Year effect	Yes	Yes	Yes	Yes		
R^2	0.1062	0.0360	0.0692	0.2448	0.3086	
Observation	672	644	644	644	644	644

Notes: t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4.1.1. Institutional Pressure and RRDBECPC

The number of staff in rural energy administrative agencies and government funding for rural energy development are adopted to depict institutional pressure, which conjunctively contribute to the behavioral lock-in of RRDBEC in China. Consistent with [69], the number of staff in rural energy administrative agencies significantly and positively contributes to RRDBECPC, which may be explained by its role in biomass technology promotion. Technology choices are determined by political processes [48]. Rural residents' perception of technology-specific characteristics significantly affects their technology adoption decisions, reflecting the crucial role of knowledge and information on the adoption of new technology [95–97]. Although the adoption of most rural energy technologies requires relevant knowledge and information, most rural residents are unaware of where to get new technologies and relevant information, and what types of technologies and financial assistance they can gain. Besides, there exist enormous external benefits of rural energy technology promotion, but rural residents concern is the direct economic benefits brought by the technology rather than the external benefits [70].

Since rural residents in China lacked the supply of commercial energy, the Chinese government has spared no efforts in alleviating rural energy shortages in the past decades [69]. The Chinese government has established rural energy administrative agencies around China, which are responsible for policy implementation, information collection, technology promotion, and so on [65]. To be specific, these agencies are assigned to organize the promotion of the technology of biogas and its comprehensive utilization, the technology of biomass gasification, curing, and carbonization, the conservation of residential technology and production, the technology of solar energy and wind power, and so on [64,65]. With the promotion of these new biomass technologies, characterized by higher efficiency and cleanliness, rural residents may switch back to biomass even after the adoption of modern energies, thereby improving biomass utilization.

Contrary to early findings that government funds or subsidies facilitate biomass energy utilization [30,98,99], the empirical results reveal a significantly negative impact of government funding on RRDBECPC in China, which can be explained by two reasons. For one, the use of government funding relating to rural energy includes: (1) rural energy technology support and services; (2) research on rural energy system construction and policies; (3) research and development of the technologies, equipment, and modes of rural energy, straw comprehensive utilization, etc.; (4) identification and development of occupational skills in rural energy, and statistics and management of industry data; (5) promotion of the multi-energy complementary model of rural energy; (6) promotion of the ecological agricultural cycle mode through the use of biogas cycling; (7) comprehensive utilization of biogas, biogas slurry, biogas residue; (8) annual report, assessment, and publicity of rural energy [100]. As can be seen, these uses aim to improve the indirect use of biomass, thereby decreasing RRDBECPC.

For another thing, the development of biomass energy projects requires high initial investment. As the agricultural production in China is dominated by families, biomass resources are characterized by scattered distribution, small-scale production, unstable supply, and inconvenience in collection [76,101], which largely improves its unit cost. Considering the low overall income level of rural residents, it makes biomass energy projects unaffordable for them solely relying on market mechanisms [102], and thereby, the Chinese government has invested largely in the development of biomass energy. However, the investment is far short of rural residents' capital demand on biomass utilization. For instance, the average investment of a household biogas-generating pit is about 3000 CNY, which is unaffordable for many rural residents in China [103]. MOA invested 8.62 billion CNY to support the construction of rural energy during 2001–2007, among which 8.3 billion CNY was used for rural household biogas projects, 0.15 billion CNY was used for large and medium-sized biogas projects, 8 million CNY was used for firewood-saving stoves, and the rest was used for other renewable energies. Hence, rural residents have to transit from biomass energy to advanced energy to satisfy their increasing energy demand, and consequently, biomass energy consumption decreases.

4.1.2. Status Quo Inertia and RRDBECPC

The lagged term of planting proportion of grain and the proportion of meat expenditure to total food expenditure are adopted to depict the status quo inertia, which facilitates the behavioral lock-in of RRDBEC in China. Different from the previous study [79], which shows the decreasing proportion of meat expenditure to total food expenditure will significantly increase RRDBECPC, the empirical results reveal a different phenomenon in rural China. Some studies [79,104] hold the belief that by complying with the healthy eating guideline of consuming less meat, energy demand will be lowered due to the decline of livestock numbers and the arable land or grassland, which, used for stock farming, can be alternatively used for the production of renewable energy feedstock in Australia, therefore improving RRDBECPC.

While those studies interpret the phenomenon from the perspective of increasing biomass production to facilitate RRDBECPC, the opposite result in China may be explained by the status quo inertia of dietary culture. Similar to the case of Jaracuaro given by [78], rural residents in China are accustomed to the food cooked with biomass fuels. Since the preparation of meat will take more fuel, the increasing proportion of meat will contribute to the consumption of biomass energy. Due to lack of biomass consumption data for cooking practices, energy mix is adopted to explain the impact of the changing dietary structure on weighted energy intensity for rural residents' food preparation. As can be seen from Table 4, rural residents' dietary structure underwent significant changes during 1991–2016, which improved the weighted energy consumption per unit of food from 116.34 kgce to 148.66 kgce. In parallel, the increasing proportion of meat consumption tends to enhance RRDBECPC.

Table 4. Energy consumption per unit of food, rural residents' dietary structure, and weighted energy consumption per unit of food in China.

	Grain	Vegetable	Meat	Egg	Poultry	Aquatic Product
Energy consumption per unit of food (kgce/ton)	129.05	32.40	647.96	161.96	161.96	404.96
Rural residents' dietary structure in 1991 (kg/year*person)	255.58	126.97	12.15	1.34	2.21	2.73
Rural residents' dietary structure in 2016 (kg/year*person)	157.24	91.46	22.71	7.91	7.49	8.48
Weighted energy consumption per unit of food in 1991 (kgce/ton)	116.34					
Weighted energy consumption per unit of food in 1991 (kgce/ton)	148.66					

Data source: The data of energy consumption per unit of food comes from [105]; the data of rural residents' dietary structure in 1991 and 2016 comes from China Statistical Yearbook of 1992 and 2017; the others are based on author's own calculation.

The lagged term of the proportion of grain planting area to total planting area has a significantly positive impact on RRDBECPC. A possible reason for the relationship is that grain crops, including cereal, beans, and tubers, are the main source of straw, and straw is the principal form of biomass energy (see Figure 2). Under the condition that the cultivated land increased steadily during the investigation period, the biomass production from straw increased as well, despite the decreasing planting proportion of grains. Hence, RRDBECPC in China increases. Another possible explanation is that as the agricultural production in China is dominated by families, biomass resources are characterized by scattered distribution, small-scale production, unstable supply, and inconvenience in collection, transportation, and storage [76,101]. It is hard for biomass to be intensively used, and rural farmers are its major users. Consequently, RRDBECPC in China increases with a consideration of collection costs and it scattered distribution, because it makes biomass be consumed by rural residents rather than centralized commercial organizations.

4.1.3. The Allure of Power and Control and RRDBECPC

Similar to cultural assets of professional groups, mainly referring to professional knowledge, firewood-saving stoves have the feature of asset specificity for rural residents. Consequently, the lagged ownership of firewood-saving stoves per 100 households is adopted as a proxy of the allure of power and control. The empirical results show that the ownership of firewood-saving stoves has a significantly positive influence on RRDBECPC, which is against common sense that compared to traditional cooking stoves, firewood-saving stoves are more efficient and can significantly reduce the demand for biomass energy. However, the results are in accordance with [69,106]. In Malawi's case, policy measures aimed at improving cooking efficiency are insufficient to decrease demand for cooking energy due to high population growth [106]. In China's case, the positive impact of firewood-saving stoves on biomass consumption is attributed to energy switching back [69]. Even after energy transition, rural residents may switch back to biomass energy consumption due to the changing fuel prices and improved efficiency of stoves [54].

This explanation of [54] is also appropriate for our results. Chinese government's promotion of the firewood-saving stoves significantly reduces pollution and improves efficiency of energy utilization, which improves rural residents' willingness for biomass consumption. In order to provide rural households with more efficient biomass stoves, the National Improved Stove Program has been carried out since the 1980s [107], and by 2014, the accumulated promotion number of energy-saving stoves around China reached 169 million units, among which 119 million units were firewood-saving stoves, 18.86 million units were energy-saving pits, and 30.91 were energy-saving furnaces [108]. Correspondingly, the average thermal efficiency of firewood-saving stoves has increased from 10% in the 1980s to over 20% in the 1990s, and over 30% after entering the new century [103]. The emissions of direct combustion are influenced by not only the fuel types, but also the combustion trains [109]. The improved firewood-saving stoves have also reduced the pollutant concentration of indoor air, which contributes to the lock-in of RRDBECPC in China.

4.1.4. Some Other Influencing Factors

In accordance with existing literature [110,111], the empirical results reveal that net income per capita has a significantly negative influence on RRDBECPC. Income level has been considered as a key determinant of energy transition for a long period [1,74,112,113]; that is, with the improvement of income, household energy transits from biomass through traditional commercial energy to modern commercial energy. Rural residents with a higher income can not only replace biomass with commercial energy for the same residential purpose, but also purchase more appliances that are powered by commercial energy [4,111].

WPICO and WPIEL have a significantly positive effect on RRDBECPC and consolidate the behavior lock-in of RRDBEC. In other words, the rising commercial energy prices enhance the utilization of biomass energy due to the substitution relationship between commercial energy and biomass. In China, rural residents collect biomass resources primarily from crop residues or forestry leftovers planted in their own contracted land or abandoned in village commons, representing zero monetary costs for rural households, because rural societies have traditionally placed no monetary value on benefits obtained from environmental resources [88,114]. On the contrary, though commercial energy prices have been chronically regulated at a lower level by Chinese government [115], rural residents are still sensitive to energy prices, as the regions with higher commercial energy prices are observed to have a lower ratio of households using commercial energy as cooking fuels, but a higher ratio of households consuming biomass [116]. The relative cost of modern fuels constitutes an economic burden for rural residents as their overall income level is comparatively low [102].

In accordance with earlier findings [110,111,117,118], the education level of rural residents is negatively correlated with the RRDBECPC, which may be attributed to rural residents' consideration of time cost of biomass collection and improvement of health awareness and environment awareness. Dependency ratio has a significantly negative influence on RRDBECPC, which is contrary to the findings of [69,119], showing that senior people and children have more free time to collect biomass. In this study, the potential explanation may be worried over health issues. Compared to the working population, children and the elderly spend most time indoors and are more sensitive to air pollution. For instance, it is found that switching to clean energy can reduce chronic respiratory illnesses in children [120]. Consequently, along with the rising dependency ratio, rural households tend to increase the consumption of modern commercial energy, such as electricity and LPG [119], thereby substituting the role of biomass energy. Besides, firewood-saving stoves are a kind of specific asset for rural residents, which hinders energy transition of rural residents and improve biomass energy transition [86,87].

4.2. Further Discussion on Robustness and Endogeneity

Robustness and endogeneity is examined as follows: Firstly, according to the approach of robustness checks through "examining how certain 'core' regression coefficient estimates behave when the regression specification is modified in some way, typically by adding or removing regressors" [121]. Stepwise regression is employed and factors of IP_{it}, SQI_{it}, and APC_{it} are successively added to test the plausible signs and magnitudes of the estimated regression coefficients [122]. The results are shown in columns (1)–(4) in Table 3, and (1)–(2) in Table 5, from which it can be concluded that the results are robust. Secondly, it is a common practice that different estimation methods are used to check the robustness. Comparing the sign, magnitude, and significance of key variables in Tables 3 and 5, it can be seen that the results are robust.

Table 5. Estimation results for robustness check.

	(1)	(2)	(3)	(4)
	FE	FE	POLS	FGLS
Agency	0.0560	0.0218	0.110 ***	0.101 ***
	(1.69)	(0.67)	(3.96)	(57.19)
Biogas	−0.134 ***	−0.180 ***	−0.153 ***	−0.121 ***
	(−4.94)	(−5.86)	(−5.48)	(−22.29)
Meat		5.727	6.677	2.435 ***
		(0.82)	(1.24)	(6.82)
Lagged straw		0.0494 ***	0.0333 ***	0.0115 ***
		(6.15)	(4.27)	(13.05)
Lagged stove		0.534 ***	0.0942	0.168 ***
		(4.20)	(1.76)	(17.20)
WPICO		0.0154	0.193 ***	0.201 ***
		(0.22)	(4.59)	(21.33)
WPIEL		0.461 ***	0.198 ***	0.133 ***
		(7.96)	(4.09)	(24.98)
Income		−0.0373	−0.228 ***	−0.150 ***
		(−0.65)	(−6.14)	(−18.76)
Education		−0.511 *	−0.0110	−0.0794 ***
		(−2.39)	(−0.11)	(−9.37)
Dependency		−0.0872	−3.936 ***	−2.191 ***
		(−0.06)	(−3.74)	(−23.94)
Constant	3.299 ***	3.094	3.445 **	3.453 ***
	(12.60)	(1.39)	(3.29)	(40.27)
Province fixed effect	Yes	Yes		
Year fixed effect	Yes	Yes		
R^2	0.0070	0.2194	0.2143	
Observations	672	644	644	644

Note: t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Thirdly, some other variables are selected as the agent variables of the three types of factors. The number of rural energy administrative agencies and the number of biogas projects are respectively adopted to replace the number of staff in rural energy administrative agencies and the government fund as the agent variables of IP_{it}. The former is adopted because the number of staff and the number of agencies are two aspects of the institutional arrangement, while the latter is adopted because a large proportion of fund for comprehensive rural energy construction projects is used for rural biogas projects [100]. The annual output of straw is adopted as the agent variable of the lagged term of the proportion of crop planting area to total planting area, because they are two aspects reflecting the production of straw from agriculture. The results are shown in Table 5, and the empirical results of Tables 3 and 5 are consistent, implying that the results are robust. From the three aspects of robustness tests, it can be concluded that the research results are robust.

One potential factor that may lead to the endogenous problem is the reverse causation between RRDBECPC and the prices of commercial energy, namely WPICO and WPIEL. However, it is believed that both WPICO and WPIEL are exogenous variables for biomass energy consumption in rural China. For one thing, energy prices have been regulated at a lower level by the Chinese government for a long time, especially the electricity price, and the potential reasons are reducing the fast-growing input cost for producers, easing inflation pressures for consumers, and achieving social equity objectives, rather than reflecting the real energy demand of the market or the energy production costs [115,123,124]. Consequently, the impact of the endogeneity problem led by energy prices in rural China is not as great as that in other countries [54]. For another thing, rural energy has chronically been excluded from the Chinese national commodity energy system [47,52,125]; fossil fuel consumption only accounts for a small proportion of total energy consumption in China, which means that its impact on the national commercial energy market is limited. For instance, residents' coal consumption in rural China only accounted for 2.18% of national coal consumption in 2015. Consequently, to some degree, it is believed that there exists no reverse causation between RRDBECPC and the prices of commercial energy.

5. Conclusions

The transition from traditional to modern energy is widely accepted as a critical facilitator of improved health, social, and livelihood outcomes, but more than three quarters of China's rural population persist with traditional energy practices. The paper aims to investigate the determinants underlying behavioral lock-in of RRDBEC in China so as to facilitate energy transition. Adopting the panel data on 28 provinces during 1991–2014, this study empirically examines the impacts of institutional pressure, status quo inertia, and allure of power and control on the behavioral lock-in of RRDBEC in China. The number of staff in rural energy administrative agencies has a significantly positive impact on the behavioral lock-in of RRDBECPC, while government funding for rural energy development has an opposite impact. With regard to status quo inertia, depicted by the planting proportion of grain and the expenditure proportion of meat, is verified to influence the behavioral lock-in of RRDBECPC significantly and positively. Allure of power and control, depicted by the ownership of firewood-saving stoves, tends to lock RRDBECPC. Apart from the former three types of factors, net income per capita, education level of rural residents, and the dependency ratio are verified to significantly and negatively affect the behavioral lock-in of RRDBECPC, while the impacts of WPICO and WPIEL are opposite.

The above findings provide some policy implications of the behavioral lock-in of RRDBECPC for China and other developing countries regarding policy formulations for facilitating energy transition in rural areas. Firstly, the functions of rural energy administrative agencies should be transformed. The current functions of these agencies include policy implementation, information collection, technology promotion, and so on, but its technology-related function is mainly related to biomass energy. However, rural energy administrative agencies are assigned with technology-related function because Chinese government needed to alleviate rural energy shortage in the 1990s and the beginning of the 21st century, which improved biomass consumption. With the increase of rural energy supply, more functions relating to energy transition should be assigned, such as the promotion of clean utilization technology of coal and the centralized supply of natural gas. Secondly, the government should increase government fund to promote indirect and clean biomass energy utilization. It is a tendency that large and medium indirect biomass utilization projects gradually replace small household biomass projects and attract the major part of funding from the Chinese government. In order to promote the clean utilization of biomass and reduce RRDBECPC, more government funding is necessary.

Thirdly, the status quo inertia of RRDBEC, especially relating to cooking practices, should be taken into consideration during the policy-making process. Public education regarding healthy and environmental issues over RRDBEC should be promoted to adjust rural residents' habits relating to biomass resource utilization. For instance, with the gradual adjustment of rural residents' food consumption structure, corresponding agricultural policies and animal farming policies should be revised to adjust the planting structure and culturing structure in rural China, which significantly influences the production of biomass resources, thereby affecting RRDBECPC. Fourthly, economic incentives should be provided to help rural residents get rid of the allure of power and control. Firewood-saving stoves have made great contributions to alleviating energy shortage and protecting environment in China for the past decades, which, however, impedes energy transition in China now. Considering its feature of asset specificity, the Chinese government should provide material incentives to firewood-saving stove users.

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Appendix A

Table A1. Major policies relating to the development of biomass energy in rural China.

Year	Policy	Content summary
1995	Development Outline of New Energy and Renewable Energy (1996–2010)	The policy aims to improve energy conversion efficiency, reduce production costs, and increase the proportion of renewable energy. In detail, the policy aims to make breakthroughs in new technologies and processes, achieve large-scale and industrialized application of mature technologies, and increase biogas consumption.
1996	The Ninth Five Year Implementation Plan of National "Forestry Energy Project"	The policy aims to accelerate the pace of afforestation and development of forest resources, develop high-quality, high-yield, and high-efficient firewood forests, ease the contradiction between supply and demand for firewood, protect forest resources, improve rural ecological environment, and promote rural economic development.
1997	Provisional Regulations for The Management of New Energy Infrastructure Projects	The policy aims to encourage and support the development of new energy industry, promote the construction of new energy industries, and accelerate the localization of new energy equipment through regulations on the management of new energy infrastructure projects.
1999	Notifications of Further Support for Issues Related to The Development of Renewable Energy	The policy aims to support the development of new energy industry and accelerate the localization of new energy equipment through fiscal measures.
2002	National Rural Biogas Construction Plan (2003–2010)	The policy aims to increase biogas utilization by 11 million households to a total of 20 million households, and improve the proportion of households using biogas to 10% by 2005. The policy aims to increase households using biogas by a further 31 million to a total of 50 million, and improve the proportion to 35% by 2010.
2003	National Bonds Project Management Measures of Rural Biogas Construction	The policy aims to strengthen the management of national bond projects of rural biogas and standardize project construction activities, so as to achieve the expected ecological, economic, and social benefits.
2004	Notice Concerning Strengthening the Safety Management of Rural Biogas	The policy aims to standardize the construction and management of biogas projects to guarantee the safety of workers.
2006	Tentative Measures for Price and Cost Sharing Management of Renewable Energy Power Generation	The policy aims to set reasonable prices of electricity generated from renewable energy and spread the cost.
2006	Temporary Measures for The Management of Special Funds for The Development of Renewable Energy	The policy aims to standardize and strengthen the management of special funds for the development of renewable energy and improve the efficiency of the use of funds.
2007	Medium-term and Long-term Development Planning for Renewable Energy	The policy aims to increase the proportion of renewable energy, solve the shortage problem of rural livelihood fuels, promote the use of organic waste as an energy source, and promote the industrialization of renewable energy technologies.
2007	Construction Plan of National Rural Biogas Service System	The policy aims to consolidate the achievements of rural biogas construction and ensure its good and fast development.

Table A1. *Cont.*

Year	Policy	Content summary
2007	Development Plan of Agricultural Biomass Energy Industry (2007–2015)	The policy aims to build a number of agricultural biomass energy bases, construct the technological innovation and industrial development systems, reduce the development and utilization costs, and achieve the market-oriented reform of the agricultural biomass energy industry by 2015.
2007	Construction Plan of National Rural Biogas Project (2006–2010)	The policy aims to develop biogas through the planning and construction of three aspects, including rural household biogas, large and medium-sized biogas projects on scaled farms, and technical support and service system construction.
2007	Management Plan of Rural Biogas Project Construction Fund	The policy aims to strengthen the management of funds for the construction of rural biogas projects and improve the use efficiency of financial funds.
2007	Suggestions on Further Strengthening The Management of Rural Biogas Construction	The policy aims to strengthen the construction and management of rural biogas through strengthening the construction and management of biogas projects, performing biogas technology promotion and innovation, supporting the construction of biogas projects on farms, strengthening the construction of biogas service system, and doing a good job of project inspection and acceptance.
2007	The Eleventh Five-year Plan for The Development of Renewable Energy	The policy aims to accelerate the development and utilization of renewable energy, increase the proportion of renewable energy, solve the shortage problem of rural residential fuels, promote the development of renewable energy technologies and industries, and increase the R&D capabilities of renewable energy technologies.
2008	Suggestions on Accelerating The Comprehensive Utilization of Crop Straw	The policy aims to speed up the comprehensive utilization of straw, realize the resource utilization and commercialization of straw, promote resource conservation, environmental protection, and increase farmers' income.
2008	Temporary Measures for The Management of Subsidized Funds for Energy Utilization of Straw	The policy aims to strengthen the management of financial funds and improve the use efficiency of fund for straw.
2008	Pilot Construction Plan of Farming and Small Household Biogas Project	The policy aims to enhance biogas use in rural areas, support the establishment of livestock and poultry excrement and sewage detoxification treatment facilities in breeding communities, and promote comprehensive management and transformation of human and animal excreta, crop straw, and household waste.
2011	Implementation Plan of Comprehensive Utilization of Crop Straw during the 12th Five-year Plan	The policy aims to improve the comprehensive utilization rate of straw to 75% by 2013 and to 80% by 2015, establish a complete system of straw field treatment, collection, storage, and transportation, and establish a comprehensive utilization industrialization pattern with rational layout and diversified utilization.
2012	Suggestions on Further Strengthening the Construction of Rural Biogas	The policy aims to provide some guidelines on biogas construction, including reasonably planning the development of biogas, increase the source of raw materials, improving the quality of biogas construction projects, perfecting the operation mechanism of biogas service system, accelerating the development of large and medium-sized biogas projects, strengthen the construction of the biogas technology support system, and improving support policies for biogas development.

Table A1. *Cont.*

Year	Policy	Content summary
2013	The Twelfth Five-year Plan for The Development of Renewable Energy	The policy aims to expand the application scale of renewable energy, promote the integration of renewable energy and conventional energy systems, significantly increase the proportion of renewable energy in energy consumption, comprehensively upgrade renewable energy technology innovation capabilities, master the core technologies of renewable energy, and establish a comprehensive system and a highly competitive renewable energy industry.
2015	Working Plan of Rural Biogas Transformation and Upgrading	The policy aims to support the construction of a number of large-scale biogas projects in suitable regions, carry out pilot projects for large-scale bio-natural gas projects, improve the annual capacity for biogas production to 487 million cubic meters, and promote rural biogas transformation and upgrading pilots.
2015	Notice on Further Accelerating the Comprehensive Utilization of Crop Straw and Prohibition of Combustion	The policy aims to achieve an overall straw utilization rate of more than 85%, reduce the number of burned fires or burned areas of straw by 5% lower than in 2016, and eliminate open burning of straw in densely populated areas, airports, traffic lines, and the areas regulated by local governments by 2020.
2016	Proposal to Promote the Agricultural Waste Resource Utilization Pilot	The policy aims to increase the proportion of the fecal sewage treatment facilities for pilot farms of pilot scale in the county-scale farms to 80%, and increase the comprehensive utilization rate of straw to 85%.
2016	Notice on Carrying Out Pilot Stages of Comprehensive Utilization of Crop Straw and Promoting the Quality Improvement of Cultivated Land	The policy aims to improve the comprehensive utilization rate of straw to reach over 90%, or increase by 5% on the basis of the previous year, prevent open burning, and improve the level of straw directly returning to the field.
2017	The Thirteenth Five-year Plan of National Rural Biogas Development	The policy aims to make significant progress in the transformation and upgrading of rural biogas, perfect the industrial system, establish the pattern of multiple coordinated development, popularize the development mode of breeding and cycling (linked by biogas projects), improve the technological support and industry supervision capabilities, and improve the service system and policy system.
2014–2017	Central Document No.1	The policies aim to develop household biogas and scale biogas according to local conditions and improve the monitoring mechanism of biogas in rural areas.

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