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Abstract

The surge of Residential Fresh Water Demand (RFWD) has raised great concern for China's water supply and understanding the driving forces of RFWD is critical to maintain a sufficient water supply. Drawing on the panel dataset from 31 Chinese provinces from 2000 to 2011, we estimate the determinants of the increase in RFWD using Ordinary Least Square (OLS) and Fixed Effects (FE) approaches. We argue that FE should be adopted as it can consider the unobserved heterogeneity among regions such as local social norms regarding hygiene habits and water resource use. Our estimation results indicate that the rapid increase in China's RFWD is mainly attributed to the improvement of household income, the aging society and the urbanization. The results imply that the Chinese government should consider the dynamics of socio-economic conditions and urbanization in reforming water and urban development policies, such as enhancing the capability of water supply services, integrating rural-urban development and encouraging water conservations.

Keywords: Water demand, water resources management, urbanization, panel data analysis

1 Introduction

Sufficient drinking water supply for residents is ranked at the top of the Chinese government agenda (China UN, 2012). Recently, an increasing number of cities have experienced fresh water shortages due to the surge of China's Residential Fresh Water Demand[1] (RFWD). In 2006, around 40% of Chinese cities lacked fresh water resources, and 13% of the cities experienced serious water shortages (Zhao et al., 2006). By 2013, two thirds of Chinese cities lacked fresh water resources and 22% of them were under serious water threats (Zhou, 2013). On the other hand, the RFWD has been increasing rapidly in the past decade. From 2000 to 2011, China's residential fresh water use rose by 37%, which is the fastest increase among all the water uses (see Table 1). The dramatic increase in RFWD has raised great concern over China's water security and understanding the driving forces of RFWD is critical to improving its water supply.

Despite the importance of understanding the dynamics of RFWD, few studies have been conducted. Chen and Yang (2009) argue that the price of water plays an important role in domestic water consumption. They predicted the potential benefits of implementing block rate pricing in Beijing based on the extended linear expenditure system model and found that block rate pricing was a useful strategy for conserving water. Nevertheless, it is very unlikely that the dramatic RFWD in recent years was driven by the price of water. In the past decade, the price of water for domestic water use has stepped up, although the degree of increase may vary from region to region. If water price is the main factor influencing RFWD, then RFWD should be reduced rather than increased[2], which contradicts the fact that the RFWD has increased in the past decade. In the urban household survey of water utilization data in Beijing and Tianjin, Zhang and Brown (2005) find that using more water appliances, a change towards modern lifestyle and less concern about water conservation result in higher water consumption. This conclusion is drawn on a cross section data analysis and it is not clear whether or not it will apply in a dynamic context. After witnessing the rapid urbanization process in the past three decades, Bao and Fang (2012) propose that rapid urbanization[3] is closely linked with the surge of RFWD in China because the high population density in urban areas increases RFWD (Van der Bruggen et al., 2010). Nevertheless, the nexus of the urbanization and RFWD has not been investigated empirically. This paper will fill this gap by examining the driving forces of RFWD and will address the impact of urbanization on RFWD in China in particular by using the panel data approach.

Former studies have identified several factors that may influence RFWD including economic, demographic, social, and climate factors. Many studies (Agthe and Billings, 1980; Foster and Beattie, 1981; Garcia and Reynaud, 2003; Gaudin, 2006; Nauges and Thomas, 2003; Martinez-Espineira and Nauges, 2004; Hoeglund, 1999; Ruijs et al., 2008; Arbues et al., 2004; Martinez-Espineira, 2002) found that the price of water was negatively correlated with the amount of water consumption; however, the price elasticity is rather low, which implies that water consumption was inelastic regarding price and that the increase of water price decreases the amount of water consumption. Schleich and Hillenbrand (2009) analyzed RFWD in Germany with aggregated data and proposed that the increasing water prices and lower income levels were causing the recent decrease in water utilization in German new states. Domene and Sauri (2006) investigated additional factors in their

[1] The RFWD in our analysis only refers to the fresh water provided by the water supply service and the self-supplied fresh water such as private wells is not included. If the underground water is polluted, the water from private wells in this area may be no longer drinkable, which leads to an increase in the RFWD in this area.

[2] The increase of water price decreases the amount of water consumption as indicated by many previous studies (Schleich and Hillenbrand, 2009; Garcia and Reynaud, 2003; Gaudin, 2006; Nauges and Thomas, 2003; Martinez-Espineira and Nauges, 2004; Ruijs et al., 2008; Arbues et al., 2004; Martinez-Espineira, 2002).

[3] Urbanization in China is a dynamic process of reallocating the population from relatively low density rural areas to relatively high density urban areas, and reallocating employment from agricultural to non-agricultural sectors.

household survey and concluded that income, housing type, family size, having a garden, owning a swimming pool and water conservation practices played important roles in water consumption in Barcelona, Spain. The housing types in China are so different from that in Spain. Moreover, residents in China have lower incomes than residents in Spain, and the types of housing with gardens and swimming pools are not common in China, so the results of the study are not universally applicable to China. Jorgensen et al. (2009) integrated institutional trust in the household water use model and demonstrated that water conservation was more apparent when individuals were aware of the scarcity of water. The institutional trust may play a role in water conservation, but it is difficult to explain the surge of water demand in China. In addition, Mazzanti and Montini (2005) propose that altitude has a significant negative impact on water consumption because it reduces temperature, and Schleich and Hillenbrand (2009) argue that rainfall patterns are correlated with water consumption. The adaptation to climate for households is shaped by habits and daily practices (Browne et al., 2013), which may be difficult to modify if the households lack knowledge or information (Beal et al., 2011). Therefore, social factors should also be considered in the analysis of RFWD. Generally, 96% of studies are based on samples from the USA, Europe and Australia (Worthington and Hoffman, 2008), and few studies on RFWD have been made in Asian countries where water shortages are threatening their sustainable social and economic development, such as China and India (Nnaji et al., 2013).

Urbanization may affect RFWD in three ways. First, migration from rural to urban areas may raise domestic water consumption. According to the National Statistics Bureau (2013), there are 263 million peasant workers in China, and about 62% of them were migrants in 2012. As the migrants move to cities such as Beijing, Shanghai, Guangzhou, Shenzhen, Hangzhou etc., the fresh water demand in these urban areas increases. Second, the expansion of urban boundaries along with farmland commercialization may increase RFWD. The official reports show that 50 million peasants have been displaced due to land commercialization between 1996 and 2003 (Hsing, 2012 pp. 2-4). Once the rural people are displaced, the source of drinking water often changes from private wells to tap water; therefore, the RFWD increases. Finally, water pollution resulting from urbanization may aggravate fresh water demand. The urbanization leads to the agglomeration of residents in cities, which increases the amount of sewage water. If the domestic sewage water cannot be treated properly and reaches the rural areas, it may pollute the underground water supply in the rural areas and lead to the water from private wells becoming undrinkable, which creates additional demand for residential fresh water (Jiang, 2009; Bao and Fang, 2012).

The objective of this study is to examine the driving forces of RFWD in China and estimate the impact of urbanization on RFWD. Based on the panel dataset of 31 Chinese provinces from 2000 to 2011, we analyzed the determinants of fresh water demand and considered the unobserved heterogeneity, such as local social norms regarding hygiene habits and water resource use, using Fixed Effects (FE) model. This paper is comprised of five sections: an overview of the RFWD in China, a description of the relationship between urbanization and water consumption, an analysis of the determinants of RFWD, and an estimate of the impact of urbanization on RFWD and conclusion.

2 RFWD in China

In the past 12 years, both industrial and residential water use in China has increased, while agricultural water use has slightly decreased. As illustrated in Table 1, from 2000 to 2011, the amount of water used for industrial purposes has increased by 2% annually, the amount of water used for residential purposes has increased by 3% annually, and the amount of water used for agricultural purposes has decreased by 0.1% annually. Clearly, the most rapid increase in the past decade is residential water use. Data regarding ecological water use was not included until 2003, however, the amount is increasing very rapidly as well. Consequently, the total water use has increased by 1% annually between 2000 and 2011.

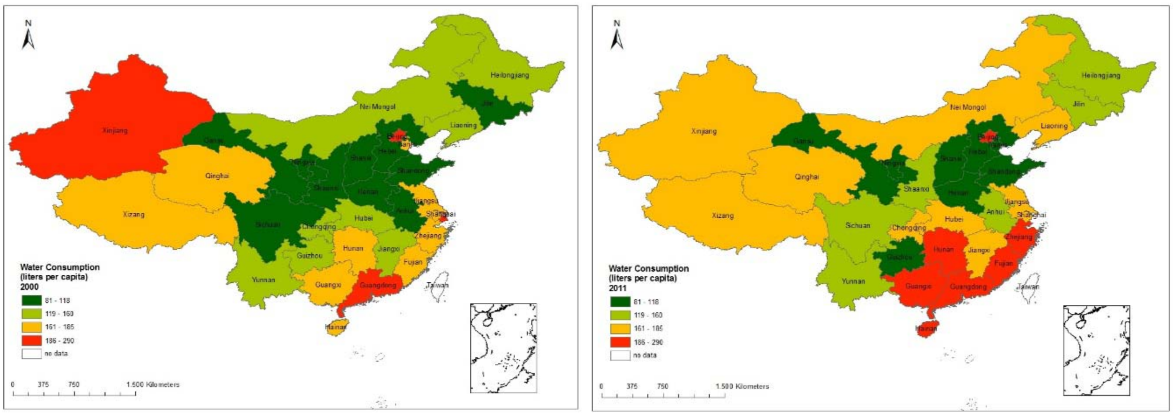
To view the increasing trend of residential water consumption more clearly, we calculate the residential water consumption per capita according to the total population data in each province. Next, we map the water consumption per capita in the years 2000 and 2011, which is presented in Figure 1. The average water consumption level in China has escalated almost 30 liters per capita per day in the past decade, and the escalation can be observed in most of the individual provinces in Figure 1. The average water consumption level did not increase significantly/slightly decreased in the Beijing, Tianjin, Hebei, Guizhou, Ningxia and Xinjiang Provinces mainly due to the serious water shortages in these regions.

Tab 1: The amount and allocation of various water uses in China (2000-2011).

	Water use amount (100 million cubic meter)				Water use share (%)			
Year	Agriculture	Industry	Residential	Ecology	Agriculture	Industry	Residential	Ecology
2000	3784	1139	574	-	68.8	20.7	10.4	0.0
2001	3826	1142	600	-	68.7	20.5	10.8	0.0
2002	3736	1142	619	-	68.0	20.8	11.3	0.0
2003	3432	1177	630	79	64.5	22.1	11.8	1.5
2004	3586	1228	651	82	64.6	22.1	11.7	1.5
2005	3580	1285	675	93	63.6	22.8	12.0	1.6
2006	3664	1343	693	93	63.2	23.2	12.0	1.6
2007	3599	1403	710	105	61.9	24.1	12.2	1.8
2008	3663	1397	729	120	62.0	23.6	12.3	2.0
2009	3723	1390	748	102	62.4	23.3	12.5	1.7
2010	3689	1447	765	119	61.3	24.0	12.7	2.0
2011	3744	1462	790	112	61.3	23.9	12.9	1.8

Source: The China Statistical Yearbook on Environment (2000-2011)

Figure 1: Water consumption per capita in Chinese provinces (2000, 2011).



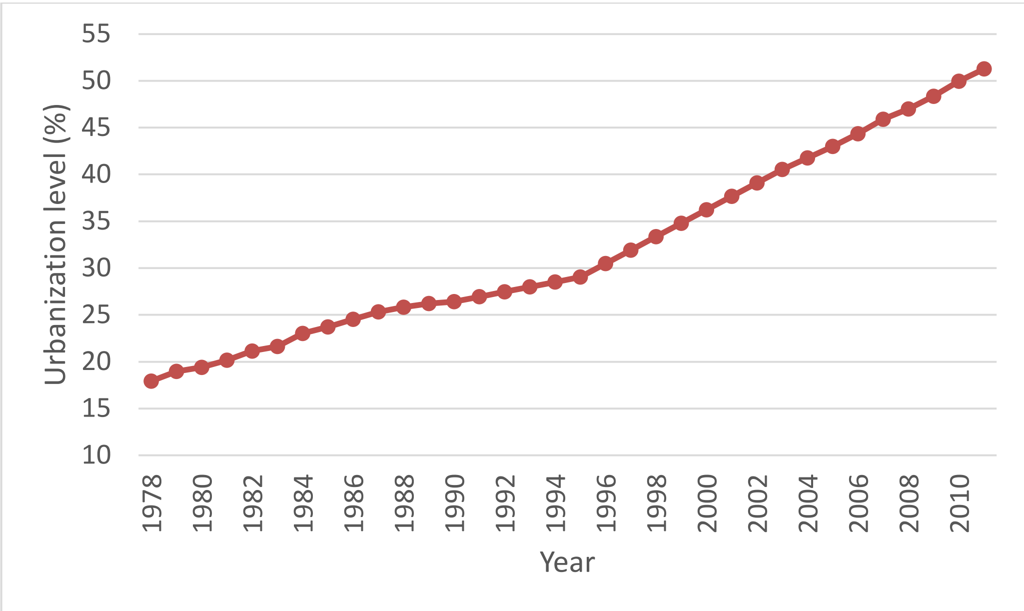
Source: China Statistical Yearbook on Environment (2000 left, 2011 right) and the China Statistical Yearbook (2001, 2012)

2.1 Urbanization and water consumption in China

The urbanization in China is predominately induced by the development of the labor market (Jia, 2012; Zhang and Song, 2003; Zhao, 1997; Wu and Yao, 2003; Gu et al., 2012). Before 1978, there was no voluntary migration. The movement of the labor force from rural to urban areas was restricted, and the urbanization was retarded (Cai et al., 2009). In the following years, the Chinese labor market experienced tremendous changes. At the beginning of the economic reform, the urbanization ratio was only 18%; this number doubled in 2000. As of 2011, 51% of the Chinese population (about 691 million) lived in urban areas (as shown in Figure 2). Between 1978 and 1995, the urbanization rate increased by 2.8% annually. Because of the slow-down of the growth of Township Village Enterprises (TVEs) and less strict migration policies, many rural laborers motivated by more job opportunities and higher wages have been migrating from rural to urban areas since the mid-1990s. From 1995 to 2011, the annual increase rate of the urbanization ratio has risen to 3.6%.

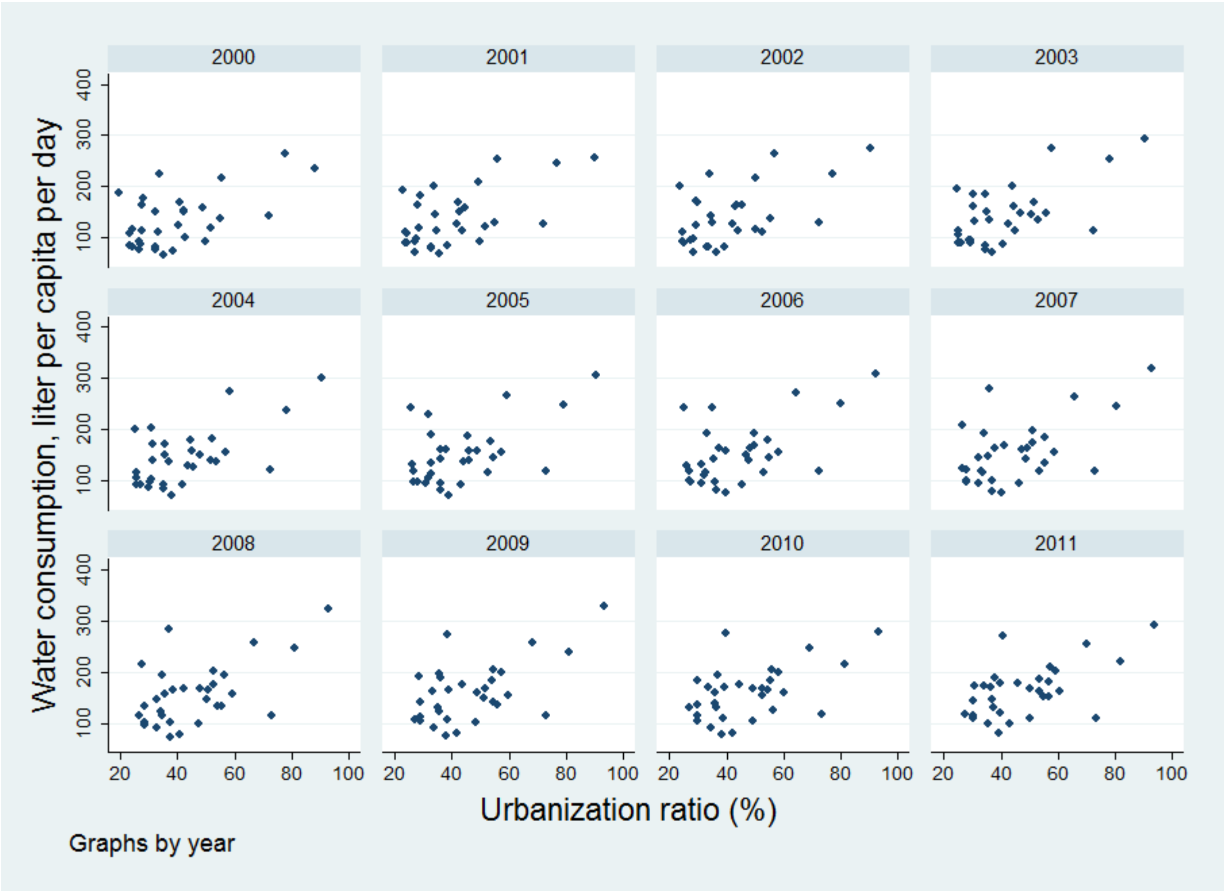
With the massive population influx from rural to urban areas, the RFWD has increased dramatically (Chen, 2007; Bao and Fang, 2012). Figure 3 depicts the relationship between urbanization and RFWD. The figure indicates that the regions with higher urbanization ratios also consume more fresh water per capita and this positive relationship between urbanization ratio and fresh water consumption per capita can be observed in all 12 years. Does urbanization contribute to RFWD? The following part of this paper will answer this question and provide an in-depth understanding of the determinants of RFWD in China.

Figure 2: Urbanization level in China (1978-2011).



Source: The China Statistical Yearbook (2012).

Figure 3: Urbanization and RFWD of Chinese provinces (2000-2011).



Source: The China Statistical Yearbook on Environment (2000-2011), Shen (2005) and Bao (2013, pp 89-129).

3 The determinants of RFWD

To better estimate the *de facto* impact of urbanization on RFWD, the empirical model includes not only urbanization but also the other factors that may potentially influence RFWD, as has been indicated in a previous section. Hence, we estimate the impacts of urbanization, social and economic factors, water resource endowment and climate change on RFWD. The model is illustrated as follows:

$$\log(\mathrm{watconper}_{it}) = \beta_0 + \beta_1 \log(\mathrm{urbratio}_{it}) + \beta_2 \log(\mathrm{watre}_{it}) + \beta_3 \log(\mathrm{hhincome}_{it}) + \beta_4 \log(\mathrm{car}_{it}) + \beta_5 \log(\mathrm{edu}_{it}) + \beta_6 \log(\mathrm{old}_{it}) + \beta_7 \log(\mathrm{preci}_{it}) + \beta_8 \log(\mathrm{temp}_{it}) + \beta_9 \log(\mathrm{indsew}_{it}) + \beta_{10}\mathrm{year} + u_{it}.$$

β_0……β_{10} are estimated parameters. $\mathrm{watconper}_{it}$ is the fresh water consumption per capita in the region i and the year t. watre_{it} is the fresh water resource per capita in the province i and the year t. $\mathrm{hhincome}_{it}$ is the household dispensable income in the province i and the year t. car_{it} indicates the number of car owned by 100 households in the province i and the year t. edu_{it} is the number of people out of 100 people in the province i and the year t who have graduated from senior school or above. old_{it} is the number of elderly people (more than 64 years old) out of 100 people in the province i and the year t. preci_{it} is the precipitation in the capital city of province i and the year t. temp_{it} is the average temperature in the capital city of province i and the year t. indsew_{it} is the total amount of industrial sewage water discharged in the province i and the year t. year is the year trend. $\mathrm{urbratio}_{it}$ is urbanization level in the province i and the year t, and u_{it} is the error term.

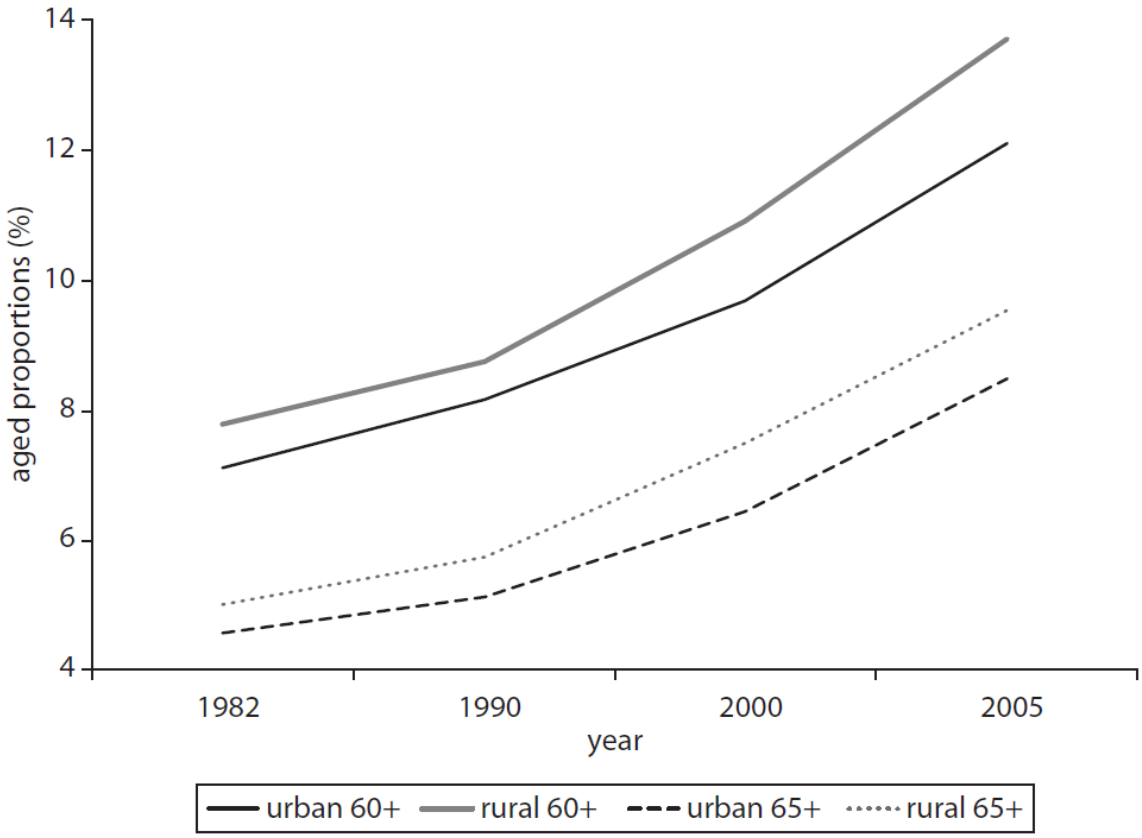
First, we tested the model with Ordinary Least Square (OLS) approach, and the results are illustrated in Table 1. To test the specification of the model, we conducted a linktest. The null hypothesis of the linktest is that no quadratic terms are needed in the model. The linktest results show that the null hypothesis cannot be rejected; hence the linear model is sufficient for our analysis (Pregibon, 1980). The OLS estimation may be biased by unobserved heterogeneity that cannot be observed in the model because the water consumption in a region is often shaped by local social norms regarding hygiene habits and water resource use, which vary among regions. To account for the unobserved heterogeneity, we estimate the model with the FE approach. The FE estimation is presented in Table 2. Further, we conduct the Hausman test and test the validity of FE model (Hausman, 1978). The null hypothesis of the Hausman test is that the difference in coefficients is not systematic. The Hausman test rejects the null hypothesis at a 1% significance level as shown in Appendix 2, which indicates that the FE model is more appropriate for our analysis than the Random Effects (RE) model.

In both OLS and FE estimations, the household income significantly contributes to the increase of RFWD in China, which is consistent with the previous findings (Schleich and Hillenbrand, 2009; Mazzanti and Montini, 2005; Zhang and Brown, 2005). As the household income increased, the lifestyle of the residents changed. For example, the number of showers possessed by urban households has increased from 49% to 89% from 2000 to 2011, the number of washing machines possessed by urban households has increased from 91% to 97% during the same period, and the number of dish washers has also increased among urban households (China Statistical Yearbook, 2012). Therefore, the shift from a traditional lifestyle to a modern lifestyle results in higher water consumption.

The residents with higher education levels are often presumed to consume more fresh water due to hygiene concerns; however, they may also conserve more water due to a better understanding of the water shortage and more environmental concerns. The positive impact that education level has on RFWD is observed in the OLS model, but the impact is no longer significant once the unobserved heterogeneity is considered in the FE model. The difference of the results between the two models reveals that regional unobserved heterogeneity, such as local norms regarding hygiene habits and water use, plays a more important role in water demand than education levels. For example, it is often observed that the people in the south of China tend to shower more frequently than the people in the north. This finding reinforces the argument of Tang et al. (2013) that social norms are important in shaping environmental behaviors for the Chinese population.

An aging society contributes to the increase of RFWD, which is significant in both the OLS and the FE models. A positive impact of aging society on water demand is found in Germany and Spain (Schleich and Hillenbrand, 2009; Domene and Sauri, 2006). This is because the elderly people spend more time at home on gardening (Billings and Day, 1989), they use the bathroom more frequently for health reasons (Schleich and Hillenbrand, 2009), and they prefer baths to showers (Schlomann et al., 2004). These reasons are unlikely to be relevant regarding China because owning a single family home with a bath or garden, which is common in Germany or Spain, is uncommon in China. In fact, the elderly people in China are more aware of water conservation than younger people, and they use water-conservative appliances and have better water conservation habits. One plausible explanation for higher water consumption due to an aging society may be the increasing access to safe drinking water among the rural elderly population. In the past two decades, Chinese government has been focusing on providing and improving drinking water supply services in rural areas. Chen and Zhang (2008) report that 32% of villages implemented drinking water improvement projects between 1997 and 2003, and the rural drinking water improvement thus increased fresh water consumption. By 2010, safe drinking water source has reached 86% of rural population (China UN, 2012). On the other hand, the number of elderly residents in the rural population is higher in comparison with the number of elderly residents in urban areas (Cai et al., 2012, as shown in Figure 4). Therefore, the increase of elderly water users in rural areas is responsible for the impact of the aging society on RFWD.

Figure 4: Comparison of Aged Population Proportions in Rural and Urban Areas.



Source: Cai et al. (2012) adapted from NBS (2008)

The fresh water resource endowment, which is the total amount of available fresh water in a region, has a significant positive impact on RFWD in the OLS estimation but not in the FE estimation as it correlates with the unobserved heterogeneity. For example, the people in Guangxi consume more fresh water on average than the people in Gansu due to the rich fresh water resource endowment.

The industrial sewage water discharge correlates with RFWD significantly in the OLS model but not in the FE model because these factors also correlate with the regional heterogeneity, such as the heterogeneous economic development and implementation of environmental policies among provinces. Surprisingly, the sign of the temperature coefficient in the OLS model is significantly positive at a 5% level and in the FE model is significantly negative at a 5% level, so the impact of the climate on RFDW is not included in this study. Because this study only adapts the temperatures of capital cities, further studies should be conducted with a more thorough temperature dataset.

4 The impact of urbanization on RFWD

Urbanization fuels economic growth in China. Despite the important role of urbanization in development, there is no universal measurement to assess the urbanization process for various reasons, such as a restrict citizenship registration system, a large number of temporal migrants, and complex definitions of urban areas. In this paper, we adjust the urbanization ratio in order to assess the urbanization level accurately, and we discuss two other measurements: non-agricultural population ratio and non-agricultural employment ratio.

In principle, we can assess the urbanization level via the share of urban population in the total population; however, the definitions of urban areas are inconsistent in Chinese population statistics, which leads to inconsistent urbanization measurements. To account for the inconsistency, we use the method proposed by Shen[4] (2005) to correct the urbanization ratios (Bao, 2013, pp.89-129).

The share of registered non-agricultural population of the total population serves as another measurement of urbanization level. Nevertheless, the registration system in China does not accurately reflect the actual residential status of the urban population and may bias the estimation. The citizenship registration system in China, called *hukou*, was first implemented in 1958. Since then, all Chinese citizens are registered as either agricultural or non-agricultural *hukou*. As the economy developed, more rural laborers migrated to urban areas, but they cannot be classified as urban *hukou* even if they have lived in urban areas for several years because of the restrictions of urban citizenship[5], and urban *hukou* has a better access to employment, social welfare, and education (Cai et al., 2009). For many of rural laborers who live in the cities temporarily and return to their hometowns to reunite with their families, they are not registered as non-agricultural citizens because they fear that they may lose the farmland in their hometown, which serves as their social safety net (Zhao, 2002; Carter and Yao, 2002). This means that the estimated non-agricultural citizens underrate the urbanization process, in another word, it cannot reflect the actual urbanization effect on RFWD, and we should be cautious in interpreting the urbanization effect using this measurement.

Urbanization is associated with the massive economic shift from agriculture to non-agriculture. Therefore, the total number of laborers employed by non-agricultural sector may provide a better understanding of the urbanization effect on RFWD. Because not all people who are involved in non-agricultural employment must move to cities, non-agricultural employment may have less of an impact on the RFWD in comparison with urbanization when they have access to other water sources such as private wells, rivers etc. In the following section, we estimate all three measurements separately and discuss the estimation results accordingly.

A description of the urbanization ratios for each region in the past 12 years is shown in Figure 5. In all regions, urbanization exhibits two distinguished patterns. Some economically advanced regions, such as the Beijing, Shanghai, Tianjin and Guangdong Provinces, have reached their urbanization peaks and entered a suburbanization period. All other provinces have experienced a period of rapid urbanization in the past decade. In general, the non-agricultural employment ratios have been increasing in all provinces, while the registered non-agricultural population ratios have not been changing much in the past decade, as revealed in Figure 5.

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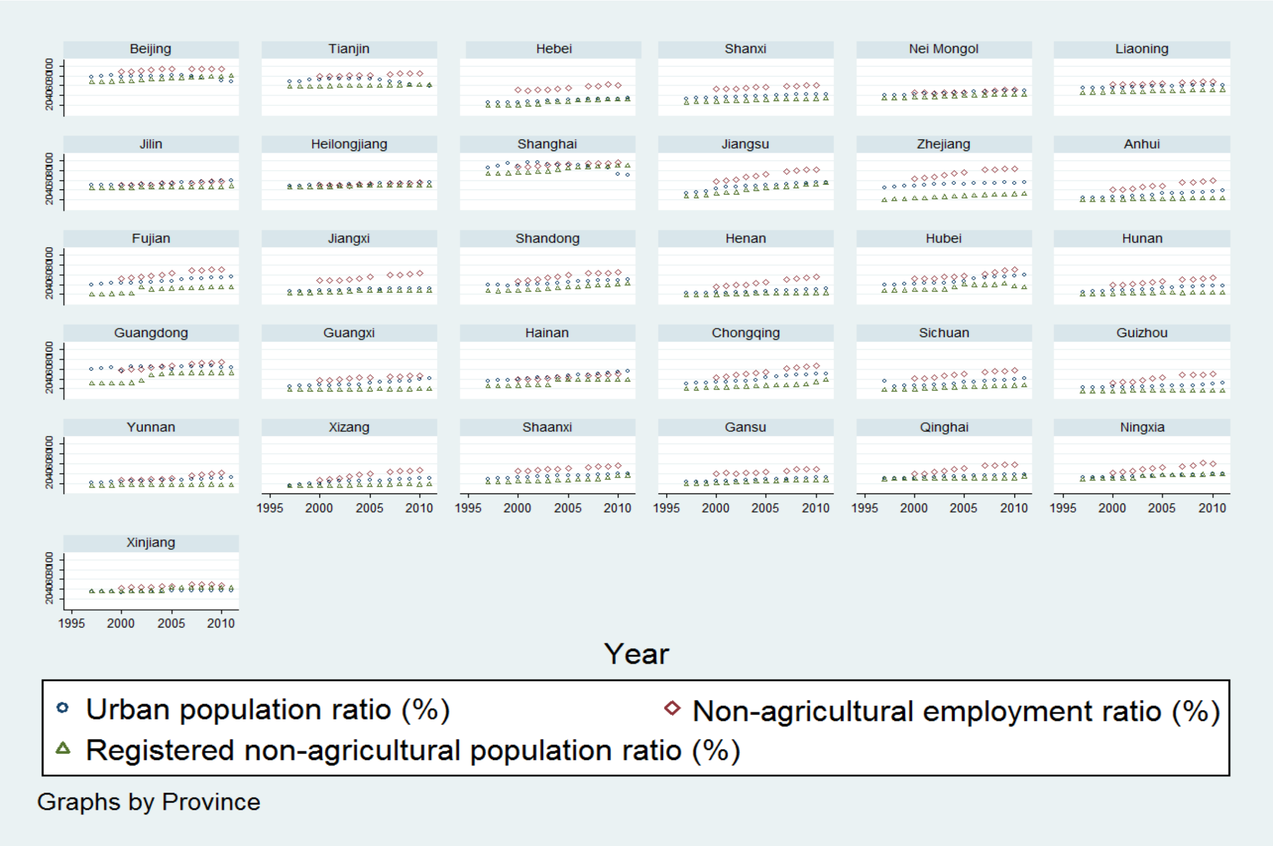
[4] The principle of the adjustment is to use the national surveys as a reference and to adjust the non-agricultural population correspondingly. The urbanization is adjusted as following: First, transform the urban population data to the date of national surveys in 1982, 2000 and 2010; second, calculate the growth rate of non-agricultural population from 1982 to 2000 and from 2001 to 2010; then, estimate the urban population according to the growth rate based on the national surveys in 1982, 2000 and 2010; at last, calculate the urbanization ratios according to the adjusted urban population and total population (Bao, 2013, pp.89-129).

[5] Although the restrictions have been lifted gradually in some small and medium cities in recent years and in pilot cities such as Chengdu (Cheng and Zheng, 2013, pp. 173-189), a general constraint on a voluntary shift from rural to urban *hukou* is remained in China.

Figure 5: Description of urban population ratio, registered non-agricultural population ratio and non-agricultural employment ratio.



Sources: The China Statistical Yearbook (2001-2012), the China Population and Employment Statistical Yearbook (2000-2011), and Shen (2005).

We estimate the urbanization effects on RFWD in three measurements, and the results are presented as Model 1, Model 2, and Model 3. The results reveal that the urbanization indeed gives rise to RFWD and that it is statistically significant at a 1% level in both the OLS and the FE estimates. In the OLS, both the urbanization ratio and the registered non-agricultural population ratio have positive impacts on RFWD in Model 1 and Model 2, and the non-agricultural employment ratio has no impact on RFWD in Model 3. Once we consider the unobserved heterogeneity among the regions, the coefficient of the urbanization ratio becomes higher; therefore, the OLS underestimates the effect of urbanization. The average urbanization ratio of all 31 provinces for the past 12 years is 43.81% (see Appendix 1). In Table 2, a 1% increase of urbanization ratio gives rise to fresh water consumption per capita by 0.97%, *ceteris paribus*. If the average urbanization ratio reaches 60%, the average residential fresh water consumption will increase to 198 liter per capita per day[6].

The registered non-agricultural population ratio also has a positive relationship with RFWD in the OLS model; however, this positive relationship is invalid once we account for the regional differences in the FE model. Because the non-agricultural population ratio depends on the initial urban development in a region and the regional migration policies to a large extent. Many migrants who are constrained by the *hukou* system have difficulty registering as a member of the non-agricultural population, even though they work and live in urban areas. In recent years, some regions have attempted to alleviate *hukou* constraints and eliminate the distinction between rural and urban *hukous*. In spite of the clarity of the policy, the implementation of the policy varies from one region to another. Consequently, regional migration policy plays a more important role in the non-agricultural *hukou* registration, and the non-agricultural population ratio becomes insignificant once

[6] Calculation process: 60%/43.81%*0.97*149.31=198.35

we consider the unobserved regional heterogeneity. Interestingly, the non-agricultural employment ratio does not have a significant impact on RFWD in the OLS model but does have a significant positive impact once the unobserved regional heterogeneity is accounted for in the FE model. A 1% increase of non-agricultural employment ratio leads to an RFWD increase by 0.6%, *ceteris paribus*. The impact of non-agricultural employment on RFWD is lower than that of urbanization, and the difference between the two factors is largely attributed to rural-urban migration.

In the robust test of our empirical estimates, the primary challenge was determining whether/how the omission of the residential water prices influenced our estimates. As discussed previously, the residential water prices cannot be considered in the model due to lack of data. Yang et al. (2003) analyzed the price of water in agricultural water use and argued that pricing alone was not a valid means of encouraging water conservation. If the price of water had no impact on consumers, our analysis of the impact of urbanization is valid. The price of residential water has increased in the past years (Zhang, 2012). If the increase of water price decreases the amount of water consumption as indicated by previous studies (Schleich and Hillenbrand, 2009; Garcia and Reynaud, 2003; Gaudin, 2006; Nauges and Thomas, 2003; Martinez-Espineira and Nauges, 2004; Ruijs et al., 2008; Arbues et al., 2004; and Martinez-Espineira, 2002), the impact of water price on RFWD should be negative. This means that the impacts of household income, aging society, and urbanization would be higher if residential water prices were included. Thus, our estimates serve as a lower bound of the impact of urbanization, in another word, the impact of urbanization would be larger if we included the price of water in the models.

5 Conclusion

The surge of RFWD has induced great concern over China's water shortages and understanding the driving forces of RFWD is critical in its water supply. Despite the importance of understanding the drivers of the dynamic RFWD, few studies have examined the causes of China's RFWD dynamics. The purpose of this study is to fill this gap by investigating the driving forces of RFWD in China and exploring the impact of urbanization on RFWD.

Based on a panel dataset from 31 Chinese provinces from 2000 to 2011, we estimated the determinants of fresh water demand using Fixed Effects (FE) models. Our empirical results indicate that household income and aging society contribute to fresh water demand. We used the urban population ratio to estimate the impact of urbanization on RFWD, and also discussed the impacts of the non-agricultural population and the non-agricultural employment ratios on RFWD. The results show that both the urban population ratio and the non-agricultural employment ratio have significant positive impacts on RFWD; the non-agricultural population ratio does not influence RFWD significantly because it does not accurately reflect the actual urban residential status. Hence the positive impact of urbanization on RFWD is evidenced.

The surge of fresh water demand that is jointly driven by the increases of household income, aging society and urbanization thus poses a great challenge to fresh water supply and sustainable development in China. On the other hand, a number of rural residents still have difficulty to access to fresh drinking water, which calls for improving the water supply services in rural areas. The Chinese government should consider the dynamics of socio-economic conditions and urbanization in reforming water and urban development policies towards more inclusive and sustainable. Our results show that the impact of non-agricultural employment on RFWD is much lower than the impact of urbanization. This implies that China can reduce water shortages in cities by developing more non-agricultural job opportunities in rural areas and integrating rural-urban development.

A 1% increase of urbanization ratio gives rise to fresh water consumption per capita by 0.97%, *ceteris paribus*. If the average urbanization ratio reaches 60%, the average residential fresh water consumption will increase to 198 liter per capita per day, which is more than 60% of the water consumption level of European countries (120-130 liters per capita per day, Aquaterra, 2008). By 2013, two thirds of Chinese cities lack fresh water resources. If the fresh water demand continues to increase, how can Chinese cities afford further urbanization? It is a high time for the Chinese government to incorporate water conservation policies into Eco-city and sustainable development policies. A systematic water conservation policy should be adopted in China to improve the efficiency of domestic water use and to encourage household water conservation. Future studies should focus on exploring policy instruments that can improve the efficiency of domestic water consumption.

Tab 1 Multiple regression results

	Model 1	Model 2	Model 3
Household dispensable annual income (1997 Yuan)	0.76***	0.76***	0.92***
	(0.08)	(0.07)	(0.10)
Car possession (per 100 households)	-0.01	-0.01	0.002
	(0.02)	(0.02)	(0.02)
Education level (senior school and above per 100 people)	0.28***	0.22***	0.41***
	(0.05)	(0.05)	(0.05)
Population more than 64 years old	0.11*	0.15**	0.19**
	(0.07)	(0.06)	(0.08)
Urban population ratio (%)	0.23***		
	(0.07)		
Registered non-agriculture population ratio (%)		0.26***	
		(0.05)	
Non-agriculture employment ratio (%)			-0.06
			(0.10)
Fresh water resource per capita (m^3/person)	0.19***	0.20***	0.19***
	(0.01)	(0.01)	(0.01)
Precipitation (mm in the year)	-0.01	-0.005	0.02
	(0.03)	(0.03)	(0.03)
Temperature (degree)	0.10**	0.14***	0.02
	(0.04)	(0.04)	(0.04)
Industrial sewage water (10 thousand tons)	-0.02*	-0.01	-0.02*
	(0.01)	(0.01)	(0.01)
Year trend	-0.06***	-0.06***	-0.08***
	(0.01)	(0.01)	(0.01)
Constant	112.17***	111.42***	146.29***
	(13.60)	(12.15)	(13.05)
Adjusted R^2	0.74	0.75	0.74
F value	106.38	111.07	86.90
Sample size	366	366	304

Note: All variables except for the year trend are in log form. *** indicates 1% significance level, ** indicates 5% significance level, and * indicates 10% significance level. Standard errors are in brackets.

Tab 2 FE model results

	Model 1	Model 2	Model 3
Household dispensable annual income (1997 yuan)	0.60*** (0.10)	0.55*** (0.11)	0.63*** (0.12)
Car possession (per 100 households)	-0.01 (0.01)	-0.002 (0.01)	-0.01 (0.01)
Education level (Senior school and above per 100 people)	-0.05 (0.04)	0.02 (0.04)	-0.02 (0.05)
Population more than 64 years old	0.15*** (0.05)	0.22*** (0.05)	0.17*** (0.06)
Urban population ratio (%)	0.97*** (0.14)		
Registered non-agriculture population ratio (%)		-0.06 (0.07)	
Non-agriculture employment ratio (%)			0.34*** (0.12)
Fresh water resource per capita (m3/person)	-0.01 (0.02)	-0.03 (0.02)	-0.02 (0.03)
Precipitation (mm in the year)	-0.02 (0.02)	-0.01 (0.03)	0.002 (0.03)
Temperature (degree)	-0.15** (0.08)	-0.17** (0.08)	-0.15* (0.09)
Industrial sewage water (10 thousand tons)	0.01 (0.02)	0.03 (0.02)	0.01 (0.03)
Year trend	-0.05*** (0.01)	-0.03*** (0.01)	-0.04*** (0.01)
Constant	96.28*** (18.02)	60.94*** (18.83)	86.67*** (22.02)
Adjusted R^2	0.52	0.45	0.44
F value	35.30	26.73	20.95
Sample size	366	366	304

Note: All variables except for the year trend are in log form. *** indicates 1% significance level, ** indicates 5% significance level, and * indicates 10% significance level. Standard errors are in brackets.

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Appendix 1: Data description

	Mean	Std. Dev.
Water consumption per capita (liter/person/day)	149.31	56.01
Water resource per capita (m3/person)	6309.81	25332.28
Household dispensable annual income (1997 yuan)	10712.81	4277.72
Education level (Senior school and above per 100 people)	0.21	0.09
Population more than 64 years old	8.51	1.91
Car possession (per 100 households)	5.34	6.70
Industrial sewage water (10 thousand tons)	73057.99	64042.91
Temperature (degree)	14.22	5.05
Precipitation (mm in the year)	858.24	499.08
Registered non-agriculture population ratio (%)	34.54	16.10
Non-agriculture employment ratio (%)	55.86	15.11
Urban population ratio (%)	43.81	15.66

Source: China statistical yearbook (2001-2012), China statistical yearbook on environment (2001-2012), China labor statistical yearbook (2000-2011), China population and employment statistical yearbook (2000-2011).
Note: All the data except for non-agricultural employment ratio is from the year 2000 to 2011. The non-agricultural employment ratios in the years 2006 and 2011 are not available.

Appendix 2 FE model results

	FE Model	RE Model
Household dispensable annual income (1997 Yuan)	0.60*** (0.10)	0.54*** (0.09)
Car possession (per 100 households)	-0.01 (0.01)	-0.01 (0.01)
Education level (senior school and above per 100 people)	-0.05 (0.04)	-0.08* (0.04)
Population more than 64 years old	0.15*** (0.05)	-0.00 (0.05)
Urban population ratio (%)	0.97*** (0.14)	0.62*** (0.07)
Fresh water resource per capita (m^3/person)	-0.01 (0.02)	0.07*** (0.00)
Precipitation (mm in the year)	-0.02 (0.02)	-0.04 (0.02)
Temperature (degree)	-0.15** (0.08)	0.06** (0.02)
Industrial sewage water (10 thousand tons)	0.01 (0.02)	-0.01 (0.02)
Year trend	-0.05*** (0.01)	-0.03*** (0.01)
Constant	96.28*** (18.02)	61.46*** (14.92)
R^2	0.52	0.52
F value	35.30	51.54
Sample size	366	366
Hausman Test	P=0.0005	

Note: All variables except for the year trend are in log form. *** indicates 1% significance level, ** indicates 5% significance level, and * indicates 10% significance level. Standard errors are in brackets.

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