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# 本科生毕业论文

题 目 基于多源数据的家庭用水相关电器

特征分析及其对用水能耗的影响

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## 摘要

在城市水资源、能源资源持续的使用压力和“双碳目标”的约束下，水资源和能源的协同管理逐渐受到管理者的关注。相对于管制目标和路径已较为明确的工业、农业等集中源，居民家庭的能源与水消费情况分散且繁杂，需要摸清各家各户的情况才能设立更加细化的节能节水措施，而用水相关电器差异是各个家庭能源与水消费情况差异的重要原因。

本论文围绕家庭用水相关电器特征变化这一主题，使用网络爬虫、SQL 数据库等多源数据获取与处理技术，融合微观家庭社会调查、电器销售和特征数据，建立清洁、沐浴和烹饪行为的用水电器特征多源数据集（MWEA）；基于多源数据集和计量经济学模型，分析用水电器特征、家庭用水能耗情况和用水电器特征变化的宏观社会经济驱动因素，明确器具特征变化的趋势及其原因；基于蒙特卡洛模拟和敏感性分析，以清洁行为为例，量化电器特征变化对用水能耗的影响，为制定用水电器能效、销售和推广政策和家庭水—能协同管理政策提供理论支持。

研究结果表明：（1）2012-2019 年，中国家庭用水电器的发售和市场选择总体上呈朝用水能耗降低方向发展：清洁行为电器按销量加权的单个运行周期用水量逐年下降、能耗量先下降再上升；烹饪行为电器用水量轻微波动、能耗量逐年下降；沐浴行为电器燃气热水器平均能效等级先上升再下降，最后平稳，电热水器平均能效等级先上升，再逐渐平稳。（2）物价和人口因素会导致用水电器的用水能耗变化：地区物价和城镇化率的提升促进波轮洗衣机特征正向变化，而对滚筒洗衣机有抑制作用；人口增长率和成年人占比的提升会显著拉动对滚筒洗衣机特征的正向变化和波轮洗衣机的反向变化。二者变化方向的差异主要源于价格、市场销售量和售出电器的能效等级分布的不同。（3）家庭用水能耗受用水电器特征变化的影响，总效应为创造和替代两种效应的叠加：清洁行为电器更新率、能效标识普及率、更新年份的共同作用最高会带来 48.2%的用水能耗强度提升、9.8%的用水量下降，但会提升用水能耗量。2012 至 2019 年间沐浴、烹饪行为的用水能耗量逐渐减小，会降低用水能耗强度。据此提出政策建议：（1）动态调整能效和水效标准，划定电器特征的市场准入红线；（2）给予更多研发支持，对不同种类低用水能耗电器和不同购买人群给予不同程度和方式的补贴。

**关键词：**家庭用水电器；用水能耗；多源数据；固定效应；敏感性分析

**Characteristics of household water-use electric appliances and  
their impact on water-related energy consumption based on multi-  
source database**

**ABSTRACT**

Under continuous pressures of urban water and energy use, the synergistic management of water and energy is gradually attracting the attention of policymakers. Compared to the centralized sources such as industry and agriculture where control objectives and paths are clear, household water and energy consumptions are more scattered and complicated. To formulate more suitable conservation policies, it is vital to understand the situation of each household, where the differences in water-use electric appliances contribute significantly to the differences in water and energy consumption.

This thesis focuses on the changes in the characteristics of household water-use electric appliances and takes the amount and intensity of water-related energy consumption as the basic perspective. Multi-source data acquisition and processing techniques including web crawlers and SQL databases are firstly employed to integrate micro household social surveys, appliance sales and characteristics data and establish a multi-source dataset of characteristics of household water-using electrical appliances for cleaning, bathing and cooking behaviors (MWEA). Based on the multi-source dataset and econometric models, the trends of changes in appliance characteristics and their macro socio-economic drivers are analyzed and quantified; Using Monte Carlo simulation and sensitivity analysis, the impact of changes in appliance characteristics on water consumption are quantified by taking cleaning behavior as an example. The conclusions of this thesis may facilitate policy decisions on the synergistic management of household water and energy.

Results show that: (1) from 2012 to 2019, the characteristics of China's household water-using electric appliances develop towards energy and water saving directions: the water consumptions of cleaning appliances weighted by sales decrease year by year, and

the energy consumptions first decrease and then rise; the water consumptions of cooking appliances fluctuate slightly and the energy consumption decrease year by year; the average energy efficiency levels of gas water heaters (bathing appliances) first rise, then decrease and finally stabilize, and the average energy efficiency levels of electric water heaters rise first and then gradually smooth out. (2) Prices and population are the driving factors for the change of appliance characteristics. The increase in regional prices and urbanization rate promote positive changes in the characteristics of pulsator washing machines and have a suppressive effect on platen washing machines. And the increase in population growth rate and the percentage of adults significantly pull the positive changes in the characteristics of platen washing machines and the reverse changes in pulsator washing machines. The difference in the direction of changes between the two is mainly due to the difference in price, market sales and the distribution of energy efficiency levels of sold appliances. (3) The total amount and intensity of household water consumption is influenced by the characteristics of water-use electric appliances. The combined effect of the renewal rate of appliances for cleaning behavior, the penetration rate of energy-efficiency labels, and the year of renewal will bring the highest 48.2% increase in water consumption energy intensity and 9.8% decrease in water consumption. While it will increase the water consumption energy. The water consumption energy for bathing and cooking behavior will gradually decrease between 2012 and 2019, which will reduce the water consumption energy intensity. Accordingly, policy implications can be provided to relevant departments: (1) dynamically adjust energy and water efficiency standards and delineate the red line of market access for electrical appliance features; (2) give more R&D support to energy-saving and water-saving appliances, subsidize different kinds of energy-saving (water-saving) appliances and different purchasing groups in different degrees and ways.

**Keywords: Household Water-Use Electric Appliances; Water Consumption; Multi-Source Data; Fixed Effects; Sensitivity Analysis**

目 录

摘 要.....	I
ABSTRACT .....	II
第 1 章 绪论.....	1
1.1 研究背景 .....	1
1.1.1 能源与水稀缺且空间分布不均.....	1
1.1.2 城市和家庭是重要的能源与水消耗部门.....	2
1.1.3 家庭水能关系密切，有较大的研究需求和现实意义.....	3
1.1.4 家庭用水能耗总量与强度受电器特征影响显著.....	4
1.2 研究目标 .....	5
1.3 研究内容与技术路线 .....	5
1.3.1 研究内容.....	5
1.3.2 研究系统边界.....	6
1.3.3 研究方法与技术路线.....	7
第 2 章 文献综述.....	10
2.1 家庭用水能耗的研究现状 .....	10
2.1.1 家庭用水量与用水能耗总量.....	11
2.1.2 家庭用水量、用水能耗总量与强度的影响因素识别.....	12
2.1.3 电器特征因素变化的驱动因素识别.....	14
2.1.4 现有研究小结.....	15
2.2 家庭水能关系相关研究工具的综述 .....	16
2.2.1 水、能源微观消费数据收集.....	16
2.2.2 家庭能源与水消费量核算.....	17
2.2.3 数据融合与补充方式.....	18
2.2.4 现有研究小结.....	18
第 3 章 用水相关电器多源数据集（MWEA）构建 .....	19
3.1 数据集描述和数据获取方法 .....	19
3.2 多源数据融合与计算方法 .....	22
3.3 多源数据融合结果 .....	23
第 4 章 用水相关电器和家庭用水能耗特征.....	25

4.1 电器特征与家庭用水能耗情况 .....	25
4.1.1 电器销售量 .....	25
4.1.2 新发售电器的能耗与用水属性情况 .....	27
4.1.3 市场实际销售的电器能耗与用水属性情况 .....	30
4.1.4 家庭用水能耗总量与强度情况 .....	32
4.2 电器特征变化的驱动因素 .....	35
4.2.1 电器特征变化驱动因素的分析方法 .....	35
4.2.2 电器特征变化驱动因素的实证结果 .....	38
4.2.3 电器特征变化驱动因素的相关讨论 .....	40
4.3 本章小结 .....	41
第 5 章 用水相关电器特征对家庭用水能耗的影响 .....	42
5.1 电器特征对家庭用水行为能耗总量与强度的影响分析方法 .....	42
5.1.1 基于蒙特卡洛模拟的用水能耗不确定性分析方法 .....	42
5.1.2 基于敏感性分析的电器特征变化对用水能耗影响分析方法 .....	44
5.2 基于蒙特卡洛模拟的家庭用水能耗不确定性分析 .....	45
5.3 基于敏感性分析的电器特征对家庭用水能耗的影响量化 .....	48
5.3.1 基于概率分布的家庭用水能耗强度影响因素敏感性分析 .....	49
5.3.2 基于参数变动比率的电器因素影响程度分析 .....	50
5.2.3 关于家庭用水能耗强度影响因素的讨论 .....	56
5.4 本章小结 .....	58
第 6 章 结论与建议 .....	59
6.1 结论 .....	59
6.2 建议 .....	60
参考文献 .....	62
附录 A 家庭用水行为能耗总量与强度的核算方法与数据 .....	69
附 A.1 家庭用水行为能耗总量核算方法 .....	69
附 A.2 家庭用水行为能耗强度核算方法 .....	72
附 A.3 模型参数设定 .....	72
附录 B Python 爬虫代码 .....	75
附录 C SQL 数据融合与分类代码 .....	78
附录 D 家庭基本信息及用水行为描述性统计 .....	80

## 目 录

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附 D.1 家庭特征信息 .....	80
附 D.2 家庭用水行为 .....	81
附录 E 电器更新带来的单周期能耗、用水变化的时空差异分析 .....	85
附录 F 计量经济学模型统计学检验与稳健性检验结果 .....	93
致 谢 .....	97
个人简历、在学期间发表的学术论文与成果 .....	99