Short Thesis for the Degree of Doctor of Philosophy (PhD)

Regional level disparities and the driving forces of energy consumption and CO_2 emissions in the residential sector of Iran

By

Behnam Ata

Supervisor: Dr. János Pénzes

Doctoral School of Earth Sciences,
University of Debrecen
Debrecen, 2024

Introduction

Climate change, manifesting through events such as floods, heatwaves, forest fires, and droughts, has emerged as one of the most urgent global challenges due to its far-reaching effects on multiple sectors. The building sector, in particular, is significantly impacted by climate change, especially with regard to energy consumption. The rising consumption of fossil fuels in the household sector contributes to increased carbon dioxide (CO_2) emissions, which in turn accelerates the progression of climate change.

Inequality in access to fossil fuels globally contributes to disparities in energy consumption and, consequently, CO_2 emissions between countries. Iran, as a nation with abundant fossil fuel resources, provides a critical case for studying energy consumption patterns and dynamics in the household sector, which is one of the largest energy-consuming sectors in the country. Given Iran's geographical and climatic diversity, it is essential to explore household energy patterns across different regions. To address these disparities, it is crucial to assess inequality in energy consumption and CO_2 emissions across Iran's provinces, identifying the key factors and applying inequality indices to help reduce emissions and reform energy consumption at the provincial level (Ata et al., 2022).

The main factors contributing to the increasing trend in energy consumption are economic growth, averaging 5% over the last 40 years, population growth of around 2%, and the heavily subsidized energy markets, which burden the government with costs equivalent to about 12% of GDP (Mirzaei & Bekri, 2017). A report by the (Statistical Center of Iran, 2018) indicates that the per capita disposable income in Iran rose from USD 10 to USD 25 between 1990 and 2016. As disposable income grew, direct energy consumption in the country also increased by 51% (Statistical Center of Iran, 2018), climbing from 1.6588 GJ to 2.5058 GJ. Despite being a key member of the Organization of the Petroleum Exporting Countries (OPEC), Iran faces restrictions on exporting its oil and natural gas due to international sanctions. As a result of the country's easy access to energy resources, a significant portion of these resources is consumed domestically across various sectors of society (Mohammadnejad et al., 2011). In this context, energy consumption and CO_2 emissions in Iran have risen by 6.2 and 6.1 times, respectively, over the past six decades (Lotfalipour et al., 2010). In Iran, water heating and space heating dominate the set of fast-growing energy end uses among households (Barkhordar, 2019; Moshiri, 2015; Soltani et al., 2020). Moreover, cultural and traditional attitudes toward specific goods and behaviors can shape household energy consumption preferences in a country like Iran. These cultural values and traditions are typically passed down through generations and are ingrained in individuals over the course of their lives (Rahmani et al., 2020).

The uneven distribution of CO_2 emissions across countries presents a major obstacle in developing an inclusive global climate policy (Padilla & Serrano, 2006). Emissions continue to accumulate in the atmosphere, increasing the risks linked to climate change. Between early 2019 and late 2022, the global energy system was responsible for emitting more than 140 gigatons of carbon dioxide (Gt CO_2) (International Energy Agency, 2023).

Various factors contribute to global environmental degradation and warming, including economic and financial growth, energy consumption, and population growth (Ding et al., 2023). Energy plays a crucial role in sustaining economic development; however, factors like the increasing energy demand driven by global population growth pose significant challenges. This surge in demand leads to the rapid depletion of resources such as coal, natural gas, and oil, alongside rising energy costs. A lack of sufficient energy resources may hinder efforts to reduce poverty and accelerate development. Moreover, the combustion of fossil fuels, which generates greenhouse gas emissions, is a major contributor to global warming (Rehman et al., 2023).

While energy consumption and population levels have remained relatively steady in developed countries, developing nations like China, India, and Thailand have experienced significant growth in both areas over recent decades. Despite this, there is still a considerable gap in per capita energy consumption between developed and developing countries, reflecting a global inequality in energy use. This disparity may be influenced by factors such as embodied energy (Duan & Chen, 2018).

Energy inequality is viewed as a more effective indicator of disparity than income inequality because it encompasses the ongoing benefits derived from durable goods and services (Wu et al., 2017). A significant challenge in creating a climate-neutral society is the increasing disparity in access to energy. Achieving a future without climate impact is pressing, requiring a balance between advancement, technology, nature, human welfare, and personal development. Europe’s green agenda focuses on this transition, aligning with the commitments of the Paris Agreement. It recognizes the global urgency of tackling climate change and emphasizes the importance of reducing inequality to achieve Sustainable

Development Goals. Addressing energy imbalances and ensuring equitable access to clean energy are crucial for safeguarding well-being and enhancing quality of life for everyone (Volodzkiene & Streimikiene, 2023).

The findings of our research underscore the significance of energy inequality and the need for reforming current policies related to household energy consumption. Our results not only validate but also strengthen previous studies in this area. Through inequality and econometric analysis, we were able to identify key factors contributing to energy consumption inequality and the resulting increase in CO_2 emissions. Notably, we found that factors such as climate, subsidies, energy efficiency, and energy prices are the most influential in driving CO_2 emissions within the household sector of Iran. This emphasizes the critical importance of regional-level research to reduce both CO_2 emissions and inequality in the household sector, with new policies being developed in line with our findings. Iran's diverse climate and social factors contribute to varying patterns of energy consumption and CO_2 emissions across its provinces. The government's current strategies are insufficient to control and reduce CO_2 emissions in the household sector. Many buildings and devices still lack energy standards, and the cost of energy remains low. This results in unequal consumption between wealthier families and those from lower-income brackets. Additionally, larger buildings contribute to further inequality.

Therefore, it is essential to continue the energy subsidy reform in the coming years, while managing the economy to prevent high inflation as a result of rising energy prices.

Study area

Iran is the country with around 91 million population which located in western Asia. The country has a diverse topography that includes mountains, deserts, coasts and plateaus. The Zagros Mountains run from the northwest to the southeast, and the Alborz Mountains in the north host the highest peak, Mount Damavand (5,671 metres). The Dasht-e Kavir and Dasht-e Lut are major deserts located in the central and southeastern parts of the country. Iran has only two significant lowland regions, the Khuzestan Plain in the southwest and the coastal plain along the Caspian Sea in the north. Along the Persian Gulf, south of Khuzestan, and the Gulf of Oman, there are no true plains, as the Zagros Mountains extend directly to the coastline in these areas.

Iran is subdivided into twenty-eight provinces, each governed from a local centre, usually the largest local city, which is the capital of that province. In this context, the analysis of variables reveals several key regional disparities in Iran. First, employment rates and income levels are highest in industrial provinces such as Tehran, Mashhad, Isfahan, Markazi, West Azerbaijan, and Bushehr, whereas they are lowest in provinces like Sistan and Baluchestan, Chaharmahal and Bakhtiari, and Khuzestan. Second, provinces with higher urbanization rates tend to have better education levels, while those with lower urbanization, such as rural areas, have significantly lower education rates. Third, the number of buildings is much higher in populous provinces with higher population densities, such as Tehran, Khorasan, West Azerbaijan, and Isfahan, compared to provinces with smaller number of population. Fourth, household sizes are largest in provinces like Sistan, and Baluchestan, Ilam, and Kohgiluyeh and Boyer-Ahmad, likely due to cultural influences. In contrast, northern provinces and Tehran have the smallest household sizes. Fifth, climate is another critical factor, varying widely across regions. Southern provinces, including Khuzestan, Bushehr, and Hormozgan experience hot weather and low rainfall throughout the year, increasing electricity demand. However, much of Iran has four distinct seasons, with hot summers and cold winters. Some provinces, like Ardebil, Azerbaijan, Zanjan, Hamedan, Ilam, and Chaharmahal and Bakhtiari, face extremely cold winters and mild summers. The highest levels of precipitation are found in northern provinces like Mazandaran and Gilan, while central provinces such as Kerman, Yazd, and Sistan and Baluchestan receive very little rainfall.

Regions with higher populations and urbanization rates typically require more energy and thus produce higher CO_2 emissions, whereas provinces with limited infrastructure or more moderate climates tend to have lower energy demand.

One of the critical issues is regarding energy subsidy in Iran, which makes Iran the largest provider of energy subsidies worldwide (International Energy Agency, 2021). In 2019, the Iranian government spent approximately $86 billion on energy subsidies, with the power sector accounting for around 60% of the total, making it the largest contributor to global energy subsidy distribution. This significant level of subsidy has led to major techno-economic issues and environmental harm (Aryanpur et al., 2022). The aim of the subsidy reform plan is to replace food and energy subsidies, which make up 80% of the total, with targeted social assistance. This aligns with the Five Year Economic Development Plan and seeks to transition towards free market prices over a five-year period

(International Energy Agency, 2021). As a result of the economic reform plan, Iran will be less susceptible to US sanctions due to a decrease in fuel imports (Atieh Bahar, 2008).

Based on the study, the following key questions should be addressed:

- What are the regional disparities in CO_2 emissions and the consumption of various fuels in the residential sector across different provinces of Iran?
- How do climate, socioeconomic factors, and energy use influence CO_2 emissions among the provinces of Iran?
- What are the trends in energy consumption and CO_2 emissions at the regional level in Iran's residential sector?
- How effective are the current policies in addressing regional disparities in CO_2 emissions and energy consumption in Iran's residential sector?
- What lessons can be drawn from developed countries to help emerging economies reduce CO_2 emissions in their residential sectors?

Data and applied Methods

1. Data

The study's data comprises two sections. In the first section, Iran's provinces are categorized interested in four groups centered on income and population, following an ad hoc approach. The twenty-eight provinces of Iran are segmented into four categories based on the averages of factors such as oil and gas consumption, electricity consumption, CO_2 emissions, income, and population. These categories are classified as very low, below average, above average, and very high.

The data in the second phase of the research are separated into two primary groups: the independent variables, which are additionally subdivided into four categories: climatic, energy, economic, and societal aspects; and the dependent variable, which is CO_2 emissions (in tons). Precipitation (mm), and climate parameters are Heating Degree Days (°C), and Cooling Degree Days (°C). The variables in the energy sub-group include the following: the amount of oil consumed (in thousand liters), the amount of natural gas consumed (in m^3), the amount of electricity consumed (in kWh), and the corresponding costs (in rials per liter, m^3, and kWh). The fuel group's consumer price index, which is indexed at 100 for 2016 as the base year, is used to alter these energy costs.

2. Inequality methods

Inequality models are frameworks or mathematical representations used to study and understand disparities in the distribution of income, wealth, resources, or opportunities within a society or between different groups. These models help researchers and policymakers assess the extent of inequality and identify its causes and potential solutions. There are several types of inequality models, each focusing on different aspects of inequality.

3. Theil index

The Gini coefficient is a macroeconomic statistic that reflects the degree of societal inequality in the distribution of certain resources. In contrast, the Theil index is scale-invariant, meaning it is not influenced by changes in value over time. Additionally, the Theil index adheres to the decomposability principle, allowing inequality to be divided into components representing disparities within groups and between groups (Tutberidze et al., 2018). The Theil index is a highly respected measure of inequality that has garnered significant interest from researchers. Although there are multiple tools for evaluating inequality, the Theil index, introduced in 1967, has consistently been one of the foremost methods in this area of study.

4. Kaya Factor

The "Kaya identity" model provides a simple mathematical formula that integrates environmental, economic, and demographic factors to estimate CO_2 emissions generated by human activities. This model offers a practical and efficient way to quantitatively evaluate how different key factors impact shifts in emissions or energy consumption.

5. Trend analysis

The Mann-Kendall (MK) test, along with Sen's Slope estimator, is employed to detect trends in time series data which developed by (Mann, 1945). The Mann-Kendall (MK) test is a nonparametric method, making it robust against outliers and well-suited for identifying trends in data series. In this test, the null hypothesis (H0) suggests that no trend is present in the series, while the alternative hypothesis (Ha) asserts that a trend does exist.

6. Econometric models

Econometric models, especially those using panel and cross-sectional data analysis techniques, are commonly employed to investigate how energy consumption and household socioeconomic characteristics affect CO_2 emissions techniques (Bai et al., 2019; Chen & Jiang, 2022; Chun-sheng et al., 2012; Donglan et al., 2010; Imran et al., 2022; Karpinska & Śmiech, 2022; Li et al., 2020; Meangbua et al., 2019; Miao, 2017; Miao, Gu, Zhang, Zhen, & 2019, 2019; Miao, Gu, Zhang, Zhen, & Wang, 2019; Wang & Zhao, 2018).

7. Static Estimation Models

Static panel regression methods include Fixed Effect (FE), Random Effect (RE), and Pooled (PLS) models. Pooled regression assumes a single intercept for all units, while FE and RE models account for heterogeneity differently. The FE model allows the intercept to vary across individuals or groups, useful with large sample sizes and short time spans. The RE model, on the other hand, treats individual-specific effects as random variables not correlated with the independent variables (Ata et al., 2023).

8. Dynamic Estimation Models

In economics, dynamic panel data methods are highly valuable, particularly in energy and environmental research. Unlike static models, dynamic panel data estimators offer several benefits, including the capacity to manage individual heterogeneity and the use of multiple instrumental variables to resolve endogeneity problems (Ata et al., 2023). The System Generalized Method of Moments (GMM) and the Difference

GMM estimator are two commonly used dynamic models. The Difference GMM estimator relies on lags of the differences as instruments, while the System GMM estimator uses both lags of differences and levels as instruments (Arellano & Bond, 1991; Arellano & Bover, 1995).

Thesis 1

Inequality in energy consumption, regarding oil, gas, representing increasing trend in household sector of Iran. Meanwhile, electricity consumption and CO_2 emissions in the household sector shows a decreasing trend for all during the study period.

The results of the Theil index indicate an increasing trend in inequality of oil consumption from 2001 to 2017, particularly marked between 2010 and 2016. The Theil index value with income weighting was 0.40 in 2001 and rose to 0.65 by 2017 (Figure 1). Additionally, the analysis shows that the share of inequality within groups was greater than that between groups, indicating that the disparities within the groups were more significant than those between different groups.

The results regarding inequality in gas consumption reveal that the trend remained stable until 2010. However, following that year, the rise in gas consumption in the household sector contributed to an increase in inequality. The Theil index values were consistent at 0.22 from 2001 to 2017 (Figure 2). Until 2010, the majority of inequality existed within groups, but after 2010, the proportion of inequality between groups began to rise.

According to Theil analysis, the inequality in electricity use showed fluctuations over the study period, with a Theil index value of 0.17 in 2001, decreasing slightly to 0.15 in 2017.

Throughout this period, within-group inequality was the predominant factor (Figure 3). In terms of CO_2 emissions inequality in Iran's household sector, there was a declining trend from 2001 to 2017, with within-group inequality remaining the most significant. The Theil index for CO_2 emissions was 0.22 in 2001 and decreased to 0.14 by 2017 (Figure 4).

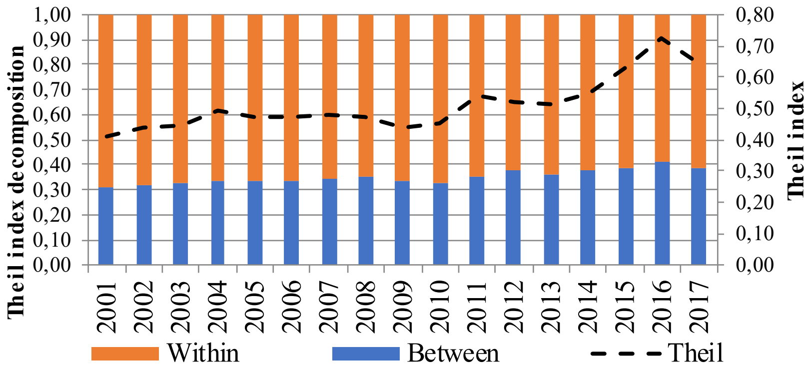

Figure 1. Income-weighted Theil Index for Petroleum Products. (Created by author)

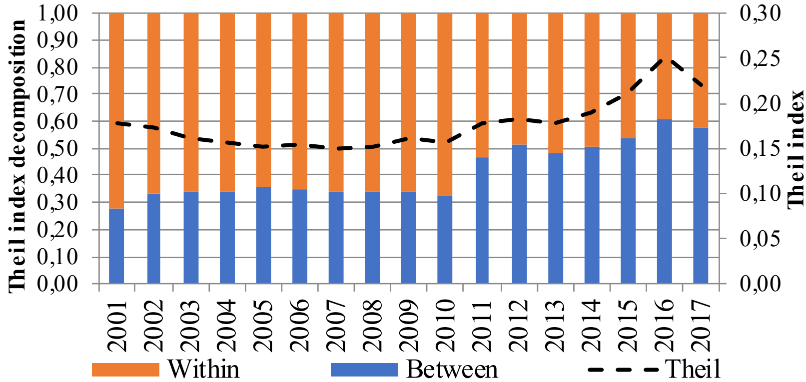

Figure 2. Population-weighted Theil Index for Natural Gas. (Created by author)

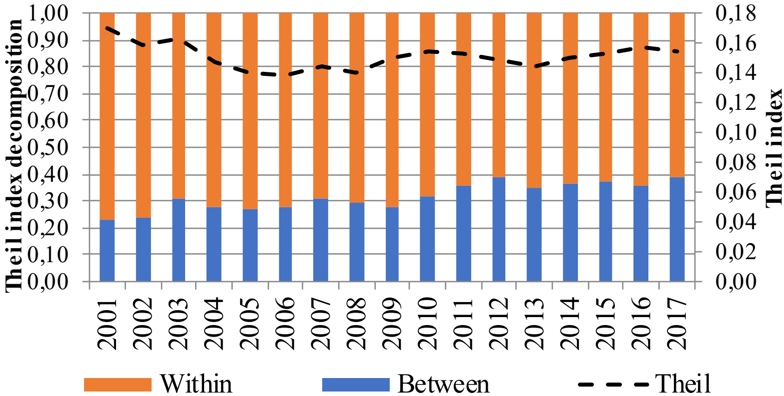

Figure 3. Population-weighted Theil Index for Electricity.
(Created by author)

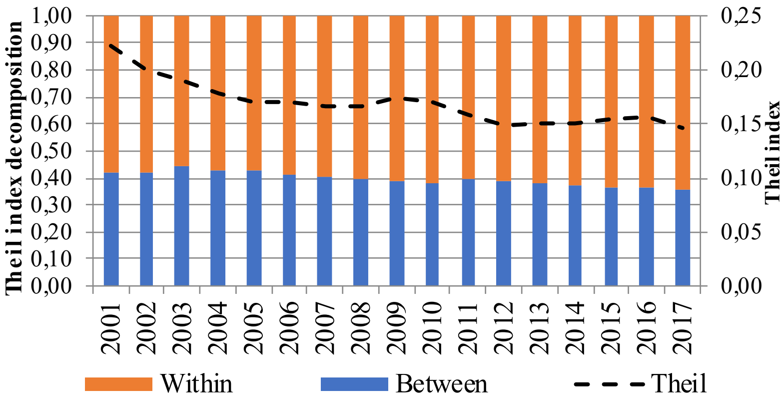

Figure 4. Population-weighted Theil Index for CO_2 Emissions.
(Created by author)

Thesis 2

The analysis identified energy efficiency (performance) as the primary factor contributing to the increasing disparity in CO_2 emissions).

The Theil indexes were recalculated using the Kaya factors. The results indicate that T beta is the most significant factor affecting CO_2 emissions inequality. T beta reflects energy efficiency (performance) (Figure 5), revealing that the devices and technology utilized in the household sector of Iran have very low-performance levels. Additionally, carbon intensity has shown an increasing trend over the study period, indicating the continued use of fossil fuels among Iranian households. In contrast, income per capita has remained stable throughout the study period according to the Kaya factor analysis.

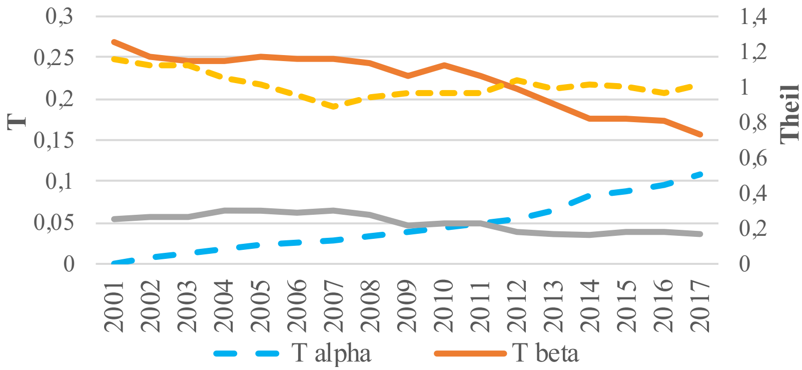

Figure 5. Analysis of CO_2 emissions through the lens of Kaya factors. (Created by author)

Thesis 3

According to both static and dynamic models, climate factors such as Heating Degree Days (HDD), Cooling Degree Days (CDD), and precipitation cause increase in household CO_2 emissions.

According to the static results, a 1 percent increase in Heating Degree Days (HDD), Cooling Degree Days (CDD), and precipitation positively affects household CO_2 emissions, with elasticities of 0.024%, 0.004%, and 0.011%, respectively (Table 1). Similarly, the System GMM results also indicate positive effects of climate factors, consistent with the static model, but with slight variations in elasticities: 0.046 for HDD, 0.038 for CDD, and 0.007 for precipitation (Table 2). Therefore, an increase in Heating Degree Days (HDD) and Cooling Degree Days (CDD) results in a higher demand for energy for heating and cooling, which varies among the provinces of Iran. Additionally, precipitation also tends to raise household CO_2 emissions, reflecting an overall increase in energy demand.

Table 1. Results of the FGLS estimation. (Created by author)

Variables	Coefficients	Std. Dev.	P-value
Log t1	0.024^{***}	0.007	0.00
Log t2	0.004^{**}	0.002	0.03
Log pr	0.011^{***}	0.003	0.00

Table 2. System GMM results. (Created by author)

Variables	Coefficients	Std. Dev.	P-value
Log t1	0.038^{***}	0.008	0.00
Log t2	0.007^{***}	0.002	0.00
Log pr	0.015^{***}	0.003	0.00

Thesis 4

The results confirm previous research which consumption of oil and gas contributed to an increase in CO_2 emissions in the household sector of Iran from 2001 to 2019.

Oil and gas are the two primary sources of fossil fuels most commonly used in Iran's household sector. According to our static analysis results, a 1 percent increase in oil and gas consumption results in a rise of 0.026 percent and 0.044 percent in CO_2 emissions, respectively (Table 3). However, the dynamic analysis shows slightly more significant effects, with a 1 percent increase in oil and gas leading to increases of 0.023 percent and 0.89 percent in CO_2 emissions (Table 4). Therefore, fossil fuels are the main contributors to the rise in CO_2 emissions in Iran's household sector.

Table 3. Results of the FGLS estimation. (Created by author)

Variables	Coefficients	Std. Dev.	P-value
Log oil	0.026***	0.004	0.00
Log gas	0.044***	0.003	0.00

Table 4. System GMM results. (Created by author)

Variables	Coefficients	Std. Dev.	P-value
Log oil	0.023***	0.006	0.00
Log gas	0.89***	0.016	0.00

Thesis 5

The results indicate that social parameters influence household CO_2 emissions in two ways: some factors have a positive effect, while others exhibit a negative effect.

According to static results, household income, size of household, and also building stocks have positive effect on household CO_2 emissions which 1 percent increase in each of them lead to increase 0.011, 0.11 and 0.014 percent household CO_2 emissions (Table 5). The dynamic results for household income and building stock with elasticities 0.049 and 0.019 percent cause increase of household CO_2 emissions (Table 6).

Social variables that have a negative impact on household CO_2 emissions include the education rate, household employment rate, and urbanization rate. This underscores the importance of awareness and employment in reducing CO_2 emissions within the household sector.

Table 5. Results of the FGLS estimation. (Created by author)

Variables	Coefficients	Std. Dev.	P-value
Log i	0.011**	0.006	0.05
Log s	0.11***	0.015	0.00
Log e	-0.428***	0.030	0.00
Log em	-0.022**	0.011	0.05
Log b	0.014***	0.005	0.00
Log u	-0.067***	0.019	0.00

Table 6. System GMM results (Created by author)

Variables	Coefficients	Std. Dev.	P-value
Log i	0.049***	0.006	0.00
Log s	0.17	0.14	0.21
Log e	-0.38***	0.19	0.00
Log em	-0.064**	0.033	0.05
Log b	0.019***	0.004	0.00
Log u	-0.38	0.44	0.38

Thesis 6

The results indicate that fossil fuels prices include oil, gas, electricity consumption and electricity prices have a negative effect on household CO_2 emissions across the provinces of Iran.

Both the static and dynamic models demonstrate a negative effect of prices and electricity use on household CO_2 emissions. According to the static model, a 1 percent increase in oil and natural gas prices tends to result in a decrease of 0.15 percent and 0.026 percent in household CO_2 emissions, respectively (Table 7). In contrast, the dynamic model shows that a 1 percent increase in oil and gas prices leads to a reduction of 0.10 percent and 0.074 percent in household CO_2 emissions (Table 8). Therefore, implementing strategies to control and raise fossil fuel prices will significantly reduce household CO_2 emissions in Iran.

Consequently, electricity has a negative impact on household CO_2 emissions, highlighting the importance of transitioning to more sustainable energy sources to mitigate CO_2 emissions. Both the static and dynamic models indicate that electricity prices negatively affect household CO_2 emissions (Table 7 and

8). However, regarding electricity consumption, only the static model demonstrates a significant negative effect (Table 7), while the results from the dynamic model are not statistically significant.

Table 7. Results of the FGLS estimation (Created by author)

Variables	Coefficients	Std. Dev.	P-value
Log elec	-0.09***	0.012	0.00
Log op	-0.15***	0.026	0.00
Log gp	-0.026**	0.013	0.04
Log ep	-0.038	0.030	0.20

Table 8. System GMM results. (Created by author)

Variables	Coefficients	Std. Dev.	P-value
Log elec.	-0.07***	0.016	0.78
Log op	-0.10***	0.030	0.00
Log gp	-0.074***	0.006	0.00
Log ep	-0.15***	0.032	0.00

Thesis 7

Based on the analysis, the energy subsidy reform plan has led to increased inequality among different fuels and the subsidy reform plan, based on both static and dynamic analyses, has a negative impact on household CO_2 emissions.

The results from the Theil index indicate a rise in inequality for oil, gas, and electricity following the implementation of the subsidy reform in 2010 (Figures 1 to 4). Although the subsidy reform plan initially resulted in a significant reduction in energy consumption within Iran's household sector, it also led to increased inequality. Subsequently, energy consumption began to rise again. However, subsidy reform plan lead to decrease consumption among low income households and on the other side for above average and high income households did not effect to decrease which makes increase inequality during subsidy reform plans.

The dummy variable used to represent the subsidy reform plan over a year indicates a negative effect on household CO_2 emissions. Specifically, in both static and dynamic models (Table 9 and 10), the dummy variable results in a 0.31 percent reduction in household CO_2 emissions. Consequently, implementing the subsidy reform plan offers significant benefits in managing energy consumption and reducing household CO_2 emissions.

Our research has provided valuable insights that can be useful for policymakers in mitigating CO_2 emissions and enhancing energy efficiency in Iran's household sector. Given the various challenges in the energy sector, such as subsidies, sanctions, economic development, and a growing population, it is essential to study energy consumption patterns and CO_2 emissions across the country to achieve sustainable energy development. However, several emerging issues, including recent developments in subsidies, inflation, bitcoin mining, energy transitions, and building standards, underscore the need for further research to deeply investigate trends and energy efficiency, especially in the context of climate change.

Table 9. Results of the FGLS estimation. (Created by author)

Variables	Coefficients	Std. Dev.	P-value
d	-0.31***	0.022	0.00

Table 10. System GMM results. (Created by author)

Variables	Coefficients	Std. Dev.	P-value
d	-0.31***	0.04	0.00

References

1. Arellano, M., & Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *The Review of Economic Studies*, *58*(2), 277–297. https://doi.org/10.2307/2297968
2. Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics*, *68*(1), 29–51. https://doi.org/10.1016/0304-4076(94)01642-D
3. Aryanpur, V., Ghahremani, M., Mamipour, S., Fattahi, M., Ó Gallachóir, B., Bazilian, M. D., & Glynn, J. (2022). Ex-post analysis of energy subsidy removal through integrated energy systems modelling. *Renewable and Sustainable Energy Reviews*, *158*. https://doi.org/10.1016/j.rser.2022.112116
4. Ata, B., Pakrooh, P., & Pénzes, J. (2023). Driving factors of energy related CO2 emissions at a regional level in the residential sector of Iran. *Scientific Reports*, *13*(1). https://doi.org/10.1038/s41598-023-44975-x
5. Atieh Bahar. (2008, October 20). *Resources - Economic Indicators.* Https://Web.Archive.Org/Web/20110513034614/Http://Www.Atiehbahar.Com/Resource.Aspx?N=1000039.
6. Bai, Y., Deng, X., Gibson, J., Zhao, Z., & Xu, H. (2019). How does urbanization affect residential CO2 emissions? An analysis on urban agglomerations of China. *Journal of Cleaner Production*, *209*, 876–885. https://doi.org/10.1016/J.JCLEPRO.2018.10.248
7. Chen, Y., & Jiang, L. (2022). Influencing Factors of Direct Carbon Emissions of Households in Urban Villages in Guangzhou, China. *International Journal of Environmental Research and Public Health*, *19*(24). https://doi.org/10.3390/IJERPH192417054
8. Chun-sheng, Z., Shu-wen, N., & Xin, Z. (2012). Effects of household energy consumption on environment and its influence factors in rural and urban areas. *Energy Procedia*, *14*, 805–811. https://doi.org/10.1016/J.EGYPRO.2011.12.1015
9. Ding, Q., Xiao, X., & Kong, D. (2023). Estimating energy-related CO2 emissions using a novel multivariable fuzzy grey model with

time-delay and interaction effect characteristics. *Energy*, *263*. https://doi.org/10.1016/j.energy.2022.126005
10. Donglan, Z., Dequn, Z., & Peng, Z. (2010). Driving forces of residential CO2 emissions in urban and rural China: An index decomposition analysis. *Energy Policy*, *38*(7), 3377–3383. https://doi.org/10.1016/J.ENPOL.2010.02.011
11. Duan, C., & Chen, B. (2018). Analysis of global energy consumption inequality by using Lorenz curve. *Energy Procedia*, *152*, 750–755. https://doi.org/10.1016/j.egypro.2018.09.240
12. Tutberidze, G., Qetevan P., & Rakviashvili, G. (2018). The measuring of the Gini, Theil and Atkinson indices for Georgia Republic and some other countries. *Globalization and Business*, 110–118. https://doi.org/10.35945/gb.2018.05.016
13. Imran, M., Zahid, A., Mouneer, S., Özçatalbaş, O., Haq, S. U., Shahbaz, P., Muzammil, M., & Murtaza, M. R. (2022). Relationship between Household Dynamics, Biomass Consumption, and Carbon Emissions in Pakistan. *Sustainability 2022, Vol. 14, Page 6762*, *14*(11), 6762. https://doi.org/10.3390/SU14116762
14. International Energy Agency. (2021, July). *Energy subsidies: Tracking the impact of fossil fuel subsidies*. Https://Www.Iea.Org/Topics/Ene Rgy-Subsidies.
15. International Energy Agency. (2023). *World Energy Outlook 2023*. www.iea.org/terms
16. Karpinska, L., & Śmiech, S. (2022). Shadow of single-family homes: Analysis of the determinants of Polish households' energy-related CO2 emissions. *Energy and Buildings*, *277*, 112550. https://doi.org/10.1016/J.ENBUILD.2022.112550
17. Li, Q., Wu, S., Lei, Y., & Li, S. (2020). Dynamic features and driving forces of indirect CO2 emissions from Chinese household: A comparative and mitigation strategies analysis. *Science of The Total Environment*, *704*, 135367. https://doi.org/10.1016/J.SCITOTENV.2019.135367
18. Mann, H. B. (1945). *Nonparametric Tests Against Trend* (Vol. 13, Issue 3). https://www.jstor.org/stable/1907187
19. Meangbua, O., Dhakal, S., & Kuwornu, J. K. M. (2019). Factors influencing energy requirements and CO2 emissions of households in Thailand: A panel data analysis. *Energy Policy*, *129*, 521–531. https://doi.org/10.1016/J.ENPOL.2019.02.050

20. Miao, L. (2017). Examining the impact factors of urban residential energy consumption and CO2 emissions in China – Evidence from city-level data. *Ecological Indicators*, *73*, 29–37. https://doi.org/10.1016/J.ECOLIND.2016.09.031
21. Miao, L., Gu, H., Zhang, X., Zhen, W., & 2019. (2019). Factors causing regional differences in China's residential CO2 emissions—evidence from provincial data. *Elsevier*. https://www.sciencedirect.com/science/article/pii/S0959652619309813
22. Miao, L., Gu, H., Zhang, X., Zhen, W., & Wang, M. (2019). Factors causing regional differences in China's residential CO 2 emissions—evidence from provincial data. *Journal of Cleaner Production*, *224*, 852–863. https://doi.org/10.1016/j.jclepro.2019.03.271
23. Padilla, E., & Serrano, A. (2006). Inequality in CO2 emissions across countries and its relationship with income inequality: A distributive approach. *Energy Policy*, *34*(14), 1762–1772. https://doi.org/10.1016/j.enpol.2004.12.014
24. Rehman, A., Alam, M. M., Ozturk, I., Alvarado, R., Murshed, M., Işık, C., & Ma, H. (2023). Globalization and renewable energy use: how are they contributing to upsurge the CO2 emissions? A global perspective. *Environmental Science and Pollution Research*, *30*(4), 9699–9712. https://doi.org/10.1007/s11356-022-22775-6
25. Volodzkiene, L., & Streimikiene, D. (2023). Energy Inequality Indicators: A Comprehensive Review for Exploring Ways to Reduce Inequality. In *Energies* (Vol. 16, Issue 16). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/en16166075
26. Wang, Y., & Zhao, T. (2018). Panel estimation for the impacts of residential characteristic factors on CO2 emissions from residential sector in China. *Atmospheric Pollution Research*, *9*(4), 595–606. https://doi.org/10.1016/J.APR.2017.12.010
27. Wu, S., Zheng, X., & Wei, C. (2017). Measurement of inequality using household energy consumption data in rural China. *Nature Energy*, *2*(10), 795–803. https://doi.org/10.1038/s41560-017-0003-1

UNIVERSITY of DEBRECEN

UNIVERSITY AND NATIONAL LIBRARY
UNIVERSITY OF DEBRECEN
H-4002 Egyetem tér 1, Debrecen
Phone: +3652/410-443, email: publikaciok@lib.unideb.hu

Registry number: DEENK/503/2024.PL
Subject: PhD Publication List

Candidate: Behnam Ata
Doctoral School: Doctoral School of Earth Sciences
MTMT ID: 10097302

List of publications related to the dissertation

Foreign language scientific articles in international journals (4)

1. Altouma, A., Bashir, B., **Ata, B.**, Ocwa, A., Alsalman, A., Harsányi, E., Mohammed, S.: An environmental impact assessment of Saudi Arabia's vision 2030 for sustainable urban development: a policy perspective on greenhouse gas emissions.
   Environ Sustain Indic. 21, 1-13, 2024. EISSN: 2665-9727.
   DOI: http://dx.doi.org/10.1016/j.indic.2023.100323
   IF: 5.4 (2023)

2. **Ata, B.**, Pakrooh, P., Pénzes, J.: Driving factors of energy related CO2 emissions at a regional level in the residential sector of Iran.
   Sci. Rep. 13 (1), 1-23, 2023. EISSN: 2045-2322.
   DOI: http://dx.doi.org/10.1038/s41598-023-44975-x
   IF: 3.8

3. Borna, R., Roshan, G., Moghbel, M., Szabó, G., **Ata, B.**, Attia, S.: Mitigation of Climate Change Impact on Bioclimatic Conditions Using Different Green Space Scenarios: The Case of a Hospital in Gorgan Subtropical Climates.
   Forests. 14 (10), 1-20, 2023. EISSN: 1999-4907.
   DOI: http://dx.doi.org/10.3390/f14101978
   IF: 2.4

4. **Ata, B.**, Pakrooh, P., Barkat, A., Benhizia, R., Pénzes, J.: Inequalities in Regional Level Domestic CO2 Emissions and Energy Use: A Case Study of Iran.
   Energies. 15 (11), 1-26, 2022. ISSN: 1996-1073.
   DOI: http://dx.doi.org/10.3390/en15113902
   IF: 3.2

UNIVERSITY of DEBRECEN

UNIVERSITY AND NATIONAL LIBRARY
UNIVERSITY OF DEBRECEN
H-4002 Egyetem tér 1, Debrecen
Phone: +3652/410-443, email: publikaciok@lib.unideb.hu

List of other publications

Foreign language scientific articles in international journals (3)

5. Mohammed, S., Arshad, S., Bashir, B., **Ata, B.**, Al-Dalahmeh, M., Alsalman, A., Ali, H., Alhennawi, S., Kiwan, S., Harsányi, E.: Evaluating machine learning performance in predicting sodium adsorption ratio for sustainable soil-water management in the eastern Mediterranean.
   J. Environ. Manage. 370, 1-14, 2024. ISSN: 0301-4797.
   DOI: https://doi.org/10.1016/j.jenvman.2024.122640
   IF: 8 (2023)

6. Barkat, A., Bouaicha, F., Bouteraa, O., Mester, T., **Ata, B.**, Balla, D. Z., Rahal, Z., Szabó, G.: Assessment of Complex Terminal Groundwater Aquifer for Different Use of Oued Souf Valley (Algeria) Using Multivariate Statistical Methods, Geostatistical Modelling and Water Quality Index.
   Water. 13 (11), 1-26, 2021. EISSN: 2073-4441.
   DOI: https://doi.org/10.3390/w13111609
   IF: 3.53

7. Benhizia, R., Kouba, Y., Szabó, G., Négyesi, G., **Ata, B.**: Monitoring the Spatiotemporal Evolution of the Green Dam in Djelfa Province, Algeria.
   Sustainability. 13 (14), 1-15, 2021. ISSN: 2071-1050.
   DOI: http://dx.doi.org/10.3390/su13147953
   IF: 3.889

Total IF of journals (all publications): 30,219
Total IF of journals (publications related to the dissertation): 14,8

The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.

07 October, 2024