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Household's Fuel Type Choice for Space Heating in Türkiye: A Comparison of Multinomial Logit and Multinomial Probit Models#

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ABSTRACT

Better understanding of households' fuel type choice behaviour for residential heating, cooking, or lighting purposes would provide valuable information in estimating households' energy use and in developing efficient fuel switching and energy saving policies; these solutions could include reducing consumption and utilising renewable energy sources. This paper aims to explore potential determinants of household's fuel choice for residential heating in Türkiye. Using nineteenth wave of Household Budget Survey which was administered to 11,828 households and 40,688 individuals throughout the country, the data were analysed using both multinomial logit (MNL) and multinomial probit (MNP) models due to unordered nature of the dependent variable category. The empirical findings indicate household type, type of dwelling, residence time, the age of dwelling, the number of rooms, housing size, household size, type of floor structure of dwelling, household annual disposable income (log), household head's occupation level, type of heating system, car ownership, and type of employment were found as statistically significant factors affecting Turkish household's fuel choice for residential heating. Household annual disposable income and type of heating system had the highest impact on household's final fuel type decision. Results also reveal that MNL is more parsimonious model than MNP model.

Keywords: Fuel Type Choice, Discrete Choice Modelling, Household, Energy Consumption, Türkiye
JEL Classifications: Q42, P18, Q51

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1. INTRODUCTION

Energy is an essential need for individuals to continue their lives. Ensuring access to energy for individuals is recognized by many leading international organizations as the most basic need to be met. Even though every individual has the right to access safe, healthy, and clean energy, especially in developing countries, many individuals still live dependent on primitive energy sources that cause serious damage to the environment and thus to human health. As primitive energy sources are not fully combusted in the atmosphere, the use of primitive energy sources causes the formation of particles in the air, and these particles trigger an increase in carbon dioxide and greenhouse gas emissions. One of the main causes of human deaths worldwide is air pollution. Ensuring the fuel switching of individuals from primitive energy sources to environmentally friendly improved energy sources will be an effective energy strategy in terms of combating many health problems.

After high blood pressure, nutritional risks, and smoking, air pollution is the fourth risk factor that threatens human health globally. Air pollution caused by energy is often associated with the stage of the economic development of a country. Households in many low-income countries in Africa and Asia rely heavily on solid biomass fuels. As a result of the use of these fuels, human health is exposed to the inhalation of harmful particles, and many health problems such as premature birth deaths are encountered. In industrializing economies, the use of fossil fuels in energy production and industry is generally increasing, thus increasing the emission of sulphur dioxide and other gases polluting the air. Besides other environmental impacts, modern agricultural methods based on mechanization, chemical artificial fertilization, and the use of pesticides cause high levels of air pollution. Nevertheless, the demand for other energy services remains high, as does the potentially high emission of sulphur oxides, nitrogen oxides, and other gases that cause air pollution. Demographic changes, such as an increase in population and urbanization, which often occur in the earlier stages of economic growth, can also increase energy-related air pollution (International Energy Agency, 2016).

Different fuel choice types by individuals for various purposes in their residences are among the main causes of human-induced air pollution. An essential component of each household's consumption basket, energy sources range from traditional biomass fuels such as firewood and coal to modern fuels such as liquefied petroleum gas (LPG) and electricity (Mensah and Adu, 2015). Harmful gases in the residential industry account for more than half of energy-related particle emissions. Many particulate emissions in the residential industry are due to the incomplete combustion of fuels used in households for residential heating (bioenergy and coal), cooking (bioenergy), and lighting (kerosene). Far more particle emissions than many other energy-derived major pollutants are highly concentrated in developing countries (International Energy Agency, 2016). As a result of increasing environmental problems such as global warming and climate change, the focus of energy policies, especially in developing countries, is shifting from "environmentally harmful" biomass and solid fuels such as firewood to "environmentally friendly" fuels such as electricity and LPG (Rahut et al., 2014). Within this scope, global energy policies aim to develop sustainable and renewable energy that can reduce carbon emissions and climate change problems (Jan et al., 2012).

The total amount of carbon dioxide (CO_2) emissions from fuel combustion in Türkiye has reached to 374,817 metric tons of CO_2 equivalent ($MtCO_2Eq$) with an 86% increase since 2000 (International Energy Agency, 2024). Turkish economy mainly relies on oil and natural gas imports and oil and natural gas still constitute 54% of total energy supply in 2022. Oil is still the most dominant energy supply source (28.7% of total energy supply) in Türkiye with a 45% increase since 2000 and net crude oil imports account for 90.9% of total crude oil supply in 2022. As a transition fuel, coal is the second most important domestic energy sources in Türkiye following wind and solar energy with 33% of share in 2022. Coal and natural gas are still two largest sources of electricity generation of Türkiye in 2022 with 35% and 23%, respectively. During the same year, the share of coal in total energy supply is 25.1% which ranks first with a 69% increase compared to 2000. Türkiye ranks 13th in the world in terms of total coal supply in 2021. As the end of 2020, the share of modern renewables in final energy consumption is only 13.7% in Türkiye with a 21% reduction compared to 2000. In 2020, Türkiye ranks only 70th globally in terms of the share of modern renewables in final energy consumption. All those energy-oriented indicators demonstrate that Türkiye has still a significant distance to cover in the energy transition process and further efficient attempts are required for fuel switching from primitive to modern fuels. The responsibility of households in fuel switching is also crucial. Despite the share of final energy consumption by households is calculated as 30.4% in 2021 (Turkish Statistical Institute, 2023a), environmental production expenditures by households in Türkiye are still limited to approximately 5 billion Turkish liras in 2022 which account only 3.6% of total environmental production expenditures compared to 6.5% in 2021 (Turkish Statistical Institute, 2023b).

The energy ladder concept is generally used to describe the process of households switching to more modern fuels as their economic situation improves. Within the energy systems of developing countries, the energy ladder model assumes that households face a sequence of energy supply sequences ordered according to increasing technological advances. In this ranking, while modern fuels are at the top of the ranking, firewood, animal wastes, and other wastes are at the bottom. Within this scope, a household transitions to a higher-ranked fuel type when its economic welfare increases. In case of a decrease in the income of the same household or an increase in fuel prices, households are expected to transition to fuels ranked lower on the energy ladder. The concept of the energy ladder can be viewed as an extension of consumer theory, which posits that as households' income increases (decreases), they tend to consume not only more (less) of the same products but also higher quality products in general. An energy ladder model is frequently used in household energy use research, analyses, and policy making. The energy ladder concept identifies differences in energy use characteristics between households with different economic statuses as a starting point. Households are assumed to behave in a manner consistent with a consumer as defined in neo-classical theory (Hosier and Dowd, 1987). It is ranked according to households' choices for fuel types on the energy ladder based on physical attributes such as less damage to the environment, ease of use, and efficiency (Hiemstra-van der Horst and Hovorka, 2008; van der Kroon et al., 2013).

Households should have access to safer and more sustainable cooking and heating fuels and intermediaries, households should have access to modern energy to enable the performance of productive economic activities, and households should have access to modern energy to enable the provision of public services. All these factors represent a set of interrelated issues that are decisive for economic growth and social development and can be broadly characterized as the quality of supply (International Energy Agency, 2015). Households' access to energy services may be limited by household purchasing power and the cost of energy, and how it is used (Pachauri and Spreng, 2004). In a sense, households' fuel choices are determined more by the availability, processing, and opportunity costs of obtaining the fuel as opposed to household budget constraints, energy prices, and costs (Farsi et al., 2007). Access to environmentally friendly, less costly, and more reliable energy sources for relatively poorer households in developing countries is seen as another important prerequisite in the fight against poverty. Although rural households have easy access to traditional forms of energy such as firewood, charcoal, and agricultural residues to meet their basic energy needs, rural fuels have negative impacts such as the emission of particles harmful to health, deforestation, and environmental degradation (Ekholm et al., 2010). Many households in developing countries are still highly dependent on firewood and other solid fuel-based energy sources for heating, cooking, lighting, and other uses. The main reasons for this dependence are still argued to be the lack of access to environmentally friendly and reliable energy sources, the unavailability of environmentally friendly sources due to their cost, or the proximity to environmentally harmful fuels such as firewood, which are less costly and more widely available (Rahut et al., 2014). In developing countries, the transition from traditional biomass fuels to modern energy sources is seen as one of the most important sustainability challenges. Fuel switching has many clear benefits for households and national economies, but the switch to modern fuels is progressing more slowly than expected (Takama et al., 2012).

The energy ladder model conceptualizes fuel switching on in three different stages. The first stage is characterized by a global dependence on biomass. In the second stage of the fuel switching, households are assumed to switch to "transitional" fuels such as kerosene, coal, and charcoal because of an increase in their income and urbanization rate and the scarcity of biomass fuels. The third and final stage of the fuel switching is characterized by households switching to modern fuels such as LPG, natural gas, and electricity for cooking. The most important observational achievement of the energy ladder model is its ability to demonstrate that fuel choices are strongly dependent on household incomes (Heltberg, 2004). One of the criticisms of the energy ladder model concerns the extent to which households are free to choose between different types of energy. Likewise, there are questions as to whether households have real experience in making choices between different fuels, or whether households' transitions on the energy ladder are largely constrained by the physical or economic environment (Hosier and Dowd, 1987). Consequently, a model of the fuel stacking has been proposed which suggests that households' fuel type choices for different purposes depend not only on their socioeconomic status but also on other factors. The energy transition model also underlines that households may choose multiple fuel types according to various factors. The fuel type choices of households do not follow sharp transitions as proposed by the energy ladder model, but rather temporary transitions based on the current situation. Some studies (Heltberg, 2004; 2005; Hiemstra-van der Horst and Hovorka, 2008; van der Kroon et al., 2013) have criticized the energy ladder model and proposed the fuel stacking model as an alternative, where fuels are used together in order of priority. Whereas there are sharp transitions in the energy ladder model, in the fuel stacking model, fuels are used together in order of priority according to the current situation. Moreover, in both mentioned household fuel choice models, the transition of households from traditional fuels to advanced fuels is depicted and the transition to modern fuels is supported according to the socio-economic status of households. Encouraging the transition to advanced fuels can incentive the reduction of anthropogenic air pollutants, such as carbon dioxide and greenhouse gas emissions.

Identifying the fuel type choice of households for space heating is important for estimating the energy use of households and developing effective fuel switching or energy conservation programs (Train, 2003). Households spend an increasing budget on direct energy consumption in households, especially in recent times. About three-quarters of the energy consumed in households, especially in temperate zone areas, is allocated to the heating of dwellings. Due to the constant attention to the efficient use of energy resources, it is very important to determine the energy-related behaviours of households (Braun, 2010). In addition, in many developing countries, households' fuel choice and fuel switching behaviour provide an important perspective in policy making, and many countries support initiatives that encourage and enable households to switch to more efficient fuels with less adverse environmental, social, and health impacts. Effective regulation of public policies at that point requires first of all to investigate and analyse the determinants affecting fuel choices and consumption behaviours of households (Farsi et al., 2007). Nevertheless, the relative importance of fuel stacking versus fuel switching remains a subject of research (Heltberg, 2005).

The main objective of the present paper is to explore households' fuel type choice for space heating in Türkiye by a comparison of unordered discrete choice models, namely, MNL and MNP models. Although there exist earlier attempts on Turkish households' fuel type choice for space heating (Çebi Karaaslan et al., 2022; Çelik and Oktay, 2019; Emeç et al., 2015; İpek and İpek, 2022; Metin Özcan et al., 2013), the present paper significantly differs from earlier contributions in terms of dataset, variable selection, and comparison of MNL and MNP models. In addition, Turkish households' fuel type choices deserve further attention periodically as contributions of past and present energy policies appear to be insufficient for sustainable modern fuel adoption which is crucial for Turkish economic development in many aspects. Due to relatively high global, economic, and geopolitical uncertainties, the Turkish economy is among the fragile five countries, coined by Morgan Stanley in 2013 for economies mainly relying on foreign investments for economic growth. The Turkish economy suffers from high inflation for a while mainly caused by negative impacts of COVID-19 pandemic and ongoing geopolitical conflicts in its region. Although Turkish economy experienced a rapid economic growth during the past two decades, heavy import dependency especially on oil (93%) and natural gas (99%) significantly increased as well. At that point, restructuring of energy system plays a vital role for the Turkish economy by rationalizing energy demand growth, lowering energy prices and slowing import growth pace. Though residential energy consumption in Türkiye has seen a remarkable switch from biofuels and oil to natural gas and electricity in recent decades, bioenergy consumption has declined by 76% since 2008. In that period, natural gas and electricity use have been fourfold and doubled in residential energy consumption (International Energy Agency, 2021). However, recent indicators show that CO_2 emissions by Turkish households are still relatively high especially for space heating purposes. In fact, space and water heating constitute 70% of total energy consumption of Turkish households in 2018 (International Energy Agency, 2021). In such a circumstance, households' fuel type choice behaviour for space heating takes its respectable place in Türkiye's past and present energy policies to achieve rapid fuel switching from fossil fuels to modern renewables. To better understand main determinants of households' fuel type choice and main reasons of relying on fossil fuels would provide fruitful information for future energy policies to identify potential mitigation measures of CO_2 emissions, reduce heavy import dependency of Turkish economy, and contribute to sustainable development goals by 2050.

The remainder of the present paper is as follows: Second section reviews the extant literature, and third section gives theoretical information about the methodological framework of household fuel type choice within the scope of MNL and MNP models. Fourth section introduces data collection, dependent and independent variables used in fitted MNL and MNP models. Fifth section presents and interprets empirical findings in detail. The paper concludes with limitations of this study and recommendations for future research.

2. LITERATURE REVIEW

In general, the process of consumer choices, which is based on the determination of the alternative that will provide the highest benefit to the consumer among many alternatives based on the theory of incidental utility, is a very complex process that takes place with the influence of many related determinants. The choice of fuel type by households is also a result of such a process and is influenced by many related determinants. In some previous studies (Farsi et al., 2007; Lay et al., 2013; Lee, 2013; Nlom and Karimov, 2015), it is found that household energy choices are suitable for the energy ladder model. However, the relevance of the energy ladder model to real life has been criticized by many previous studies (Hosier and Dowd, 1987; Hiemstra-van der Horst and Hovorka, 2008; van der Kroon et al., 2013). In some other studies (Heltberg, 2004; Ouedraogo, 2006; Hiemstra-van der Horst and Hovorka, 2008; Ogwumike et al., 2014; Rahut et al., 2014; Zhang and Hassen, 2017; Nlom and Karimov, 2015), it is revealed that household energy choices are more appropriate for the fuel stacking or energy transition model. Furthermore, many empirical studies (Pachauri et al., 2004; Pachauri and Spreng, 2004; Ekholm et al., 2010; Jan et al., 2012; Ogwumike et al., 2014) highlight the difficulties for households to access environmentally friendly forms of advanced energy.

Determinants that may affect household fuel type choices can be categorized as socio-demographic characteristics, housing-related characteristics, spatial characteristics, and other characteristics. Under socio-demographic and socio-economic characteristics, demographic characteristics of the household head and other household-related characteristics can be mentioned. In previous studies, the gender of the household head stands out as a variable affecting household fuel choices. In a previous study (Mensah and Adu, 2015), male heads of households are found to more likely to choose primitive fuels. Unlike these findings, in other studies (Farsi et al., 2007; İpek and İpek, 2022; Rahut et al., 2014; Zhang and Hassen, 2017), it is concluded that female-headed households have a higher choice for advanced fuels. In previous studies, the age of the household head has been identified as another socio-demographic variable affecting household fuel choices. In previous studies (Ogwumike et al., 2014; Rahut et al., 2014; Mensah and Adu, 2015; Nlom and Karimov, 2015), it is found that as the age of the household head increases, households choose traditional fuels more. In other studies (Chen, 2021; Nesbakken, 2001; Farsi et al., 2007; Zhu et al., 2023), it is concluded that an increase in the age of the household head will increase the probability of choosing advanced fuels.

In many previous studies (Chen, 2021; Nesbakken, 2001; Heltberg, 2005; Ouedraogo, 2006; Rao and Reddy, 2007; Braun, 2010; Ogwumike et al., 2014; Rahut et al., 2014; Mensah and Adu, 2015; Vo et al., 2024; Zhu et al., 2023), it is found that higher education level of the household head increases the probability of choosing advanced fuel types. In another study (Farsi et al., 2007), it is found that household heads who are literate or have basic education are more likely to choose primitive and transitional fuels such as firewood or kerosene. Unlike these findings, in another study (Nlom and Karimov, 2015), it is concluded that the educational level of household head being primary or secondary education increases the probability of choosing environmentally friendly fuel types. In another study (Laureti and Secondi, 2012; Emeç et al., 2015), it is found that households are more likely to choice coal or electricity when the education level of the household head is relatively lower. It is observed by Heltberg (2004) that households choose non-solid fuels more in case of an increase in the education level of the household head. The household type has been considered in the existing literature as another determinant that may affect household fuel type choices. In a previous study (Laureti and Secondi, 2012), it is concluded that nuclear families without children are more likely to choose natural gas than single-adult households.

The income level of a household, whether it is measured monthly or annually, is a crucial factor in determining their fuel choices. This is highlighted in various models such as the energy ladder, fuel stacking, and energy transition models, which all point to income as the primary determinant. Many previous studies conducted to determine household energy choices have revealed the effect of household income variables. Metin Özcan et al. (2013) found that the probability of households choosing coal, natural gas, electricity, and LPG for heating purposes is higher than the probability to choose firewood in case of an increase in household monthly income. That is to say, as also found in some other previous studies (Vaage, 2000; Rao and Reddy, 2007; Laureti and Secondi, 2012; Emeç et al., 2015; Mensah and Adu, 2015), an increase in household monthly income increases the probability of switching from primitive fuels to advanced fuels. Other studies (Ouedraogo, 2006; Farsi et al., 2007) have similarly found that low-income households are more likely to favour primitive fuels such as firewood. In previous studies (Heltberg, 2005; Rao and Reddy, 2007; Lay et al., 2013; Ogwumike et al., 2014; Rahut et al., 2014), it is revealed that increasing household expenditures will facilitate switching from primitive fuels to advanced fuels.

Another socio-demographic variable that is expected to affect household fuel type choices is household size. Previous studies (Farsi et al., 2007; Rao and Reddy, 2007; Rahut et al., 2014; Mensah and Adu, 2015) suggest that an increase in household size will increase the probability that traditional fuel types will be chosen. In contrast to this result, in another study (Heltberg, 2005) it is found that smaller households continue to use only advanced fuels due to the increasing opportunity costs of procuring their primitive fuels. In some other studies (Iraganaboina and Eluru, 2021; Nesbakken, 2001; Farsi et al., 2007; Ogwumike et al., 2014), it is concluded that households choose more advanced fuels with increasing household size. Heltberg (2004) revealed that an increase in household size increases the probability of households favouring both solid and non-solid fuels. In another study (Braun, 2010), it is found that the increase in household size decreases the heating system using natural gas. In a recent study (Metin Özcan et al., 2013), it is found that an increase in household size decreases households' electricity use for heating purposes. In another study conducted in the sample of Türkiye (Emeç et al., 2015), it is determined that when the household size increases, coal choice for heating increases while electricity consumption decreases. Pundo and Fraser (2006) found that the probability of coal choice also increases with increasing household size. In contrast, Chen (2021) indicated that the use of coal and electricity decreases when household size increases.

Among the characteristics related to the households, the type of the dwelling, the ownership status of the dwelling, the heating system of the dwelling, the year the dwelling is built, the size of the dwelling, and the number of rooms in the dwelling can be listed. In a previous study (Metin Özcan et al., 2013), it is found that households living in apartment buildings with ten or more flats are about 3 times more likely to choose electricity for heating than households living in smaller apartment buildings. In another previous study, a similar result is reached and it is concluded that households residing in apartment buildings had a higher choice for electricity (Vaage, 2000). In another study (Mensah and Adu, 2015); it is determined that in households where areas such as open space, kitchen, toilet, and bathroom are shared, advanced fuel choices are higher than other fuel types. In another study (Laureti and Secondi, 2012), it is found that households residing in detached houses are more likely to choose coal and firewood. In a previous study (Nesbakken, 2001), it is found that households living in separate houses tended to choose a combination of electricity and firewood as their fuel choice. In previous studies (Nesbakken, 2001; Laureti and Secondi, 2012), it is found that households that own a house using advanced fuels more. In another similar study (Pundo and Fraser, 2006), it is revealed that the coal and kerosene choices of the households who do not own a house are higher. In another study (Ogwumike et al., 2014), it is concluded that homeowner households are more likely to choose primitive fuels.

Households' residential heating types can be considered as a variable that can have a direct impact on their choices for household heating. However, Nesbakken (2001) pointed out that the choice of the type of residential heating system is ignored in many studies when analysing household energy demand. In analysing the residential heating system type choice, several previous studies (Kasanen and Lakshmanan, 1989; Braun, 2010; Michelsen and Madlener, 2012; Decker and Menrad, 2015) have included only households that are homeowners in their analyses to ensure that only households make the choice. According to previous studies, household income is effective on the fuel type choice used in the residential heating system. Braun (2010) concluded that the increase in household income will increase the choice for heating systems using natural gas. In another study (Metin Özcan et al., 2013), it is found that households that prefer communal or central heating systems choose coal as a fuel type 10 times more than firewood.

Nesbakken (2001) revealed that with the increase in the size of households, the tendency to choose firewood only or electricity, oil, and firewood together as fuel type will increase. In a previous study (Laureti and Secondi, 2012), it is determined that households residing in newly built houses are more likely to choose natural gas. In another study (Vaage, 2000), a similar result determine that households residing in new households are more likely to choose electricity as a fuel type. In many studies (Heltberg, 2005; Emeç et al., 2015), it is found that increasing the number of household rooms significantly increases the probability of choosing advanced fuel types. In another study (Metin Özcan et al., 2013), it is concluded that increasing the number of rooms in the household increases the probability of coal choice for heating purposes.

3. METHODOLOGY

In many discrete-choice modelling applications, an independent variable takes different values for different response choices and this type of independent variables are called as characteristics of the choices (Agresti, 2022). Under a random utility framework, a household i chooses (i = 1, 2,…, n) from a finite of alternatives, j = 1, 2,…, m and the utility of alternative j is defined as

$$U_{ij} = \beta_j' x_i + \varepsilon_{ij} \tag{1}$$

Where x_i denotes independent variables, β_j denotes unknown coefficients, and ε_{ij} denotes the error term. Since the utility from alternative j is the highest among all alternatives, household i prefers to choose alternative j. When errors are specified as independently identically distributed according to type I extreme value distribution, and independent variables are characteristics of the households, the probability to choose fuel type j for residential heating is as the following (Braun, 2010):

$$P_{ij} = \frac{\exp(\beta_j' x_i)}{1 + \sum_{k=1}^{J} \exp(\beta_j' x_i)} \quad \text{for } j = 1, 2, ..., J \tag{2}$$

The MNL model requires not to violate the independence of irrelevant alternatives (IIA) assumption. Following from the initial assumption that the disturbances are independent and homoscedastic (Greene, 2008), the IIA assumption means that the relative odds between two alternative outcomes depend exclusively on characteristics pertaining to the two outcomes and are independent of the number and the nature of all other outcomes that are simultaneously considered (Powers and Xie, 2000). If the restrictive IIA assumption is violated, several alternative approaches are proposed including the MNP model which relaxes the IIA assumption of independent errors across alternatives (Powers and Xie, 2000). Following the similar mathematical notations, the structural equations of the MNP model are defined as

$$U_{ij} = x'_{ij}\beta + \varepsilon_{ij}, \quad j = 1,2,...,J, \left[\varepsilon_{i1}, \varepsilon_{i2},...,\varepsilon_{ij}\right] \sim N\left[0, \Sigma\right] \qquad (3)$$

Here, the term in the log-likelihood for the choice of alternative fuel type q is written as

$$\Pr\left[\text{fuel type choice}_{iq}\right] = \Pr\left[U_{iq} > U_{ij}, \ j = 1,2,...,J, j \neq q\right] \qquad (4)$$

And the probability for this occurrence is defined as

$$\Pr\left[\text{fuel type choice}_{iq}\right] = \Pr\left[\varepsilon_{i1} - \varepsilon_{iq} < (x_{iq} - x_{i1})'\beta,...,\varepsilon_{iJ} - \varepsilon_{iq} < (x_{iq} - x_{iJ})'\beta\right] \qquad (5)$$

For the J–1 other fuel type choices, which a cumulative probability from a (J–1)-variate normal distribution (Greene, 2008). Maximum likelihood estimation is used for both MNL and MNP models.

Elasticities are preferably computed to evaluate the marginal effects of the independent variables to better understand the implications of parameter estimation results. Elasticities present fruitful information on the impact of an independent variable on the expected frequency. One can interpret elasticities as the impact of a 1% change in the variable on the expected frequency λ_i. For continuous independent variables, elasticity of frequency λ_i is defined as the following

$$E_{x_{ik}}^{\lambda_i} = \frac{\partial\lambda_i}{\lambda_i} \times \frac{x_{ik}}{\partial x_{ik}} = \beta_k x_{ik} \qquad (6)$$

Where E denotes elasticity; x_{ik} denotes the value of kth independent variable for observation i, β_k denotes the estimated parameter of the kth independent variable, and λ_i denotes the expected frequency for observation i. For discrete variables that takes values on only 0 and 1, a pseudo-elasticity is calculated as the following (Washington et al., 2011):

$$E_{x_{ik}}^{\lambda_i} = \frac{\exp(\beta_k) - 1}{\exp(\beta_k)} \qquad (7)$$

4. MATERIALS AND METHODS

4.1. Study Design, Sample and Data Collection

This section established the econometric analysis of MNL and MNP models using Stata/MP 16.0 package program. Accordingly, the metadata set of the nineteenth wave of Turkish Statistical Institute Household Budget Survey (Turkish Statistical Institute, 2018a) was employed to identify the factors affecting fuel type choices of households for space hating in Türkiye. The 2018 Turkish Statistical Institute Household Budget Survey was applied to 11,828 households and 40,688 individuals. The Turkish Statistical Institute Household Budget Survey is a large-scale, repeated cross-sectional survey initiated in 1987 and has been carried out regularly every year since 2002. Turkish Statistical Institute Household Budget Surveys are designed to provide information on the socioeconomic structure, living standards, and consumption patterns of households and to review the validity of the socioeconomic policies implemented. Turkish Statistical Institute Household Budget Surveys attempt to determine individuals' and households' consumption patterns and income levels by rural, urban, regional, and socioeconomic classes (Turkish Statistical Institute, 2018b).

Each household budget survey is carried out throughout Türkiye for 1 year, with the number of samples changing monthly. There are three different data sets in household budget surveys: household, individual, and consumption. These data sets can be matched with each other with household bulletin numbers. Rural settlements in the household budget surveys are settlements with a population of 20,000 or less within the borders of the Republic of Türkiye, and urban settlements are settlements with a population of more than 20,000. The first stage in the sampling design of Turkish Statistical Institute Household Budget Surveys is the selection of blocks, which are sampling units and are determined according to the size of the housings. The National Address Database is considered in selecting these blocks, and the final sampling units are selected as households. Thus, Turkish Statistical Institute uses stratified two-stage cluster sampling for the Household Budget Surveys. The weight coefficients used in the results of the household budget surveys are calculated based on the current population projections based on the Address-Based Population Registration System (Turkish Statistical Institute, 2018b).

In the Turkish Statistical Institute Household Budget Survey, there are 16 variable categories belonging to the dependent variable in question. The relevant categories are listed as "coal and coal derivatives," "firewood," "sawdust," "shells (hazelnut, walnut, etc.)," "pomace," "dung," "fuel-oil," "natural gas," "LPG," "electricity," "steam-hot water energy," "solar energy," "geothermal energy," "wind energy," "hydroelectric energy" and "other fuel types." However, energy types less preferred in frequency are combined under the other fuel types. This does not significantly affect the econometric estimation results to be realized and evaluated over the four categories with the highest frequency values households choose for heating purposes. Accordingly, the final dependent variable categories used to implement MNL, and MNP models include "coal and coal derivatives," "firewood," "natural gas," and "other fuel types." Similarly, in some of the independent variable categories used in the application, similar categories were logically combined to avoid the problem of a high degree of multicollinearity and to prevent low-frequency categories from affecting the analysis results. Table 1 shows the descriptive statistics of the variables in the data set used to estimate MNL and MNP models.

As seen in Table 1, many variables used in the application are defined as dummy variables to reflect the effect of variable categories on the dependent variable. However, the number of

Table 1: Descriptive statistics

Variables	Frequency (%)
Dependent variable	
Fuel type	
Coal/Coal derivatives	4,155 (35.13)
Firewood	1,739 (14.70)
Natural gas	5,052 (43.71)
Others*	882 (7.46)
Independent variables	
Household type	
Single person	1,149 (9.71)
Core family	8,949 (75.66)
Others*	1,730 (14.63)
Type of dwelling	
Detached house	3,877 (67.22)
Two houses*	1,491 (12.61)
3-9 houses	3,125 (26.42)
>9 houses	3,335 (28.20)
Housing tenure	
Owner-occupied	7,184 (60.74)
Renter	2,764 (23.37)
Others*	1,880 (15.89)
Year (s) of residence	
≤1*	1,232 (10.42)
2-5	2,818 (23.82)
6-10	2,111 (17.85)
11-15	1,233 (10.42)
>15	4,434 (37.49)
Dwelling construction period	
Before 1971*	1,364 (11.53)
1971-1980	1,602 (13.54)
1981-1990	2,265 (19.15)
1991-2000	2,684 (22.69)
2001-2005	1,284 (10.55)
After 2005	2,665 (22.53)
Number of rooms	
Housing size (m^2)	
<100	4,664 (39.43)
100-149	5,923 (50.08)
≥150*	1,241 (10.49)
Type of floor	
Hardwood	6,689 (56.55)
Wood	1,414 (11.95)
Tile ceramic	1,213 (10.26)
Black concrete	1,639 (13.86)
Others*	685 (5.79)
Type of heating system	
Flat heating/combi (combi boiler etc.)	4,538 (38.37)
Stove (firewood, coal, natural gas, electricity, gas cylinder, etc.)*	5,753 (48.64)
Joint/central heating	1,134 (9.59)
Others	403 (3.41)
Second home ownership	
Yes	995 (8.41)
No*	10,833 (91.59)
Automobile ownership	
Yes	5,110 (43.20)
No*	6,718 (56.80)
Savings status	
Yes	4,540 (38.38)
No*	7,288 (61.62)
Household annual disposable income (log)	
Household size	
Household head's gender	
Male	10,002 (84.56)
Female*	1,826 (15.44)

(*Contd...*)

Table 1: (*Continued*)

Variables	Frequency (%)
Household head's age	
Household head's educational level	
Illiterate*	1,317 (11.13)
Primary	6,696 (56.61)
Secondary	2,041 (17.26)
Tertiary	1,774 (15.00)
Household head's marital status	
Married	9,662 (81.69)
Single*	2,166 (18.31)
Household head's occupational group	
Lawmakers, top managers, and directors	561 (4.74)
Professional occupation groups	676 (5.72)
Assistant professional occupation groups	431 (3.64)
Office and customer services	377 (3.19)
Service and sales workers	1,338 (11.31)
Skilled agriculture, forestry, and aquaculture workers	1,482 (12.53)
Crafts and other related works	1,211 (10.24)
Plant and machine operatives and assemblers	956 (8.08)
Elementary occupation groups	884 (7.47)
Others*	3,912 (33.07)
Type of employment	
Full-time	4,550 (38.47)
Part-time	302 (2.55)
Temporary	297 (2.51)
Others*	6,679 (56.47)

*Reference category

rooms, household annual disposable income, household size, and the age of the household head were used as continuous variables. Table A1 presents the maximum likelihood estimation results of the MNL model. As seen in Table A1, the estimated MNL model is statistically significant (Prob > chi^2 = 0.000) at the 1% significance level. The estimated MNL model with 11,828 observations yielded results in 8 iterations (log-likelihood: −6.496, 7772). The Pseudo-R^2 value calculated to estimate the MNL model is 0.5447. It shows statistically high goodness of fit compared to the Pseudo-R^2 values recommended for discrete choice models in the previous studies (Louviere et al., 2000). The MNP model is a multinomial discrete choice model usually preferred when the MNL model violates the restrictive assumption of independence of unrelated alternatives. Table A1 shows the maximum likelihood estimation results of the MNP model. The MNP model was estimated with 11,828 observations and 4 iterations. The estimated MNP model was statistically significant (Prob > chi^2 = 0.000) at the 1% significance level. Table A1 shows that the adjusted Pseudo-R^2 value of the MNP model was 0.587, implying a high goodness of fit (Louviere et al., 2000).

The MNL model estimation results calculate the estimation results of the independent variables separately for each dependent variable category. The estimation results of the MNL model provide information about the direction of the relationship between the dependent and independent variables. Statistical analyses, including relative risk ratio, marginal effects, and elasticity values, were calculated to obtain information about the magnitude of the relationship. In this section, the detailed interpretation of the MNL model estimation results is based on average direct pseudo-elasticities, which have been shown to provide better results for discrete choice models than marginal effects and relative risk ratios (Washington et al., 2011).

In Table 2, MNL and MNP models, estimated by the maximum likelihood method, are compared in terms of statistical precision employing log-likelihood values, degrees of freedom, and Akaike (AIC) and Schwarz information (BIC) criteria. As seen in Table 2, the two multinomial models estimated for all variables yielded close values. The existing literature states that discrete choice models with lower AIC and BIC are statistically more parsimonious. In the present study, the BIC values were considered the main criterion to determine the best model fit, since the BIC is adopted to impose a higher penalty for additional parameters (Williams, 2016; Dziak et al., 2020). In this context, as seen in Table 2, the MNL model with lower BIC values (and lower AIC) is statistically more parsimonious than the MNP model for the data set used in the application.

4.2. Estimation Results

Table 3 shows the average direct pseudo-elasticities for both MNL and MNP models estimated by maximum likelihood method. Household type is found to have a significant impact of Turkish households' fuel choice. Accordingly, the results of the pseudo-elasticities for coal choice showed that single person households are approximately 2% (−0.023; $P < 0.01$) less likely to choose coal and coal derivatives for heating their housings compared to other household types. Single person households are also found to have 9% (0.087; $P < 0.01$) more probability of choosing other fuel types than other household types. Core families are approximately 10% (−0.095; $P < 0.01$) less likely to choose coal and its derivatives than other household types. Specifically, core families are more likely to choose modern fuels than other household types. The results revealed that core families are 21% (0.213; $P < 0.05$) more likely to choose natural gas for space heating than other household types.

Households living in detached houses are found to more likely to choose primitive (i.e. firewood) and transition (i.e. coal/coal derivatives) and less likely to choose modern fuel (i.e. natural gas) fuel type for space heating. Numerically, households residing in detached houses are approximately 6% (0.058; $P < 0.01$) more likely to choose coal and coal derivatives than households residing in two-housing dwellings. If the house type is a detached house, the probability of choosing firewood is approximately 11% (0.110; $P < 0.01$) higher than households living in dwellings with two houses. It is found that households living in detached houses are 18% (−0.183; $P < 0.01$) less likely to choose natural gas than dwellings with two houses. This result is in accordance with some recent studies (Belaïd and Massié, 2022; İpek and İpek, 2022). Similarly, Turkish households living in dwellings with more houses (i.e. 3-9 houses and i.e. >9 houses) are more likely to choose modern fuels natural gas and less likely to choose primitive (i.e. firewood) and transition fuels (i.e. coal/coal derivatives) consistent with some recent research (Çebi Karaaslan et al., 2022). Turkish households residing in buildings with 3-9 houses and buildings with ten or more houses are approximately 15% (−0.153; $P < 0.01$) and 32% (−0.321; $P < 0.01$) less likely to choose coal and coal derivatives, respectively, than households residing in dwelling with two houses. This result shows consistency with earlier research (Jaime et al., 2020). Households living in dwellings with 3-9 houses and buildings with 10 or more housings are 36% (0.355; $P < 0.01$) and 68% (0.685; $P < 0.01$) more likely to choose natural gas, respectively. However, households residing in dwellings with 3-9 houses and dwellings with 10 or more housings are approximately 10% (−0.104; $P < 0.01$) and 15% (−0.149; $P < 0.01$) less likely to choose firewood than those residing in buildings with two houses, respectively. Finally, Turkish households residing in 3-9 and 10 or more houses have 12% (0.122; $P < 0.01$) and 37% (0.370; $P < 0.01$) more tendency to choose other fuel types. Those results show similarity with earlier studies (Vaage, 2000; Couture et al., 2012).

Housing tenure is found to have a significant impact on Turkish households' fuel type choice for space heating. Owner-occupied households are 15% (−0.149; $P < 0.01$) less likely to choose natural gas and 20% (0.198; $P < 0.01$) more likely to choose other fuel types. On the other hand, renters are found to be 7% (−0.688; $P < 0.01$) less likely to choose firewood. Rehdanz (2007) argues that owners are more likely to have energy-efficient heating and renters are less likely to improve their existing heating conditions. Households living in their dwellings for 6-10 years tend to be approximately 3% (0.026; $P < 0.01$) more likely to choose coal and coal derivatives than households living in their homes for 1 year or less. Households living in their homes for 11-15 years and more than 15 years are 8% (−0.082; $P < 0.01$) and 26% (−0.262; $P < 0.01$) less likely to choose other fuel types. Households residing in buildings constructed between 1981 and 1990 (0.034; $P < 0.01$), 1991 and 2000 (0.027; $P < 0.01$), 2001 and 2005 (0.027; $P < 0.01$), and 2006 and later (0.031; $P < 0.05$) are approximately 3% more likely to choose coal and its derivatives than households residing in buildings constructed in 1970 and before. Those findings are consistent with earlier findings (Al Qadi et al., 2018; Belaïd and Massié, 2022; Iraganaboina and Eluru, 2021; İpek and İpek, 2022).

The number of rooms are found to increase the probability of Turkish households' coal/coal derivatives choice by 17% (0.171; $P < 0.01$) but decrease other fuel type choices by 90% (−0.903; $P < 0.01$) for space heating. This evidence differs from some earlier findings (Vaage, 2000). Housing size is found another significant factor of Turkish households' fuel type choice for space heating. Accordingly, households residing in dwellings of 100-149 m^2 are 7% (0.072; $P < 0.01$) more likely to choose coal and coal derivatives than households residing in 150 m^2 and larger houses. The MNL model analysis revealed that the probability of choosing natural gas is 11% (0.113; $P < 0.10$) higher in houses with an area of <100 m^2 and 14% (−0.141; $P < 0.05$) lower in houses with an area of 100-149 m^2 than in houses with an area of 150 m^2 and larger. When housing size is <100 m^2, the probability of choosing other

Table 2: Comparison of MNL and MNP models

Model	n	LL (Null)	LL (Full)	AIC	BIC	Pseudo-R^2
MNL	11,828	–14,268.09	–6,496.78	13,293.55	14,400.29	0.5447
MNP	11,828	–6,535.77	–6,514.20	13,328.40	14,435.13	0.5870

Table 3: Elasticities for the MNL and MNP models

Dependent variable	Coal/coal derivatives		Firewood		Natural gas		Others	
	MNL	MNP	MNL	MNP	MNL	MNP	MNL	MNP
Household type								
Single person	−2.33*	−2.72*	1.47	0.10	2.23	1.86	8.69*	8.02*
Core family	−9.50*	−9.55*	2.27	2.01	21.30**	15.23***	1.11	3.10
Type of dwelling								
Detached house	5.79*	5.32*	11.05*	15.03*	−18.32*	−16.02*	3.54	5.89
3-9 houses	−15.32*	−14.54*	−10.43*	−12.02*	35.52*	25.93*	12.19*	10.65*
>9 houses	−32.07*	−32.11*	−14.92*	−21.77*	68.47*	52.89*	36.99*	32.29*
Housing tenure								
Owner-occupied	3.24	2.39	2.88	3.25	−14.90*	−12.25**	19.76*	21.30*
Renter	0.02	0.46	−6.88*	−7.82**	2.27	2.30	−1.76	−2.06
Time of residence								
6-10	2.56*	2.32**	−4.10	−4.45	3.30	3.33	−5.24	−4.77
11-15	1.24***	1.39**	−1.19	−1.05	0.11	0.42	−8.23*	−7.73*
>15	2.92	2.91	−4.61	−4.92	3.02	4.81	−26.21*	−25.57*
Dwelling construction period								
1981-1990	3.43*	3.74*	−0.02	0.08	−7.03**	−6.49*	−3.03	−1.07
1991-2000	2.71**	3.13**	−1.03	−0.05	−5.97	−5.83***	−0.03	1.42
2001-2005	2.72*	3.04*	1,76	2.82	−6.85*	−6.45*	−0.04	0.06
After 2005	3.06**	3.57**	−2.69	−1.83	−4.82	−4.45	−4.78	−3.91
The number of rooms	17.10**	21.05**	−10.80	−4.55	−7.81	−9.18	−90.31*	−80.86*
Housing size (m^2)								
<100	−1.37	−0.45	−4.08	−3.37	11.32***	8.91***	−21.10*	−21.50*
100-149	7.21*	8.02*	−1.03	0.06	−14.05**	−11.63**	−8.15	−8.24
Type of floor								
Hardwood	−1.83	−0.95	−9.93***	−12.20***	10.08	9.01	−7.98	−10.73
Wood	2.24*	2.36*	3.77*	4,79*	−5.41*	−4.82*	−3.35	−2.57
Tile ceramic	3.63*	3.27*	3.11**	3.74**	−12.83*	−10.55*	10.15*	10.97*
Black concrete	6.79*	6.20*	4.06**	5.14**	−21.55*	−17.31*	13.19*	14.46*
Type of heating system								
Flat heating/combi	−47.74*	−49.01*	−124.56*	−132.33*	175.10*	150.66*	−70.67*	−69.35*
Joint/central heating	3.20*	3.19*	−40.03*	−38.39*	12.79*	12.75*	−23.41*	−19.58*
Others	−1.96*	−2.13*	−5.14*	−5.76*	2.11**	0.74	12.95*	14.62*
Second home ownership, yes	−0.98**	−1.08**	2.62*	3.21*	2.25**	1.50***	−2.41	−1.78
Automobile ownership, yes	3.71*	4.15*	6.61**	9.29**	−8.38*	−7.92*	−7.70***	−7.02
Savings status, yes	4.50*	4.76*	4.21	7.15**	−11.12*	−10.42*	−2.55	−0.07
HH annual disposable income (log)	−304.02*	−306.72*	−198.33*	−292.91*	730.03*	605.23*	155.65	84.82
Household size	0.29	−0.03	−10.91	−14.43	−13.09	−10.62	49.41*	47.66*
HH's gender; male	5.84	5.06	23.81**	28.46**	−26.52*	−21.97**	16.00	12.66
HH's age (log)	10.20	19.18	71.34	108.10	87.65	68.35	−418.28*	−413.11*
HH's educational level								
Primary	−0.61	−1.77	10.09***	11.49***	−0.68	−0.04	−3.49	−1.21
HH's occupational group								
Lawmakers, top managers, and directors	0.90**	1.01*	0.14	0.07	−1.80**	−1.56**	−1.11	−0.74
Professional occupation groups	1.99*	2.32*	0.14	0.29	−5.01*	−4.48*	0.88	0.89
Assistant professional occupation groups	0.58	0.71**	−1.85	−0.20	−1.06	−0.98	0.85	1.08
Office and customer services	1.04*	1.19*	−2.92**	−3.06**	−0.90	−0.61	−1.91	−1.67
Service and sales workers	2.03*	2.26*	2.44	3.20	−5.66*	−5.34*	0.32	1.07
Skilled agriculture, forestry, and aquaculture workers	6.64*	5.80*	13.04*	16.60*	−21.45*	−17.77*	5.09**	7.19*
Crafts and other related works	1.08***	1.41**	−0.04	−0.03	−0.07	−1.03	−5.12**	−4.13**
Plant and machine operatives and assemblers	1.21**	1.56*	−1.93	−2.32	−0.14	−1.27	−2.58	−2.29
Elementary occupations	1.90*	1.98*	0.66	0.82	−4.19*	−3.48*	−1.55	−0.81
Type of employment								
Full time	−4.21**	−4.28**	0.66	1.24	17.56*	15.74*	−24.43*	−26.03*

*P<0.01; **P<0.05; ***P<0.10; HH: Household head; Only statistically significant values are presented. If at least one cell (in a row) of each variable is statistically significant, insignificant values for such independent variable are also presented for consistency

fuel types decreases by 21% (−0.211; P < 0.01). Those results are in accordance with earlier contributions (Bai et al., 2023; Belaïd and Massié, 2022; Jaime et al., 2020; Iraganaboina and Eluru, 2021).

The MNL estimation results yielded that having hardwood, tile ceramic, and black concrete floor structure in the living room increases the probability of choosing coal and its derivatives for space heating approximately by 2% (0.022; P < 0.01), 4% (0.036; P < 0.01) and 7% (0.068; P < 0.01), respectively. The probability of choosing firewood for heating in buildings with hardwood floors tends to be 10% (−0.099; P < 0.10) less than other floor structures. The probability of natural gas choice is

13% (−0.128; P < 0.01) and 22% (−0.216; P < 0.01) lower if the floor of the housing is tile ceramic or black concrete compared to other floor types, respectively. The probability of choosing other fuel types increases by 10% (0.102; P < 0.01) and 13% (0.132; P < 0.01) when type of floor is tile ceramic and black concrete, respectively.

Households using flat heating/combi as their heating system choose coal and coal derivatives approximately 48% (−0.477; P < 0.01) less than households residing in housing with stoves. The estimation results showed that the probability of choosing firewood for heating purposes decreased by 125% (−1.246; P < 0.01) when the heating system is a flat heating/combi system compared to a stove. In a similar manner, the probability of households choosing firewood for heating decreases by 40% (−0.400; P < 0.01) if the heating system is central heating in the building. This finding shows similarity with some prior attempts (İpek and İpek, 2022). Households are 175% more likely to choose natural gas if the heating system is flat heating/combi, whereas 13% (0.128; P < 0.01) are more likely if the heating system is central heating. The probability of choosing other fuel types decreases by 71% (−0.707; P < 0.01), and 23% (−0.234) and increases by 13% (0.130; P < 0.01) when the heating system is flat heating/combi, joint/central heating, and other heating systems, respectively, in contrast with some prior findings (Belaïd and Massié, 2022; Çebi Karaaslan et al., 2022).

The MNL estimation results indicate that second home ownership has significant minor impacts on household fuel type choice for space heating. Second homeowners have found to have 1% less tendency on choosing coal (−0.011; P < 0.05) and 3% more tendency to choose firewood (0.026; P < 0.01) and natural gas (0.032; P < 0.01). Households that own an automobile are approximately 4% (0.037; P < 0.01) more likely to choose coal and coal derivatives and 7% more likely to choose firewood than those that do not own an automobile. Automobile owners have also 8% less tendency to choose natural gas (−0.084; P < 0.01) and other fuel types (−0.078; P < 0.10), respectively. Households that save money are 11% (−0.111; P < 0.01) less likely to choose natural gas than non-saving households consistent with prior contributions (Çebi Karaaslan et al., 2022).

The empirical findings of this paper demonstrate that the probability of households' modern fuel (i.e. natural gas) choice significantly increases by an increase on their household annual disposable income. In contrast, their primitive (i.e. firewood) and transition (i.e. coal/coal derivatives) fuel use significantly decreases when their household annual disposable income increases. Households are 304% (−3.04; P < 0.01) less likely to use coal and coal derivatives if household annual disposable income increases. In the firewood category, as in the coal category, an increase in household annual disposable income decreases the probability of choosing firewood by approximately 198% (−1.983; P < 0.01). while an increase in household annual disposable income increases the probability of natural gas choice by 730% (7.300; P < 0.01). This finding demonstrates that Turkish households' fuel type choice behaviour for space heating purpose is suitable to energy ladder model. Many earlier contributions (Vaage, 2000; Bakaloglou and Charlier, 2019; Chen, 2021; Couture et al., 2012; Iraganaboina and Eluru, 2021; İpek and İpek, 2022; Jaime et al., 2020; Lee, 2013; Nlom and Karimov, 2015; Zhu et al., 2020; 2023) have also found that an increase on household income boosts the probability of using clean fuels.

Household size is found to increase other fuel type choice by 50% (0.494; P < 0.01). This evidence shows similarity with earlier studies (Nesbakken, 2001; Çebi Karaaslan et al., 2022). The empirical findings of the present paper revealed that male household heads are more likely to choose firewood and less likely to choose natural gas as fuel type. Male household heads are by 24% (0.238; P < 0.05) more likely to choose firewood and 27% (−0.265; P < 0.05) less likely to choose natural gas. This finding shows similarity with some earlier studies (Mensah and Adu, 2015), but contradicts with others (İpek and İpek, 2022; Ogwumike et al., 2014). Household head's age is found to have a statistically significant decreasing effect (−4.183; P < 0.01) on choosing other fuel types. Couture et al. (2012) found a negative association with household head's age and firewood use. Zhu et al. (2023) also found increasing household head's age increases the probability of using clean fuels. When household head is primary educated, the probability of choosing firewood increases by 10% (0.101; P < 0.01). This evidence is consistent with some prior research (Bai et al., 2023; Chen, 2021; İpek and İpek, 2022; Vo et al., 2024; Zhu et al., 2023) and differs from other contributions (Çebi Karaaslan et al., 2022).

The estimation results indicate that households working at skilled agriculture, forestry, and aquaculture workers are more likely to choose firewood, coal, and other fuel types and less likely to choose natural gas. Skilled agriculture, forestry, and aquaculture workers are approximately 7% (0.066; P < 0.01) and 13% (0.130; P < 0.01) more likely to choose coal and coal derivatives and firewood for space heating than other occupational groups, respectively. Turkish households employed in skilled agriculture, forestry, and aquaculture are 22% (−0.215; P < 0.01) less likely to choose natural gas for heating in their housing. Skilled agricultural, forestry, and aquaculture workers are approximately 13% (0.130; P < 0.01) more likely to choose firewood for heating than other occupational groups. Services and sales workers, and household working at professional occupations are less likely to choose natural gas for spacing heating purposes. Crafts and other related works and professionals are also found to 5% less likely to choose other fuel types (−0.051; P < 0.05) and natural gas (−0.050; P < 0.01), respectively. When household head is currently working at elementary jobs, the probability of choosing natural gas decreases by 4% (−0.042; P < 0.01). If the household head has a permanent job, the probability of choosing coal and coal derivatives and other fuel types decreases by approximately 4% (−0.042; P < 0.05) and 24% (−0.244; P < 0.01), respectively. In contrast, if the household head has a permanent job, the probability of choosing natural gas increases by18% (0.176; P < 0.01) compared to other employment types. This evidence shows similarity with earlier studies (Çebi Karaaslan et al., 2022).

Table 4: Test of independence of irrelevant alternatives assumption

Fuel type	lnL (Full)	lnL (Omit)	Chi-square	P-value
Coal/Coal derivatives	−821.972	−771.889	100.166	0.477
Firewood	−1,498.486	−1,453.931	89.111	0.774
Natural gas	−2,483.606	−2,427.163	112.887	0.178
Others	−2,315.701	−2,258.721	113.960	0.161

4.3. Model Specification Tests

Before estimating the MNL and MNP models, testing the presence of a significant multicollinearity problem among the independent variables is necessary. The variance inflation factor (VIF) values are frequently used in practice to test for multicollinearity. Generally, a VIF value <5 indicates no significant multicollinearity problem among the independent variables. Since the VIF values of all independent variables are below the recommended value of 5 (Gujarati, 2011), it is determined that there is no significant multicollinearity problem among the independent variables used that may affect the estimation results. The most critical assumption of the MNL model is the IIA and one of the tests used to analyse the assumption is Small and Hsiao (1985). Table 4 shows the Small-Hsiao test results for the estimated MNL model.

The rightmost column in the output of Table 4 shows the statistical significance results for the dependent variable categories of the estimated model. To statistically state that the estimated MNL model does not violate the IIA assumption, the significance results should be higher than 0.10. As seen in Table 4, since the calculated dependent variable statistical significance values of the MNL model estimated in the application are higher than 0.10, the estimated MNL model meets the IIA assumption according to the Small-Hsiao test.

5. CONCLUSION AND POLICY IMPLICATIONS

5.1. Policy Implications

The empirical findings of the present paper demonstrate that energy ladder hypothesis is valid for Turkish households' fuel type choice for space heating. Household heads working full time is also revealed to have more tendency to use modern fuels in relation to household income. Despite Turkish households show their clear intention to use modern fuels when their income increases, the Turkish economy suffers from relatively high inflation that has a significant negative impact on households' purchasing power parity. Whilst there has been a significant increase on wages countrywide, the fuel prices are increased as well. Energy consumption per capita is overwhelming increasing in Türkiye with a very remarkable 116% increase in 2022 compared to 2000 (International Energy Agency, 2024). The fuel switching from primitive fuels to modern fuels for space heating proceeds in Türkiye. In 2021, 62% of Turkish households have access to natural gas (International Energy Agency, 2021), and natural gas accounts for 58% of residential total final energy consumption (International Energy Agency, 2024). In the present study, type of dwelling (more than nine houses) is found to increase Turkish households' natural gas choice for space heating consistent with this energy consumption. However, the use of other modern renewables for space heating is still very rare, most probably relative high prices. The Turkish government started paying a certain portion of natural gas bills every month, valid between 2023 and 2024. This successful practice should become permanent, and the share of government pays should be increased until the negative impacts of high inflation issue is substantially resolved. Hence, Turkish households would be encouraged towards fuel switching to modern fuels. Further energy policies should concentrate on finding a proper solution to increasing fuel prices, particularly modern fuels to meet increasing energy demand and allocate modern fuels in households. Türkiye firmly continues its natural gas exploration process especially in Black Sea which can be a permanent solution for higher modern fuel prices and its dependency on natural gas imports. Additionally, the TurkStream natural gas project commissioned in early of 2020 is expected to make significant contributions on solving such pricing issues of natural gas. Meanwhile, more efficient further policies can be developed to use other modern renewables along with natural gas dominancy in dwellings.

The evidence gathered from the present study indicates that flat heating/combi and central heating as a heating system increases the probability of choosing modern fuels. This result is expected as natural gas is the dominant fuel in many heating systems particularly in apartments and the natural gas supply is provided to almost all 81 provinces of Türkiye. However, many Turkish households especially living in rural settlements still use various types of stoves and use fossil fuels for space heating. The empirical findings also put forward that households living in detached houses are more likely to use coal and firewood and less likely to use natural gas. Skilled agriculture, forestry, and aquaculture workers are also found to have less tendency to use natural gas. In Türkiye, living in detached house is very common particularly in rural settlements and many of them is still using fossil fuels (i.e. dungs, firewood) for space heating. More attempts should be carried out to raise awareness of those households on using modern fuels. The deployment of natural gas infrastructure in many rural settlements proceeds and the advantages of both natural gas and other modern fuels should be carefully explained to avoid fossil fuel use.

In terms of housing size, small houses are found to more likely to choose natural gas than larger houses. The number of rooms in dwellings is found to increase coal use for space heating. It is more costly to use natural gas for space heating when the number of rooms and housing size increases and thus Turkish households seek other less clean fuel types for space heating. Additionally, Turkish households residing in older dwellings are found to have less tendency to use natural gas. This evidence can be explained older houses do not have sufficient infrastructure to use modern fuels. Within the scope of urban transformation, old buildings should be demolished and new buildings compatible with modern fuels should be built as soon as possible.

Core families are found to have high tendency to use natural gas and household size is associated with other fuel type use.

The use of modern fuels mainly depends on the number of employed individuals in a household. Along with the employed individual's household income increases that facilitates modern fuel type choice. Household size variable also deserves further investigation as the use of modern fuels is not confirmed in the present study when household size is increased. Homeowners had a more tendency to use other fuel types and automobile owners are found to less likely to use natural gas than other fuel types. Automobile owners are also found to have more tendency to use firewood. Households who save money are also found to have less natural gas choice tendency. Those findings can be interpreted as household income is not spent on using modern fuel choice for space heating. Bank loans for home and automobile ownership cover a repayment period that takes many years. If houses and/or automobiles are bought with bank loans, households could not have additional budget to use modern fuels they forcedly continue to use primitive fuels such as firewood.

5.2. Limitations and Recommendations for Future Research

This paper is carried out in one country within a limited time. The empirical findings of this paper cannot be generalized for other countries. Longitudinal studies are highly recommended as household fuel type choice should be carefully monitored periodically. Within the availability of dataset, cross-country comparisons are also recommended that can provide valuable information for future energy policies. Turkish Statistical Institute should administer a unique survey only for energy consumption behaviour of households as some important variables are required in Turkish Household Budget Survey. The prices of fuels to capture the actual impact of prices without using proxy variables. More information should also be provided in future surveys about the month in which the survey is conducted to better understand seasonal effects on household fuel type choice. Further studies can use ordered discrete choice models such as generalized ordered logit, partial proportional odds, and heteroskedastic choice models based on dependent variable categories. Future research should explore households' fuel switching and fuel stacking behaviour that would also be valuable for future energy policies.

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APPENDIX

Table A1: Estimation results for the MNL and MNP models

Dependent variable	Coal		Firewood		Natural gas	
	MNL	MNP	MNL	MNP	MNL	MNP
Household type						
Single person	−1.135*	−0.762*	−0.743*	−0.443**	−0.665***	−0.367***
Type of dwelling						
Detached house	0.069	0.031	0.229	0.168***	−0.667*	−0.484*
3-9 houses	−1.041*	−0.740*	−0.856*	−0.522**	0.883*	0.497*
>9 houses	−2.449*	−1.724*	−1.841*	−1.167*	1.116*	0.717*
Housing tenure						
Owner-occupied	−0.272***	−0.182**	−0.278***	−0.182***	−0.571*	−0.367*
Time of residence						
2-5	0.214	0.117	0.048	0.009	0.359***	0.231
6-10	0.526*	0.340*	0.410***	0.247***	0.160	0.129
11-15	0.908*	0.579*	0.675**	0.393**	0.801*	0.490**
>15	0.777*	0.492*	0.576**	0.337**	0.780*	0.520*
Dwelling construction period						
1981-1990	0.337**	0.209***	0.147	0.059	−0.209	−0.222
1991-2000	0.132	0.085	−0.033	−0.053	−0.251	−0.233
2001-2005	0.297	0.220	0.207	0.126	−0.610***	−0.501**
After 2005	0.348***	0.250***	0.093	0.057	−0.002	0.042
Number of rooms	0.302*	0.194*	0.224*	0.131**	0.232**	0.121***
Housing size (m^2)						
<100	0.500**	0.328**	0.431***	0.282***	0.822*	0.509*
100-149	0.307***	0.245**	0.142	0.107	−0.118	−0.074
Type of floor						
Hardwood	0.109	0.104	−0.034	−0.015	0.319	0.240
Wood	0.467**	0.308**	0.595**	0.374**	−0.173	−0.175
Tile ceramic	−0.636*	−0.378**	−0.687*	−0.433*	−2.241*	−1.443*
Black concrete	−0.462**	−0.247**	−0.659*	−0.414*	−2.507*	−1.594*
Type of heating system						
Flat heating/Combi	0.597**	−0.003	−1.405*	−0.984*	6.406*	4.114*
Joint/central heating	2.776*	1.589*	−1.732*	−1.178*	3.776*	2.298*
Others	−4.379*	−3.203*	−5.312*	−3.647*	−3.183*	−2.478*
Second home ownership, yes	0.170	0.013	0.599*	0.360*	0.555**	0.263***
Automobile ownership, yes	0.264**	0.185**	0.331*	0.230*	−0.016	−0.034
Savings status, yes	0.184	0.121	0.176	0.123	−0.224	−0.196**
HH annual disposable income (log)	−0.988*	−0.699*	−0.761*	−0.492*	1.234*	0.876*
Household size	–0.143*	–0.086*	–0.175*	–0.110*	–0.182*	–0.109*
HH's gender; male	–0.120*	–0.041	0.092	0.112	–0.503**	–0.292***
HH's age (log)	2.542*	1.613*	2.904*	1.887*	3.001*	1.818*
HH's occupational group						
Professional occupation groups	0.193	0.267	−0.130	−0.066	−1.032*	−0.692*
Assistant professional occupation groups	−0.072	−0.003	−0.739	−0.519***	−0.522	−0.384
Office and customer services	0.926**	0.666**	−0.315	−0.263	0.318	0.185
Service and sales workers	0.151	0.118	0.188	0.113	−0.529***	−0.419**
Skilled agriculture, forestry, and aquaculture workers	0.125	0.051	0.636*	0.452*	−2.117*	−1.438*
Crafts and other related works	0.605*	0.373**	0.457***	0.227	0.427	0.174
Plant and machine operatives and assemblers	0.469***	0.350**	0.080	−0.001	0.144	0.056
Elementary occupation groups	0.463***	0.304***	0.297	0.133	−0.353	−0.286
Type of employment						
Full time	0.526*	0.319*	0.652*	0.433*	1.092*	0.728*
Constant term	1.098	1.193	−1.072	−0.658	−12.465*	−7.913*
Summary statistics						
Number of observations	11,828	11,828	11,828	11,828	11,828	11,828
Log-likelihood (null)	−14,268.09	−6,575.77	−14,268.09	−6,575.77	−14,268.09	−6,575.77
Log-likelihood (full)	−6,496.78	−6,514.20	−6,496.78	−6,514.20	−6,496.78	−6,514.20
Likelihood ratio/Wald χ^2 (147)	15,542.62	4,276.47	15,542.62	4,276.47	15,542.62	4,276.47
Prob > χ^2	0.000	0.000	0.000	0.000	0.000	0.000
Pseudo-R^2	0.5447	0.5810	0.5447	0.5810	0.5447	0.5810

*P<0.01; ** *P*<0.05; *** *P*<0.10; Reference category is other fuel types; HH: Household head; Only statistically significant values are presented. If at least one cell (in a row) of each variable is statistically significant, both significant and insignificant values for such variable are also presented for consistency